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Compensatory changes of occlusal plane angles in relation to skeletal factors

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The purpose of this study was to evaluate the compensatory changes of occlusal plane angle in relation to skeletal factors. Lateral cephalograms of 61 adults with normal occlusion and 92 adults with skeletal malocclusions were traced and measured to analyze skeletal factors and occlusal plane angles. In terms of horizontal relationships, the normal occlusion group and malocclusion group were classified into subgroups of skeletal Classes I, II, and III, while in terms of vertical relationships, each group was also classified into horizontal, average, and vertical subgroups. Some measurements were evaluated statistically by ANOVA and Post Hoc, and the others were reviewed by Paired t-tests. In this study, only the occlusal plane angle to AB plane did not show a significant difference between the normal occlusion group and malocclusion group. After treatment, the occlusal plane angle to the AB plane of the malocclusion group was approximated to that of normal occlusion group. The LOP to AB plane angle of the normal occlusion group was 91.7 in skeletal Class I, 88.8 in skeletal Class II, and 93.5 in skeletal Class III.

This study was done to assess the treatment changes of the occlusal plane in the malocclusion group, and to draw a comparison with the normal occlusion group in order to present a reference to establish a new occlusal plane inclination.

Key words : Compensatory change, Occlusal plane, Skeletal factor

The bisected occlusal plane is defined as an imaginary plane that bisects the overlap of the distobuccal cusp of the first molars and incisor overlap, while the functional occlusal plane is that which follows the molars and premolars. The occlusal plane inclination has been evaluated as the angle between the occlusal plane and the reference plane of the cranial base.[1]

The occlusal plane reflects the state of both upper and lower arches, however the development and characteristics of each arch is different. The inclination of the upper occlusal plane is determined by the growth and rotation of the sphenoid bone and maxillary bone, and by the vertical growth of the maxillary alveolar bone. In the mandible, the rotation of the mandibular plane is induced by growth of the mandibular ramus and/or condyle and the inclination of the maxillary occlusal plane. The mandibular occlusal plane is also determined by vertical growth of the mandibular alveolar bone[2].

In skeletal malocclusions originated from maxillary

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and mandibular growth discrepancies, the occlusal plane inclination could be abnormal and induce functional deviation of the mandible, thereby causing change in the maxillofacial configuration through the growth process.[3]

Skeletal discrepancies often accompany occlusal discrepancies. In many cases, however, people maintain normal occlusal relationships despite the skeletal discrepancies, and such normal occlusal relationships are accomplished mainly by the mechanism of dentoalveolar compensation. Occlusal plane inclination acts as an important factor in dentoalveolar compensation.[2,4,5]

Orthodontic treatment is a process of establishing a new occlusal relationship. The main treatment goals of clinical orthodontics are the improvement of dentofacial esthetics, the establishment of a functional occlusion, and achieving occlusal stability after treatment. Among these goals, the treatment modalities for correcting skeletal discrepancies include occlusal plane reconstruction, incisal inclination reconstruction, and dentofacial frame reconstruction by orthognathic surgery and orthopedics. In order to achieve these goals, establishing the appropriate occlusal plane is considered to be an essential factor.[6]

There have been many studies focused on occlusal plane characteristics of normal occlusion and malocclusion both before and after treatment. Many researchers have also suggested critical guidelines for the re-establishment of the occlusal plane after orthodontic treatment. Bjork[7] found that occlusal plane angle to cranial base is reversely correlated to SNB in adults with normal occlusion. Riedel[8] reported that the occlusal plane angle to AB plane in normal occlusion groups maintains a constant value, which is close to 90 degrees. Also, Lee and Chang[9] have found that the effect of vertical skeletal pattern to occlusal plane angle is greater in malocclusion groups than in normal occlusion groups. Schudy[10] accentuated the high correlation of occlusomandibular angle to facial configuration, while Di Paulo[11] noted that the position of the occlusal plane is influenced by the existing skeletal pattern, and changes in individual skeletal configuration could influence the position of the occlusal plane. He tried to establish an individual anatomical occlusal plane for patients with favorable skeletal configuration. Hyun[12] also emphasized that a proper occlusal plane is important for individual skeletal patterns and attempted to establish an individualized lower occlusal plane according to vertical dimension ratio, via a regression equation. Based on a geometric analysis. Yang[6] suggested that if the occlusal plane angle to lower occlusal plane is 91, an ideal lower occlusal plane could be established after treatment regardless of the denture frame.

Although Hyun[12] conducted his study using diverse patient case samples, he mainly focused on the vertical height ratio. The research carried out by Yang[6], on the other hand, was only on the basis of geometric analysis. Yang[6] did not test his conclusions clinically through a statistical analysis of the occlusal planes of normal occlusion and malocclusion group.

This study was investigated to assess the treatment changes of occlusal plane inclination in normal occlusion group and malocclusion group in order to present a reference for establishing a new occlusal plane inclination.

