Changes in occlusal function after surgical and nonsurgical treatment of anterior crossbite: 2-year follow-up

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Graduate School
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June 2025

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이 논문의 준비에 큰 도움을 준 소중한 의국 후배 이현지, 조병수, 김연희, 조신영, 임재현, 주희돈 선생에게 고마운 마음을 전합니다.

언제나 저를 격려해주시는 사랑하고 존경하는 부모님에게 감사의 마음을 전합니다. 마지막으로 저를 이 자리까지 인도해주신 하나님께 감사드립니다.

2025 년 6 월
저자 씀

TABLE OF CONTENTS

LEGENDS OF FIGURES ········ ii

LEGENDS OF TABLES ········ iii

ABSTRACT (ENGLISH) ········ iv

I. INTRODUCTION ········ 1

II. MATERIAL AND METHODS ········ 4

1. Subjects ········ 4
2. Assessment of occlusal force (OF) and occlusal contact area (OCA) ········ 6
3. Statistical analysis ········ 9

III. RESULTS ········ 17

IV. DISCUSSION ········ 32

V. CONCLUSION ········ 37

VI. REFERENCES ········ 38

ABSTRACT (KOREAN) ········ 44

LEGENDS OF FIGURES

Figure 1. Two types of occlusion in patients with anterior crossbite ··· 3

Figure 2. Study flowchart ··· 6

Figure 3. Cephalometric measurements ··· 8

Figure 4. The Dental Prescale System (GC Corp., Tokyo, Japan) ··· 9

Figure 5. Bland-Altman Plot ··· 11-16

Figure 6. Changes in total occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ··· 28

Figure 7. Changes in anterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ··· 29

Figure 8. Changes in posterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ··· 30

Figure 9. Changes in the anterior/total ratios of occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ··· 31

LEGENDS OF TABLES

Table 1. Cephalometric measurements before treatment (T0) in the camouflage, surgery, and control groups ········ 19

Table 2. Changes in cephalometric measurements before (T0), immediately after (T1), and two years after treatment (T2) in the camouflage, surgery, and control ········ 20

Table 3 OGS scores immediately after treatment (T1) in the camouflage, surgery, and control groups ········ 21

Table 4. Total occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ········ 22

Table 5. Anterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ········ 23

Table 6. Posterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ········ 24

Table 7. Anterior/Total ratios of the occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups ········ 25

Table 8. Effect of the number of maxillary anterior crossbite teeth on OF and OCA at T0 ········ 26

Table 9. P-values for fixed effects and covariates in the linear mixed model ········ 27

ABSTRACT

Changes in occlusal function after surgical and nonsurgical treatment of anterior crossbite: 2-year follow-up

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Department of Dentistry

(Directed by prof. Kyung-Ho Kim, D.D.S., M.S., Ph.D.)

Anterior crossbite (ACB) leads to functional impairments, such as reduced masticatory efficiency due to improper occlusion of the anterior teeth. This study evaluated how treatment of ACB affected the occlusal force (OF) and occlusal contact area (OCA), focusing on anterior, posterior, and total teeth.

This retrospective study included 122 female patients aged 18–40 years, divided into 3 groups: camouflage (n=32), surgery (n=34), and control (n=56). The OF and OCA were measured using the Dental Prescale System before treatment (T0), immediately after treatment (T1), and 2 years after treatment (T2). Lateral cephalograms were obtained simultaneously to evaluate skeletal and dental changes. And we got the following results.

1. At T0, the anterior OF and OCA of the camouflage and surgery groups were lower than those of the control group ($P < .01$). The posterior OCA of the surgery group was lower than that of the camouflage group ($P < .05$) and lower than that of the control group ($P < .05$), but there was no significant difference in the posterior OF. The total OCA of the surgery group was lower than that of the camouflage group ($P < .05$) and lower than that of the control group ($P < .01$), but there was no significant difference in the total OF.
2. At T1, the anterior, posterior, and total OF and OCA of the camouflage and surgery groups were not significantly different from the control group.
3. At T2, the anterior OF and OCA of the camouflage and surgery groups were not significantly different from the control group. The posterior OCA of the surgery group was lower than that of the control group ($P < .05$), but the posterior OF was not significantly different. The total OCA of the surgery group was lower than that of the control group ($P < .05$), but the total OF was not significantly different.

Patients with ACB had lower anterior OF and OCA, but these increased after nonsurgical orthodontic camouflage treatment. In contrast, severe skeletal Class III patients with ACB had lower posterior OCA and total OCA, which increased as much as those in the nonsurgical patients after orthognathic surgery. Although these treatments can help patients obtain a more balanced occlusion between the anterior and posterior teeth, it seems that more than two years of observation will be needed to functionally restore them to the control level.