MATERIALS AND METHODS

Materials

The normal occlusion group consisted of 61 adults who were a mean age of 23 years, and had a functionally and esthetically favorable occlusal relationship between the upper and lower arches according to Angle's classification of malocclusion. The malocclusion group included 92 patients who had a skeletal malocclusion and were treated with fixed appliances and nonsurgical methods. All the patients in the malocclusion group were over the age of 18, and their average age was 25 years. The lateral cephalograms of these 153 adults were evaluated. Each group was subdivided into 3 subgroups as shown in Table 1.

The normal occlusion group was divided into three groups according to skeletal antero-posterior relationship and the angle of the occlusal plane to cranial base was measured. The mean and standard

Table 1. Distribution of samples

	Normal occlusion group			Malocclusion group		
A-P skeletal relation	Sk. Cl I (group 1a)	Sk. Cl II (group 1b)	Sk. Cl III (group 1c)	Sk. Cl I (group 2a)	Sk. Cl II (group 2b)	Sk. Cl III (group 2c)
	33	18	10	30	32	30
Vertical skeletal relation	Horizontal	Average	Vertical	Horizontal	Average	Vertical
	20	30	11	20	45	27

deviation of each group was also calculated.

Subjects whose ANB values were higher than +1 standard deviation were classified into skeletal the Class II subgroup, while those with values less than −1 standard deviation were classified into the skeletal Class III subgroup. The remaining subjects, whose ANB values were within standard deviation, were included in skeletal Class I subgroup. In terms of vertical relationship, the subjects were subdivided into vertical, average, and horizontal subgroups, according to lower gonial angle, Bjork's sum, and facial height ratio.

The malocclusion group was also subdivided in the antero-posterior and vertical relationships as described above.

Methods

A lateral cephalometric radiograph of each subject was taken and traced manually. Angular and linear measurements of skeletal and occlusal factors were measured to the nearest 0.5, and 0.1mm, respectively. A bisected occlusal plane, functional occlusal plane, and lower occlusal plane were used to evaluate the characteristics. The reference points (Fig 1), reference planes (Fig 2), measurements (Fig 3, 4) and occlusal planes (Fig 5), used in this study were illustrated in figures.

The statistical analysis was carried out with the SPSS (Statistical Package for the Social Science) 9.0 program.

In the skeletal Class I, the mean and standard deviation of the angles between the occlusal plane and each reference plane were calculated in the malocclusion group both before and after treatment. One-way ANOVA and Post Hoc Test were done to compare the difference between the normal occlusion and malocclusion groups. The same statistical processes were also performed on

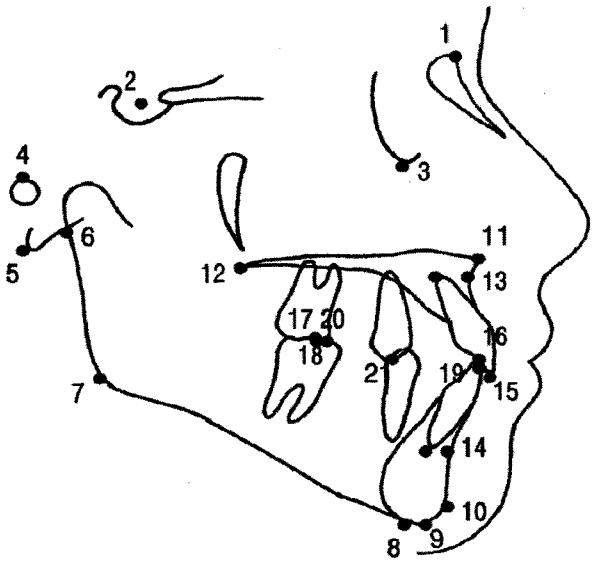

Fig. 1. Cephalometric landmarks used in this study.
1. Na (Nasion) 2. S (Sella) 3. Or (Orbitale)
4. Po (Porion) 5. Ba (Basion) 6. Ar (Articulare)
7. Go (Gonion) 8. Me (Menton) 9. Gn (Gnathion)
10. Pog (Pogonion) 11. ANS (Anterior nasal spine)
12. PNS (Posterior nasal spine) 13. A (Subspinale)
14. B (Supramentale) 15. U1 (Upper incisor tip)
16. L1 (Lower incisor tip)
17. U6 (midpoint of crown of upper 1st molar)
18. L6 (midpoint of crown of lower 1st molar)
19. Is (Incisal superius)
20. Mo(midpoint of buccal cusp of upper and lower 1st molars)
21. P(midpoint of buccal cusp of upper and lower 1st premolars)

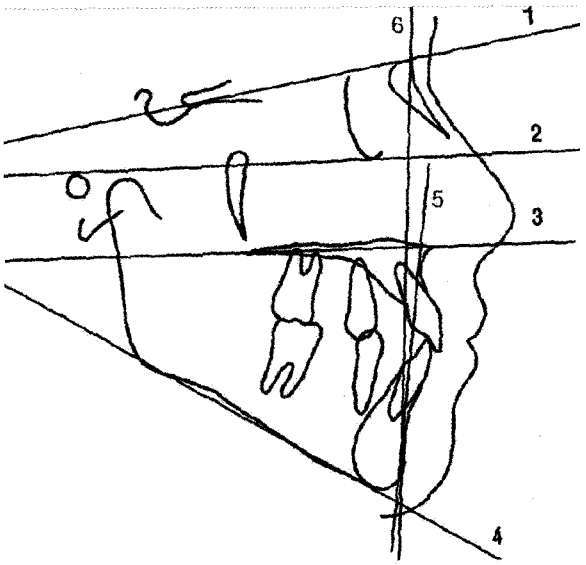

Fig. 2. Reference planes.
1. SN plane 2. FH plane 3. Palatal plane
4. MP plane 5. AB plane 6. N-Pog plane

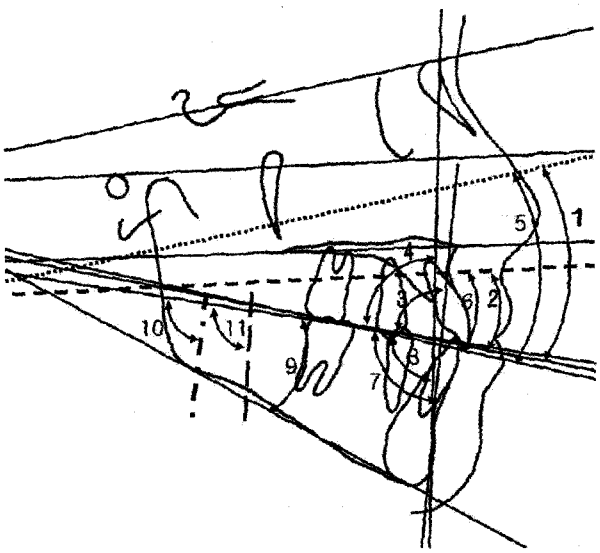

Fig. 3. Measurements of occlusal plane angles.
1. BOP-SN 2. BOP-FH 3. BOP-AB
4. BOP-N-Pog 5. FOP-SN 6. FOP-FH
7. FOP-AB 8. FOP-N-Pog 9. LOP-MP
10. LOP-AB 11. LOP-N-Pog

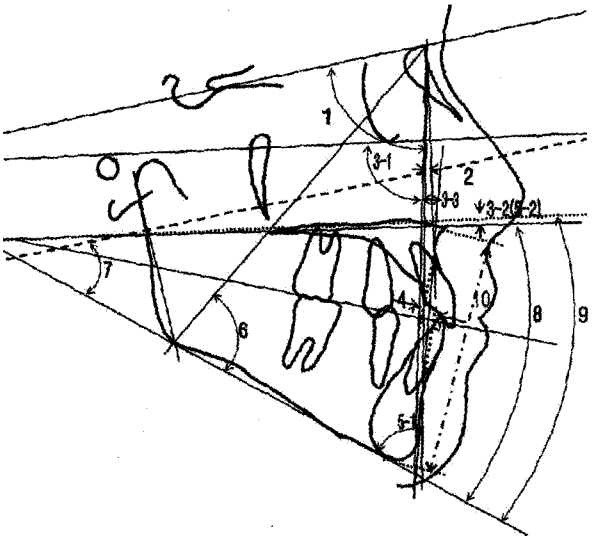

Fig. 4. Skeletal measurements.
1. SNB
2. ANB
3. APDI (Anteroposterior dysplasia indicator)
4. Wits' appraisal
5. ODI (Overbite depth indicator)
6. lower gonial angle
7. SN-MP angle
8. Palatomadibular angle 9. FMA
10. lower anterior facial height
11. facial height ratio

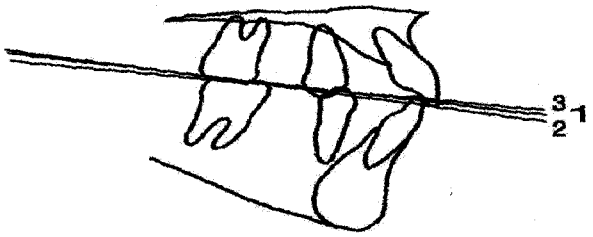

Fig. 5. Occlusal planes.
1. Bisected occlusal plane (BOP)
2. Functional occlusal plane (FOP)
3. Lower occlusal plane (LOP)

the skeletal Class II and skeletal Class III groups.

Treatment changes in the occlusal plane angles of malocclusion groups during treatment were calculated in each antero-posterior subgroup and compared by paired t-test.

In addition, the two groups were subdivided into three subgroups according to vertical relationship. The mean and standard deviation of occlusal plane angle to each reference plane of each subgroup was calculated, and one-way ANOVA was done to evaluate and compare

Table 2. Mean values of occlusal plane angles of each subgroups of normal occlusion group (Mean±S.D.)