Key words: Anterior crossbite, Orthodontic treatment, Orthognathic surgery, Occlusal force, Occlusal contact area, Anterior teeth, Posterior teeth

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I. Introduction

Anterior crossbite (ACB) is a malocclusion that results from the lingual position of the maxillary anterior teeth relative to the mandibular anterior teeth. Patients with ACB can experience various functional and esthetic problems. From a functional perspective, ACB has been shown to negatively affect masticatory muscle activity and subsequent patterns of jaw movements during chewing, reducing masticatory efficiency.(Sohn BW, Miyawaki S et al. 1997) In adults, ACB can be treated by 2 modalities, depending on the etiology and severity. Orthodontic treatment can be selected for ACB treatment if the patient's skeletal discrepancy is not severe and the teeth can be moved physiologically within the alveolar bone. However, if skeletal Class III malocclusion is severe, ACB needs to be treated by orthognathic surgery accompanied with orthodontic treatment.(Proffit WR, Phillips C et al. 1992, Ngan P, Moon W. 2015)

The main goal of ACB treatment is to provide both a functional occlusion and an esthetic appearance.(Haydar B, Ciğer S et al. 1992) One of the ways to assess the achievement of functional occlusion after orthodontic treatment is to measure the occlusal force (OF) and occlusal contact area (OCA), which have a significant effect on masticatory function.(Owens S, Buschang PH et al. 2002, Lepley CR, Throckmorton GS et al. 2011) Several tools have been developed to measure OF and OCA before and after orthodontic treatment. Among them, the Dental Prescale System (GC Corp., Tokyo, Japan) has proven highly reliable and clinically useful for measuring the absolute values of the OF and OCA in the anterior and posterior teeth.(Ando K, Fuwa Y et al. 2009, Wang Q, Zhao Z et al. 2022)

Changes in OF and OCA following nonsurgical camouflage treatment in patients with ACB have been rarely reported. In contrast, these changes have been more extensively studied in patients with skeletal Class III malocclusion undergoing orthognathic surgery.(Islam I, Lim AAT et al. 2017) However, previous studies on orthognathic surgery did not account for the initial anterior overbite, despite evidence that patients with anterior open bite exhibit significantly lower OF and OCA (Figure 1).(Kim DH, Lee DJ. 1995, Lee J, Choi YJ et al. 2024) Additionally, premolar extraction—known to reduce OCA after orthodontic treatment(Yoon W, Hwang S et al. 2017)—was not clearly identified in previous studies, even though maxillary premolar extractions are commonly performed in Class III orthognathic surgery cases.

This study aimed to evaluate changes in OF and OCA following the treatment of ACB. To ensure an accurate analysis of ACB's effects on occlusal function, we selected patients without anterior open bite who had not undergone premolar extraction. And we compared them with a control group of patients with Angle Class I malocclusion. OF and OCA were assessed across camouflage, surgery, and control groups, with a specific focus on anterior, posterior, and total dentition.

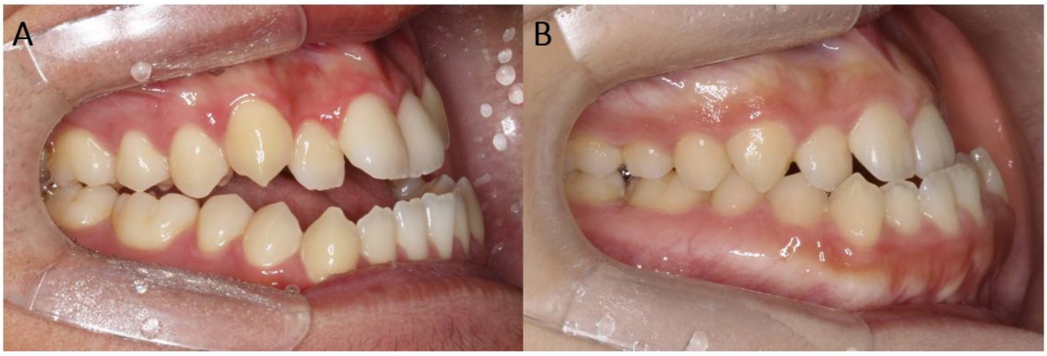


Figure 1. Two types of occlusion in patients with anterior crossbite. (A) anterior crossbite with anterior openbite. (B) anterior crossbite without anterior openbite.