Variables	group 1a	group 1b	group 1c
∠BOP-SN	15.8 ± 4.0	15.7 ± 2.7	14.8 ± 8.0
∠BOP-FH	8.9 ± 3.8	8.3 ± 2.3	7.6 ± 4.9
∠BOP-AB	93.6 ± 2.9	89.5 ± 1.7	95.5 ± 2.0
∠BOP-N-Pog	97.3 ± 2.8	95.9 ± 1.8	95.5 ± 4.2
∠FOP-SN	16.1 ± 3.7	15.4 ± 2.6	14.0 ± 7.8
∠FOP-FH	8.9 ± 3.5	7.9 ± 2.2	7.2 ± 4.6
∠FOP-AB	93.4 ± 2.3	89.5 ± 2.0	94.9 ± 2.1
∠FOP-N-Pog	97.1 ± 2.7	95.6 ± 3.0	96.6 ± 3.6
∠LOP-MP	18.6 ± 4.7	18.5 ± 4.2	16.9 ± 6.3
∠LOP-AB	91.7 ± 2.9	88.8 ± 3.0	93.5 ± 2.5
∠LOP-N-Pog	95.4 ± 3.0	94.5 ± 2.4	93.6 ± 4.1

group 1a : normal occlusion group, Sk. Cl I,
group 1b : normal occlusion group, Sk. Cl II
group 1c : normal occlusion group, Sk. Cl III

the occlusal plane angles among the three groups.

The changes of occlusal plane angles of malocclusion groups during treatment according to vertical relationship were evaluated by paired t-test.

RESULTS

1. Anteroposterior skeletal pattern and occlusal plane

1) Occlusal plane angle in the skeletal Class I

The angle between SN plane and BOP in the normal occlusion group with a skeletal Class I relationship was 15.8. BOP to FH plane was 8.9, BOP to AB plane was 93.6, and LOP to AB plane was 91.7 (Table 2).

In group 2a, the occlusal plane angles to FH plane were significantly different from that of group 1a ($P<0.01$), but the occlusal plane angles to AB plane did not show any significant difference among group 1a, group 2a, and group 2a' (Table 3).

2) Occlusal plane angle in the skeletal Class II

The BOP to SN plane in the skeletal class II normal occlusion group was 15.7, and BOP to FH plane was 8.3. BOP to AB plane was 89.5, and LOP to AB plane was 88.8 (Table 2).

In group 2b, the occlusal plane angles to SN plane and FH plane were significantly greater than group 1b ($P<0.001$). This means that the occlusal planes were antero-inferiorly inclined, but the angles of occlusal plane to AB plane were not significantly different among group 1b, group 2b and group 2b'(Table 4).

3) Occlusal plane angle in the skeletal Class III

The BOP to SN plane in skeletal Class III was 14.8, and BOP to FH plane was 7.6. BOP to AB plane was 95.5, and LOP to AB plane was 93.5 (Table 2).

The angles of occlusal plane to SN plane, FH plane, and AB plane were not significantly different among group 1c, group 2c and group 2c' (Table 5).

4) Changes of occlusal plane angle by treatment

In comparing occlusal plane angles before and after treatment, occlusal plane angles to the SN plane or FH plane were significantly different among all skeletal patterns, but occlusal plane angles to the AB plane showed a relatively low statistical significance. However,

Table 3. Comparison of occlusal plane angles of Sk. Cl I normal occlusion group and malocclusion group before and after treatment (Mean ± S.D.)

Variables	Sk. Cl I			difference
	group 1a	group 2a	group 2a'	(F-value)
∠BOP-SN	15.8 ± 4.0	20.1 ± 13.3	18.9 ± 4.0	2.616n.s.
∠BOP-FH	8.9 ± 3.8	10.0 ± 3.6	13.3 ± 4.5	2.369n.s.
∠BOP-AB	92.5 ± 2.9	90.8 ± 3.7	91.7 ± 3.1	2.588n.s
∠BOP-N-Pog	97.3 ± 2.8	95.1 ± 4.5	96.8 ± 4.0	2.853n.s.
∠FOP-SN	16.1 ± 3.7a	19.8 ± 5.6b	18.7 ± 4.6b	5.852**
∠FOP-FH	8.8 ± 3.5a	11.9 ± 3.7b	10.5 ± 3.9b	6.547**
∠FOP-AB	93.4 ± 2.9	92.6 ± 5.2	91.7 ± 3.4	1.363n.s.
∠FOP-N-Pog	97.1 ± 2.7	97.1 ± 5.8	96.8 ± 4.4	0.034n.s.
∠LOP-MP	18.6 ± 4.7	20.2 ± 4.8	20.6 ± 4.7	1.781n.s.
∠LOP-AB	91.7 ± 2.8	89.9 ± 5.3	87.9 ± 4.6	1.527n.s.
∠LOP-N-Pog	95.4 ± 2.9	94.5 ± 4.9	95.6 ± 3.5	0.738n.s.

(** : $p < 0.01$, n.s. : not significant) (Data with same letter(a,b) are not significantly different- by Post Hoc test)
group 1a : normal occlusion group, Sk. Cl I
group 2a : malocclusion, pre-treatment, Sk. Cl I
group 2a' : malocclusion, post-treatment, Sk. Cl I

Table 4. Comparison of occlusal plane angles of Sk. Cl II normal occlusion group and malocclusion group before and after treatment (Mean ± S.D.)

Variables	Sk. Cl II			difference
	group 1b	group 2b	group 2b'	(F-value)
∠BOP-SN	15.5 ± 2.9a	18.9 ± 5.3b	21.9 ± 4.1c	8.764***
∠BOP-FH	7.9 ± 2.2a	12.0 ± 4.3b	13.6 ± 3.5b	12.064***
∠BOP-AB	89.4 ± 1.9	88.7 ± 4.1	88.7 ± 3.2	0.244n.s.
∠BOP-N-Pog	96.0 ± 2.0	95.9 ± 3.6	97.3 ± 2.7	1.898n.s.
∠FOP-SN	15.4 ± 2.8a	20.9 ± 5.0b	21.1 ± 4.2b	10.175***
∠FOP-FH	7.7 ± 2.2a	13.6 ± 4.9b	14.3 ± 4.6b	12.333***
∠FOP-AB	89.5 ± 2.1	88.2 ± 3.6	89.1 ± 3.7	0.146n.s.
∠FOP-N-Pog	95.7 ± 3.1	97.5 ± 3.3	96.6 ± 3.8	1.557n.s.
∠LOP-MP	18.9 ± 4.0	21.7 ± 3.7	21.2 ± 4.9	2.437n.s.
∠LOP-AB	88.0 ± 1.8	82.7 ± 16.4	87.3 ± 3.6	1.996n.s.
∠LOP-N-Pog	94.4 ± 2.6a	93.4 ± 4.3a	95.8 ± 3.0b	3.886*

(* : $p < 0.05$, *** : $p < 0.001$, n.s. : not significant) (Data with same letter(a,b) are not significantly different- by Post Hoc test)
group 1b : normal occlusion group , Sk. Cl II
group 2b : malocclusion, pre-treatment, Sk. Cl II
group 2b' : malocclusion, post-treatment, Sk. Cl II

Table 5. Comparison of occlusal plane angles of Sk. Cl III normal occlusion group and malocclusion group before and after treatment (Mean ± S.D.)

Variables	Sk. Cl III			difference
	group 1c	group 2c	group 2c'	(F-value)
∠BOP-SN	13.0 ± 8.0	16.0 ± 5.2	14.9 ± 4.5	0.798n.s.
∠BOP-FH	6.6 ± 5.1	8.0 ± 4.2	6.9 ± 3.4	0.763n.s.
∠BOP-AB	95.6 ± 2.3	96.9 ± 4.9	95.8 ± 3.6	0.647n.s.
∠BOP-N-Pog	95.4 ± 4.6	97.9 ± 3.7	96.1 ± 3.4	2.212n.s.
∠FOP-SN	12.6 ± 8.3	16.8 ± 5.9	15.9 ± 4.9	1.032n.s.
∠FOP-FH	6.5 ± 5.0	8.9 ± 4.7	8.1 ± 3.5	0.720n.s.
∠FOP-AB	95.4 ± 2.1	97.7 ± 4.6	93.4 ± 6.5	0.972n.s.
∠FOP-N-Pog	96.8 ± 2.9	98.4 ± 3.8	97.1 ± 3.3	1.232n.s.
∠LOP-MP	15.4 ± 6.1	19.7 ± 3.6	21.7 ± 3.9	5.563n.s.
∠LOP-AB	93.9 ± 2.7	96.2 ± 5.0	94.6 ± 3.3	1.286n.s.
∠LOP-N-Pog	93.1 ± 4.5	97.4 ± 3.7	95.1 ± 3.4	4.353n.s.

(n.s. : not significant)
group 1c : normal occlusion group , Sk. Cl III
group 2c : malocclusion, pre-treatment, Sk. Cl III
group 2c' : malocclusion, post-treatment, Sk. Cl III

Table 6. Comparison of treatment changes of occlusal plane angle according to anteroposterior relationship (Mean±S.D.)

Variables	Treatment changes		
	group a	group b	group c
∠BOP-SN	1.05 ± 2.48*	1.59 ± 2.84**	-1.05 ± 2.18*
∠BOP-FH	1.05 ± 3.03	1.31 ± 2.88*	-1.32 ± 2.27**
∠BOP-AB	.71 ± 2.78	.16 ± .68	-1.18 ± 3.40
∠BOP-N-Pog	1.47 ± 3.19*	1.07 ± 2.76*	-1.38 ± 2.39**
∠FOP-SN	-1.32 ± 4.00	.05 ± 3.27	-2.36 ± 2.36*
∠FOP-FH	-1.69 ± 3.27**	.55 ± 2.99	-1.28 ± 2.47**
∠FOP-AB	1.20 ± 4.05	-1.57 ± 3.92*	-1.36 ± 4.49
∠FOP-N-Pop	-.50 ± 5.04	-1.05 ± 3.86	-1.28 ± 2.61*
∠LOP-MP	-.59 ± 4.93	-1.30 ± 3.55*	2.02 ± 3.38**
∠LOP-AB	.61 ± 4.48	.77 ± 5.25	-1.57 ± 4.26
∠LOP-N-Pog	-1.01 ± 4.29	2.34 ± 4.34**	-2.30 ± 3.85**

paired t-test (* : $p < 0.05$, ** : $p < 0.01$)
group a : Sk. Cl I, group b : Sk. Cl II, group c : Sk. Cl III

Table 7. Comparison of occlusal plane angles in normal occlusion group according to vertical relationship (Mean±S.D.)