II. Materials and methods

1. Subjects

This study was conducted retrospectively from archived records of 6,415 patients who presented to the Department of Orthodontics, Gangnam Severance Dental Hospital, Yonsei University, between 2008 and 2020 for orthodontic treatment. The inclusion criteria were female, 18–40 years old, Frankfort-mandibular plane angle (FMA) between 25° and 35°, anterior overbite of >0 mm before treatment (T0), second molars in occlusion both immediately after treatment (T1) and two years after treatment (T2), and availability of lateral cephalograms, dental study models, and records of occlusal function measured by Dental Prescale System at T0, T1, and T2. Additionally, only cases with Angle Class I molar key, anterior overbite of 1.0 – 4.5 mm, and anterior overjet of 1.0 – 4.5 mm at T1 were included. Of the 6,415 patients screened, 2,114 were initially included based on the inclusion criteria. The exclusion criteria were patients with missing or extracted teeth (except the third molar), a history of orthodontic treatment, facial asymmetry (menton deviation of >2 mm in posteroanterior cephalogram), occlusal adjustment during finishing phase of orthodontic treatment, and craniofacial disorders, including temporomandibular disorder. Of the 2,114 patients screened, 1,687 were initially included based on the exclusion criteria. Among them, 66 patients who had ACB in at least four out of the six maxillary anterior teeth were selected as the experimental group. These patients were further categorized into the camouflage group (n = 32), consisting of those treated with orthodontic treatment alone, and the surgery group (n = 34), consisting of those treated with orthognathic surgery. Additionally, 56 patients with a positive overbite (0.5 mm to 6.6 mm), a positive overjet (0.5 mm to 5.8 mm), and crowding less than 4mm, who had Angle Class I malocclusion (± 0.5 mm from the ideal Angle Class I molar key) at T0 and were treated with orthodontic treatment alone, were selected as the control group (n = 56) (Figure 2).

In the camouflage group, the average number of maxillary teeth in ACB was 4.5 (± 0.6). ACB was corrected by lower full-arch distalization using miniscrews or Class III elastics. Patients with mild Angle Class III malocclusion (< 2 mm) and a hypodivergent facial profile were treated with Class III elastics, while those with severe Angle Class III malocclusion (> 2 mm) or a hyperdivergent facial profile underwent mandibular distalization using miniscrews. In the surgery group, the average number of maxillary teeth in ACB was 4.9 (± 0.7), and surgery-first approach cases were not included. A single oral and maxillofacial surgeon performed all orthognathic surgeries, consisting of a Le Fort I osteotomy for the maxilla and bilateral intraoral vertical ramus osteotomy for the mandible. Maxillary anterior decompensation was achieved through distalization using orthodontic miniscrews or Class II elastics, while mandibular anterior decompensation was performed by flaring the teeth during crowding relief. The average maxillary posterior impaction was 3.0 (± 0.9) mm, and the average mandibular setback was 8.5 (± 2.2) mm. Following two weeks of intermaxillary fixation, patients underwent active physical therapy for 4–6 weeks to achieve a mouth opening of >40 mm and to facilitate the natural repositioning of the mandibular condyle. The average postoperative orthodontic treatment period was 7 (± 2.6) months. In the control group, the maxillary and mandibular full-arch distalization were performed using miniscrews to correct malocclusions such as crowding or to reduce lip protrusion. The orthodontic treatment process of all subjects (n=122) in the three groups was supervised by two orthodontists with more than 15 years of experience.

After debonding the fixed orthodontic appliances in all the 3 groups, the fixed retainers were bonded on the lingual sides from the canine to canine on both arches. All patients were asked to wear upper and lower circumferential removable retainers. Patients were instructed to wear the removable retainers all day for the first 6 months after debonding and every night thereafter.

The Institutional Review Board (IRB) at Yonsei University Gangnam Severance Hospital approved for this study (IRB no. 3-2023-0212). The IRB waived obtaining informed consent due to the retrospective nature of the study. During this study, only anonymized data was used, with personal information concealed.