Variables	Horizontal group	Average group	Vertical group	difference (F-value)
∠BOP-SN	14.0 ± 3.7	16.4 ± 4.0	17.0 ± 4.2	2.90
∠BOP-FH	7.5 ± 3.3	8.3 ± 2.9	11.5 ± 3.8	5.96**
∠BOP-AB	91.9 ± 2.4	92.2 ± 3.2	94.5 ± 4.1	2.73
∠BOP-N-Pog	96.0 ± 2.6	96.7 ± 2.7	98.4 ± 2.6	3.01
∠FOP-SN	14.2 ± 3.6	16.4 ± 4.0	16.8 ± 3.4	2.56
∠FOP-FH	7.2 ± 2.9	8.1 ± 2.9	11.5 ± 3.1	8.43**
∠FOP-AB	91.8 ± 2.5	91.1 ± 3.3	94.2 ± 3.6	2.49
∠FOP-N-Pog	96.4 ± 2.3	96.2 ± 3.1	98.2 ± 2.4	2.33
∠LOP-MP	16.0 ± 3.4	18.8 ± 5.0	21.6 ± 2.9	6.86**
∠LOP-AB	89.9 ± 2.4	90.6 ± 3.1	93.9 ± 3.4	7.15**
∠LOP-N-Pog	94.0 ± 2.4	94.8 ± 2.9	97.2 ± 2.9	5.41**

(** : $p < 0.01$)

there was an obvious trend wherein the occlusal plane angle to AB plane tended to decrease during treatment in skeletal Class III, while they were increased in skeletal Class II, and were approximated to those of the normal occlusion group (P<0.01) (Table 6).

In skeletal Class I, the angle of BOP to AB plane was 93.6, 93.4 in FOP and 91.7 in LOP. In skeletal Class II, the angle of BOP and FOP to AB plane were 89.5 and 88.8 in LOP. In skeletal Class III the angle of BOP to AB plane was 95.5, 94.9 in FOP, and 93.5 in LOP (Table 2).

2. Vertical relationship and occlusal plane angle

1) Occlusal plane angle in normal occlusion group

The occlusal plane angle to FH plane among the three subgroups according to vertical relationship showed a significant difference, and the values were greatest in the vertical subgroup and smallest in the horizontal subgroup. The measurements of lower occlusal plane to all reference planes showed a significant difference among subgroups, and the value was greatest in the vertical subgroup and smallest in the horizontal subgroup (Table 7).

2) The changes of occlusal plane angle by treatment

The values of FOP in the vertical subgroup and BOP in the horizontal subgroup showed a statistical significance. Statistically significant measurements in both the horizontal and vertical subgroups during treatment were the angle of the mandibular plane and LOP. They decreased in the horizontal subgroup while increasing in the vertical subgroup (Table 8).

DISCUSSION

Bjork[7] mentioned that the occlusal plane angle to cranial base (ArNa) in normal occlusion was as diverse as 48.1~21.5°, while according to Reidel[8], in normal occlusion the occlusal plane angle to the AB plane shows constant correlation and has a value of 90. Also, Nahm and Jung[13] indicated that the normal occlusion of Korean male adults has an occlusal plane angle to FH plane inclined more postero-inferiorly than that of Caucasians.

It has been reported that these diverse occlusal plane angles are the results of individual compensations for diverse skeletal patterns.[2),4),5)] By comparing the occlusal plane angles of normal occlusion groups with those of malocclusion groups both before and after

Table 8. Comparison of changes of occlusal plane angles by treatment according to vertical relationship (Mean±S.D.)

Variables	Treatment changes		
	Horizontal group	Average group	Vertical group
∠BOP-SN	1.65 ± 2.33**	0.17 ± 2.72	0.39 ± 2.92
∠BOP-FH	1.37 ± 2.11**	0.09 ± 3.21	-0.37 ± 2.79
∠BOP-AB	0.76 ± 3.64	-0.50 ± 2.85	-0.44 ± 4.22
∠BOP-N-Pog	1.13 ± 2.71	0.27 ± 3.15	-0.05 ± 3.10
∠FOP-SN	0.74 ± 3.74	-0.61 ± 2.89	-2.33 ± 3.17**
∠FOP-FH	0.12 ± 3.05	-0.45 ± 2.88	-2.18 ± 3.08**
∠FOP-AB	0.01 ± 5.10	-1.56 ± 2.99***	-2.15 ± 4.99*
∠FOP-N-Pop	0.72 ± 3.41	-0.75 ± 4.14	-2.73 ± 3.27***
∠LOP-MP	-2.28 ± 4.25*	0.04 ± 3.90	1.85 ± 3.99**
∠LOP-AB	2.21 ± 5.54	-0.40 ± 4.13	-1.14 ± 4.86
∠LOP-N-Pog	1.66 ± 4.02	0.41 ± 4.88	-0.69 ± 3.67

paired t-test (* : $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$)

treatment, we could discover the skeletal variation range capable of being corrected to acquire normal occlusion. This could be used as a reference for individualized treatment plans and treatment mechanisms.