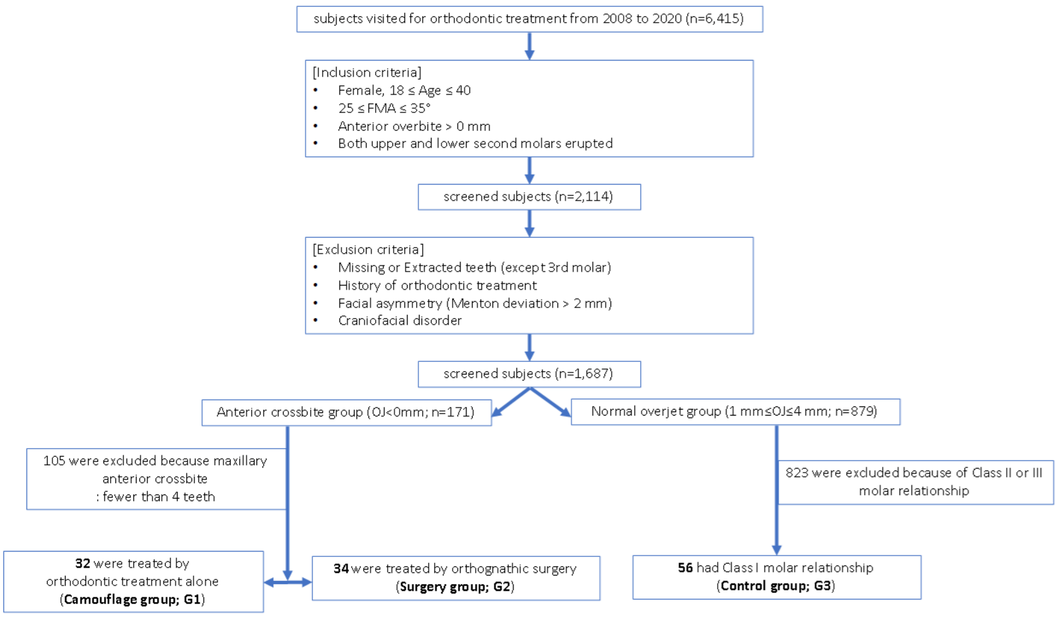


Figure 2. Study flowchart.

2. Assessment of occlusal force (OF) and occlusal contact area (OCA)

On the lateral cephalograms, the horizontal reference plane was set as a plane rotated 7° clockwise from the sella–nasion (SN) plane through the nasion, and the vertical reference plane was set as a plane perpendicular to the horizontal reference plane through the nasion. We obtained seven angular measurements, including sella-nasion-A point angle (SNA), sella-nasion-B point angle (SNB), A point–nasion–B point angle (ANB), FMA, U1–FH, incisor mandibular plane angle (IMPA), and interincisal angle (IIA), and four linear measurements, including overbite, overjet, distance from A point to a vertical line passing through Ptm (A'-Ptm'), and mandibular body length. The angles and lengths were measured to the nearest 0.1° and 0.1 mm, respectively (Figure 3).

To measure OF and OCA, a pressure-sensitive film (Dental Prescale System, 50H, type R, GC Corp.) was selected based on the patient's dental arch size and placed between the occlusal surfaces, ensuring full coverage. Patients were instructed to bite with maximum clenching force for 5 seconds in the natural head position. The pressure-sensitive film reacted to occlusal pressure by releasing a chromogenic substance. The film was then analyzed using a charge-coupled device (CCD) camera (Occluzer FPT 709, GC Corp.), which measured OF to the nearest 0.1 N and OCA to the nearest 0.1 mm^2 (Figure 4). A CCD camera detects light and converts it into a digital signal via a CCD sensor, making it an effective tool for analyzing OF and OCA. In this study, the anterior teeth refer to a group of the central incisors, lateral incisors, and canines, and the posterior teeth refer to a group of the premolars and molars. Additionally, the occlusal grading system (OGS) scores, which represent the finishing quality of each case, were evaluated from dental casts at T1 to determine whether finishing quality influences OF and OCA.

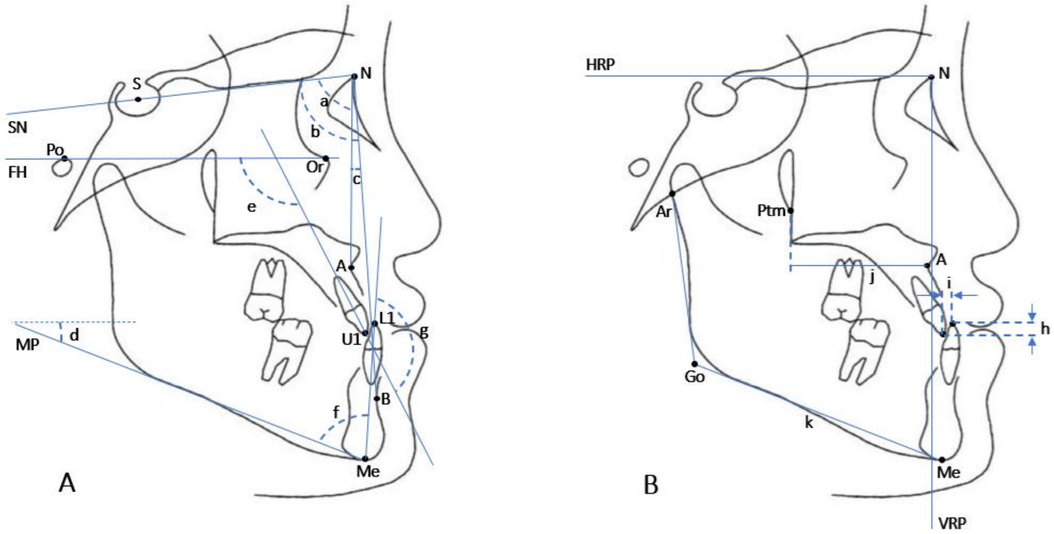


Figure 3. Cephalometric measurements. (A) angular measurements: a, SNA; b, SNB; c, ANB; d, FMA; e, U1-FH, f, IMPA; g, interincisal angle. (B) linear measurements: h, overbite; i, overjet; j, A-Vertical line from Ptm; k, mandibular body length.

Cephalometric landmarks: S, sella; N, nasion; Po, porion; Or, Orbitale; A, A point; B, B point; U1, upper incisal tip; L1, lower incisal tip; Ptm, pterygomaxillary fissure; Me, menton; Go, gonion; Ar, articulare; SN, SN plane; FH, FH plane; MP, mandibular plane; HRP, horizontal reference plane; VRP, vertical reference plane.

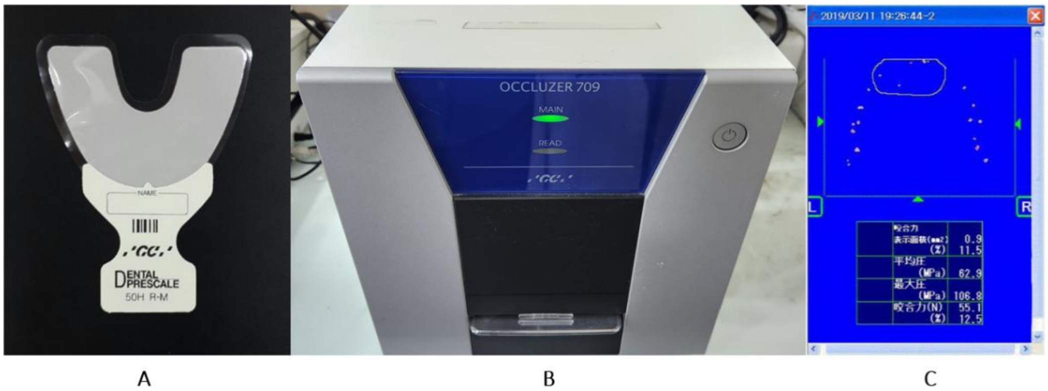


Figure 4. The Dental Prescale System (GC Corp., Tokyo, Japan). (A) Pressure-sensitive sheet (50H, type R). (B) Image scanner (Occluzer FPD-709). (C) Example of the results showing the ratios and absolute values of the anterior occlusal force and occlusal contact area.

3. Statistical analysis

To evaluate the intraexaminer reliability, we randomly selected 20 radiographs from the 366 lateral cephalograms obtained at T0, T1, and T2 for all 122 patients. All variables were measured by an orthodontist (JL) on the 20 randomly selected radiographs twice, 4 weeks apart, and a Bland-Altman analysis was conducted to evaluate measurement error and bias. Based on Bland-Altman analysis, the mean differences for linear and angular measurements were -0.01 mm and 0.03°, respectively, with ranges of -1.7 mm to 2.4 mm and -3.3 ° to 4.3°, all within two standard deviations, indicating high measurement reliability (Figure 5).

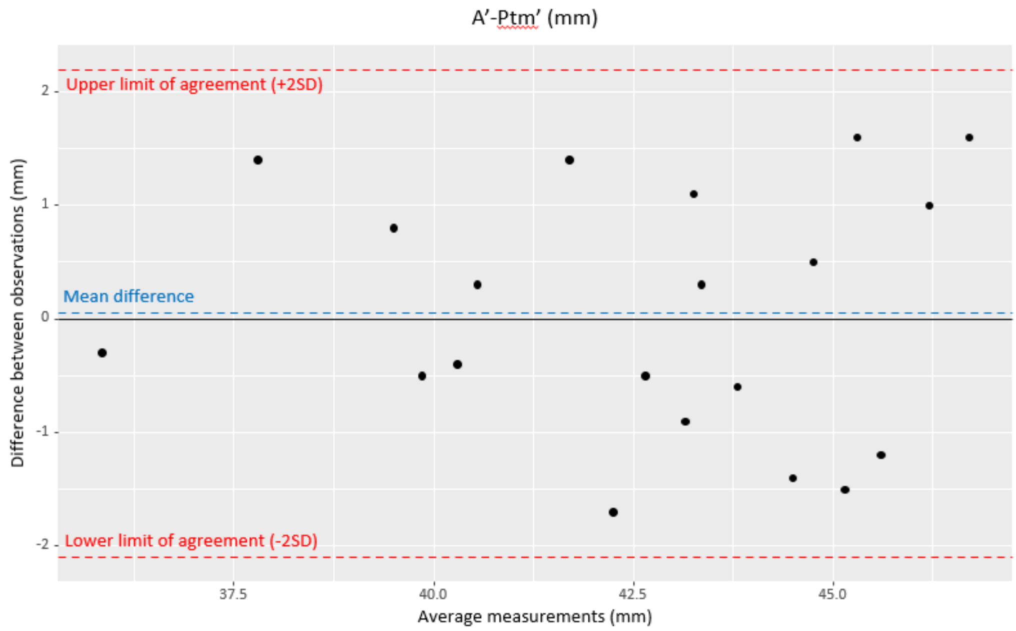
The sample size was calculated using PASS version 15 (NCSS, LLC, Kaysville, UT, USA). We determined that 28 patients per group were required to reach 80% power at a medium effect size of