Thayer[15] mentioned the differences and characteristics of the bisected occlusal plane and functional occlusal plane, and Lee and Jang[9] reported the higher correlation of functional occlusal plane with skeletal items in the malocclusion group compared to the correlation of the bisected occlusal plane. Thus, we investigated three types of occlusal planes, the bisected occlusal plane (Downs' occlusal plane angle), functional occlusal plane[14], and lower occlusal plane. The SN plane, FH plane, mandibular plane, AB plane, and N-Pog plane were used as reference planes.

The subjects were also subdivided antero-posteriorly and vertically, and through a comparison of occlusal plane angles to various reference lines among subgroups, we tried to find a consistent item amongst the normal occlusion group, pre-treatment malocclusion group, and post-treatment malocclusion group.

In skeletal Class I, the malocclusion group showed a significant difference in occlusal plane angles to the SN plane or FH plane in comparison to the normal occlusion group of skeletal Class I, but they did not show significant difference in occlusal plane angles to the AB plane.

After orthodontic treatment, the occlusal plane angles to SN plane, FH plane and AB plane did not show a significant change in skeletal Class I compared to pre-treatment values. Therefore the occlusal plane angles to AB plane in skeletal Class I were not significantly different amongst the normal occlusion, pre-treatment, and post-treatment groups.

In skeletal Class II, the occlusal plane angles to SN plane and FH plane showed a significant difference between the malocclusion group and the normal occlusion group. The occlusal plane of the malocclusion group was more anteroinferiorly tilted than that of the normal occlusion group. The angle of BOP to SN plane also showed a significant difference when the pre-treatment and the post-treatment values were compared. However, there was no difference in the occlusal plane angle to AB plane among the normal occlusion group, pre-treatment malocclusion group, and post-treatment malocclusion group. Therefore, the occlusal plane angle to AB plane in the skeletal Class II did not show a significant difference amongst the normal occlusion group, pre-treatment malocclusion

group, and post-treatment malocclusion group.

In skeletal Class III, the occlusal plane angles to SN plane, FH plane, and AB plane did not show a significant difference amongst the normal occlusion group, pre-treatment group, and post-treatment group. Therefore, the occlusal plane angles to AB plane in skeletal Class III were not significantly different among the normal occlusion group, pre-treatment malocclusion group, and post-treatment malocclusion group.

The occlusal plane angles to AB plane did not show a significant difference amongst the normal occlusion group, pre-treatment malocclusion group, and post-treatment malocclusion group in the skeletal Classes I, II, and III. Therefore, the occlusal plane angle to AB plane could be the reference to reestablish the occlusal plane by treatment, and this is consistent with the previous proposal of Yang[6], which stressed the importance of lower occlusal plane angle to AB plane through geometric deduction.

In the results of paired t-testing between pre- and post-treatment, according to the antero-posterior relationship, the occlusal plane angles to SN plane or FH plane showed a significant difference, but the occlusal plane angle to AB plane showed relatively less significance once again. However, the direction was apparent in that the occlusal plane angle to AB plane of the skeletal Class III malocclusion group was decreased, and was approximate to that of the normal occlusion group of skeletal Class III. On the other hand, in the malocclusion group of skeletal Class II, the occlusal plane to AB plane was increased and approximated to that of the normal occlusion group of skeletal Class II. Therefore, the patterns of change of the occlusal plane were different in the treatment of skeletal Classes II and III. Such changes of occlusal plane angles in opposite directions according to skeletal pattern suggest that these are the results of dentoalveolar compensation of occlusal plane by treatment mechanics[16], and it is reasonable to take the respective value of the normal occlusion group of each skeletal pattern as a standard of treatment. The occlusal plane angle of BOP to AB plane in skeletal Class I normal occlusion group was 93.6°, FOP to AB plane was 93.4°, and LOP to AB plane was 91.7°. In skeletal Class II, the occlusal plane angle of BOP to AB plane and FOP to AB plane were 89.5° in normal occlusion, and LOP to AB plane was 88.8°. In the normal occlusion group of skeletal Class III, the occlusal plane angle of BOP to AB plane was 95.5°, FOP to AB plane was 94.9°, and LOP to AB plane was 93.5°. These could be used as standard values. According to Yang[6] if the lower occlusal plane to AB plane is corrected to 91°, an ideal lower occlusal plane could be acquired after treatment regardless of denture frame. In our study, the occlusal plane angle to AB plane of the normal occlusion group in skeletal Class I was91.7°, 88.8° in skeletal Class II,and 93.5° in skeletal Class III.