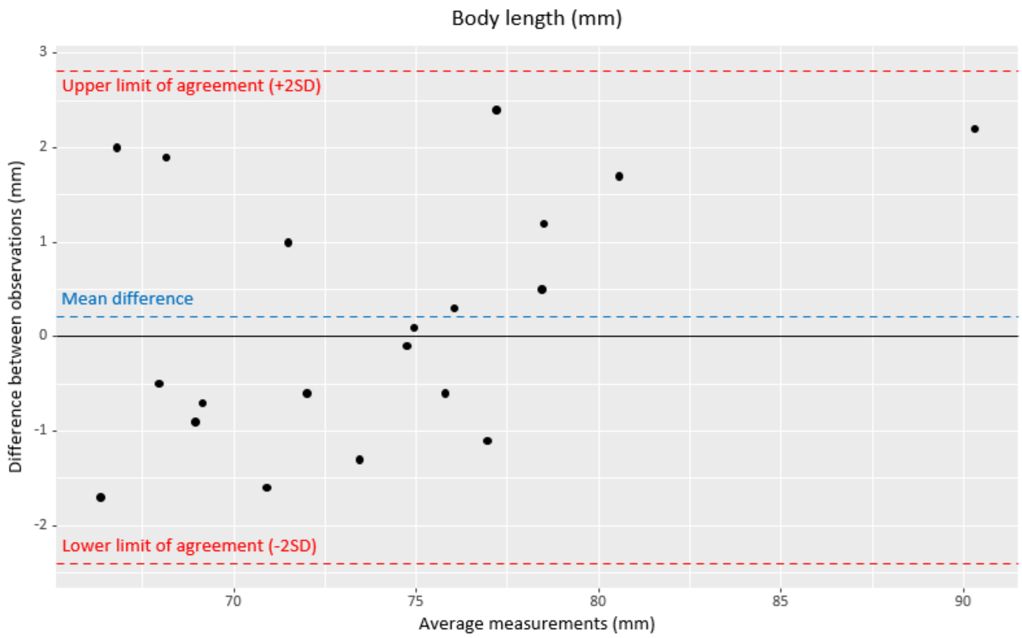
0.35, based on a previous study,(Turkistani KA, Alkayyal MA et al. 2023) and a significance level of 0.05.

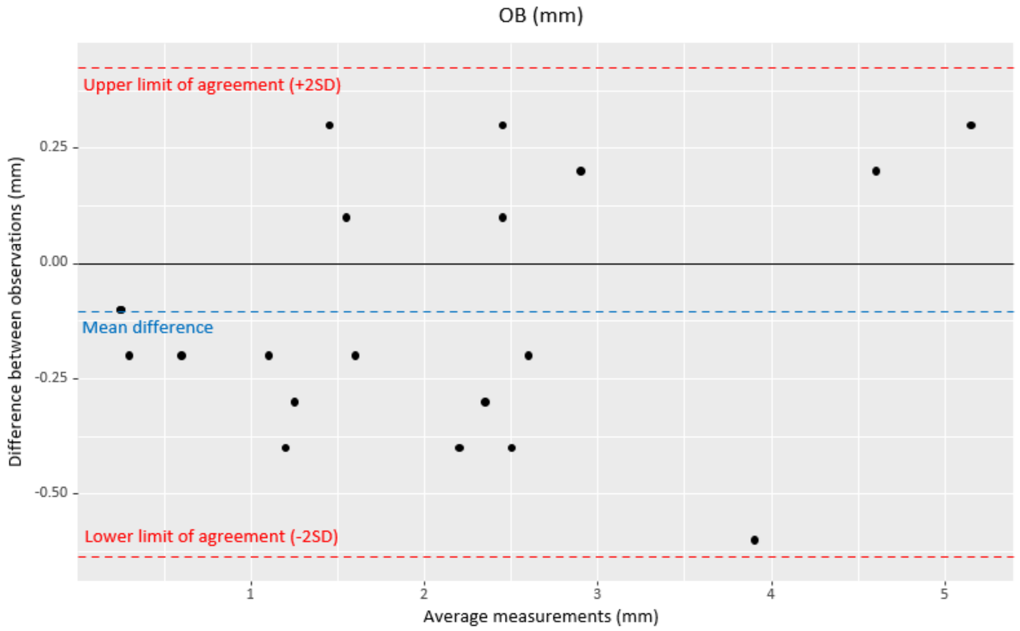
The normal distribution of the data was confirmed for all variables using the Shapiro-Wilk test. We used an 1-way analysis of variance (ANOVA) to compare the lateral cephalometric measurements at T0 and OGS scores at T1 among the three groups. We used repeated-measures ANOVA to compare the changes in measurements within each group from T0 to T2. We used a linear mixed model to compare changes in the OF and OCA in various areas (anterior, posterior, and total teeth) among the 3 groups. In addition, the anterior/total ratios of the OF and OCA among the 3 groups were compared using the same method. Nine lateral cephalometric parameters, including ANB, FMA, U1 to FH, IMPA, IIA, overbite, overjet, A'-Ptm' and mandibular body length, were set as covariates. We used the Bonferroni correction as the post hoc test.

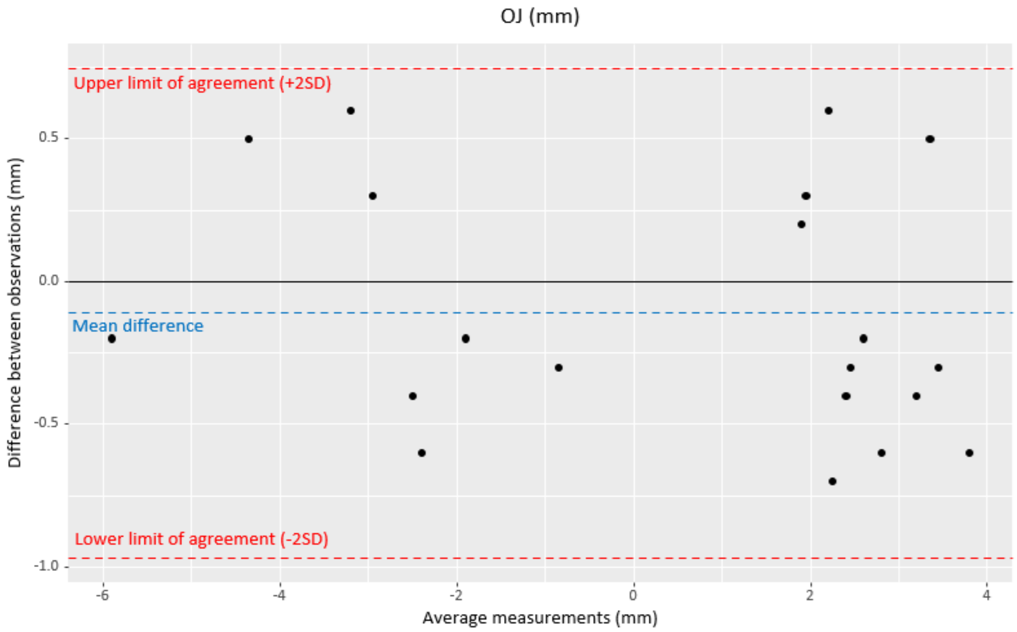
We used a multivariable linear regression analysis to evaluate the effect of the number of maxillary teeth in ACB on the decrease in OF and OCA at T0, adjusting for overbite (overbite at T0 was used as a covariate). Regardless of group classification (camouflage or surgery), patients with ACB were reclassified based on the number of maxillary teeth in ACB at T0 (4, 5, or 6) and compared with the control group.

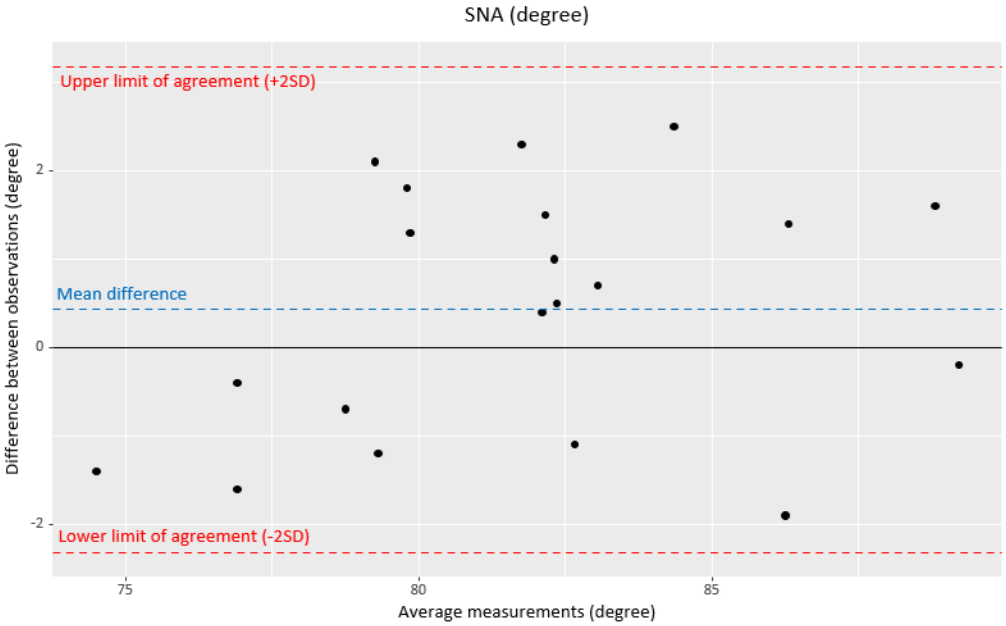
We performed the statistical analyses using SAS version 9.4 (SAS Institute, Cary, NC, USA), with the significance level set at 0.05.