In addition, in skeletal Class II, the occlusal plane angle to cranial base showed a significant difference between the normal occlusion group and malocclusion group. The value was greater in the skeletal Class II malocclusion group than in the normal occlusion group. This result coincides with Nahm and Jung's[13] and Lee and Chang's[9] research, but is contrary to the opinions of Sanborn[17] and Hitchcock[18]. We can conclude that the occlusal plane angle of skeletal Class II malocclusion can be established with a tendency to compensate for skeletal discrepancy, but the extent of compensation is not enough to acquire normal occlusion.

Lee and Chang[9] reported that the effects of the vertical relationship are larger than the effects of the antero-posterior relationship in the occlusal plane. In the normal occlusion group, the occlusal plane angles to FH plane were different among the subgroups according to vertical relationship, and the occlusal plane angle to cranial base was greatest in the vertical subgroup, while it was smallest in the horizontal subgroup. This coincides with the reports of Lee and Chang[9], and Subtelny and Sakuda[19]. Among the three occlusal planes, the measurements of the lower occlusal plane angle in particular showed the greatest significant intersubgroup difference. Statistically significant measurements in the horizontal and vertical subgroups during treatment were the angle between the lower occlusal plane and mandibular plane, and it increased in the vertical subgroup and was decreased in the horizontal subgroup. The importance of the lower

occlusal plane angle in the vertical relationship was mentioned by Kim and Nahm[20], and they noted that deep bite vertical discrepancy was prominent in the lower face and was related to the morphology of mandible and mandibular plane inclination.

After all, skeletal discrepancies could be considerably compensated for by changes in the inclination of the occlusal plane. The occlusal plane angle was decreased in skeletal Class III and increased in skeletal Class II to improve the occlusal relationship.

Therefore, as the standard for reconstructed occlusal plane angle by compensation treatment, the lower occlusal plane angle to AB plane, which is 91.7° in skeletal Class I, 88.8° in skeletal Class II, and 93.5° in skeletal Class III, can be used. In terms of vertical relationship, the lower occlusal plane angle to mandibular plane could be used as a reference to reestablish the occlusal plane, but we could not establish a vertical reference through this study.

CONCLUSION

This study was done to evaluate the compensatory changes of occlusal plane angle in relation to skeletal factors. Lateral cephalograms of 61 normal occlusion adults and 92 malocclusion patients were traced and measured for skeletal factors and occlusal plane angles. The normal occlusion group and malocclusion group were classified into subgroups of skeletal Classes I, II, and III, and also classified into horizontal, average, and vertical subgroups. Some measurements were evaluated statistically by ANOVA and Post Hoc, and the others were carried out by paired t-tests.

The results were as follows:

1. In comparing the normal occlusion group and malocclusion group, not the occlusal plane angle to SN plane or FH plane but the occlusal plane angle to AB plane showed consistent values.
2. With treatment, the occlusal plane angle to AB plane of the skeletal Class III malocclusion group was decreased and approximated to that of the normal occlusion group. In the malocclusion group of skeletal Class II, the occlusal plane angle to AB plane was increased and approximated to that of the normal occlusion group.
3. The angle of lower occlusal plane to AB plane in the normal occlusion group was 91.7° in skeletal Class I, 88.8° in skeletal Class II and 93.5° in skeletal Class III.

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국문초록

골격적 요소에 따른 교합평면 경사도의 보상적 변화

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본 연구는 정상교합군과 부정교합군의 교합평면경사도와 부정교합군의 치료 전후의 교합평면 경사도를 비교 분석함으로써 골격관계에 따른 교합평면의 치아 치조성 보상에 대하여 알아보고 교정치료 시 교합평면 설정의 기준을 마련하고자 61명의 정상교합자와 92명의 부정교합자의 치료 전후 측모 두부방사선사진을 분석하여 골격 관계에 따른 교합평면 경사도를 비교하였다. 정상교합군은 전후방적 골격양상에 따라 골격성 I급군, II급군, III급군으로 나누었으며, 수직적 골격양상에 따라서는 수평군, 정상군, 수직군으로 분류하였다. 각 군의 계측치를 일원 분산분석과 사후검정을 통해 분석하였고 치료전후의 변화는 paired t-test로 유의성 검정을 하였다.

본 연구의 결과는 다음과 같다.

1. 정상교합군과 부정교합군간의 비교에 있어 일정한 값을 보인 계측치는 AB평면에 대한 교합평면 경사도이었다.
2. 치료 후의 AB평면에 대한 교합평면 경사도는 II급 골격관계에서는 증가하는 방향으로, III급 골격관계에서는 감소하는 방향으로 정상교합군의 값에 근접하였다.
3. 정상교합군에서 AB평면에 대한 하악 교합평면 경사도는 I급 골격 관계에서 91.7°, II급 골격 관계에서 88.8°, I격 관계에서는 93.5° 이었다.

주요 단어 : 보상적 변화, 교합평면, 골격관계