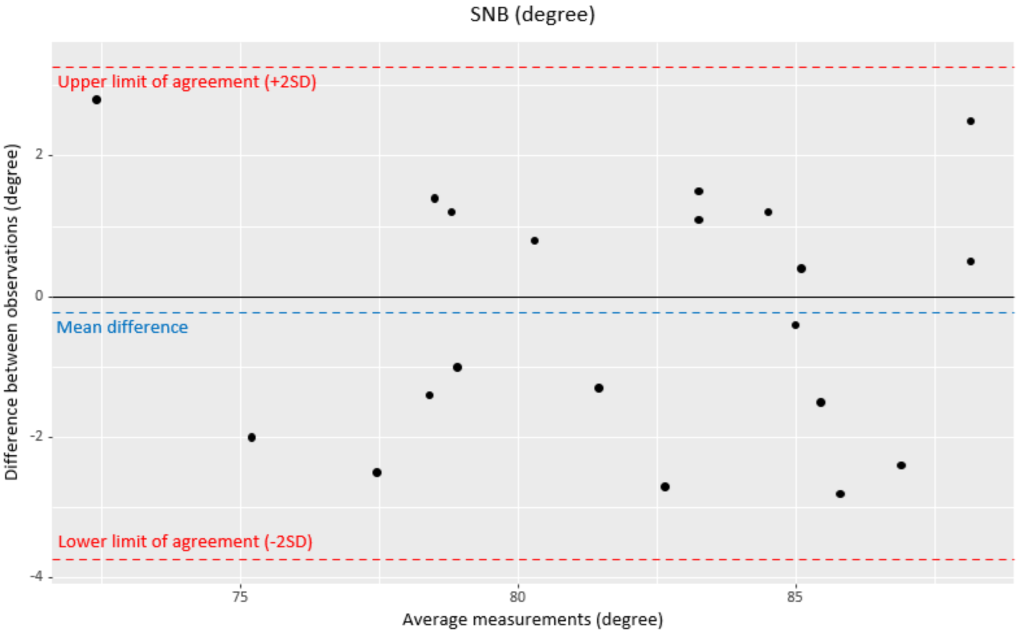

A'-Ptm' (mm)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (mm)
Average measurements (mm)
2
1
0
-1
-2
37.5
40.0
42.5
45.0

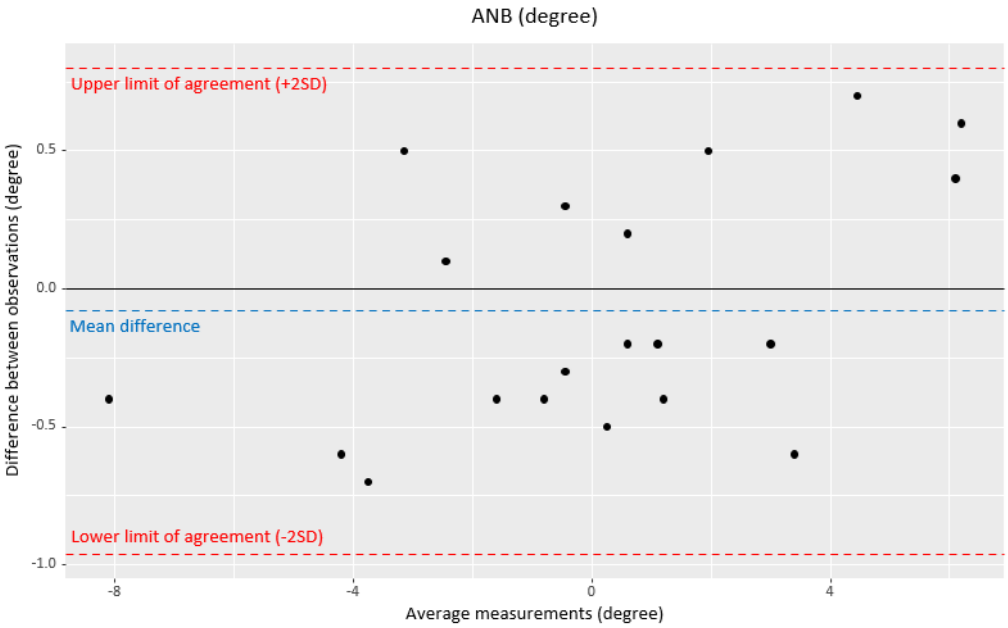

Body length (mm)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (mm)
Average measurements (mm)
3
2
1
0
-1
-2
70
75
80
85
90

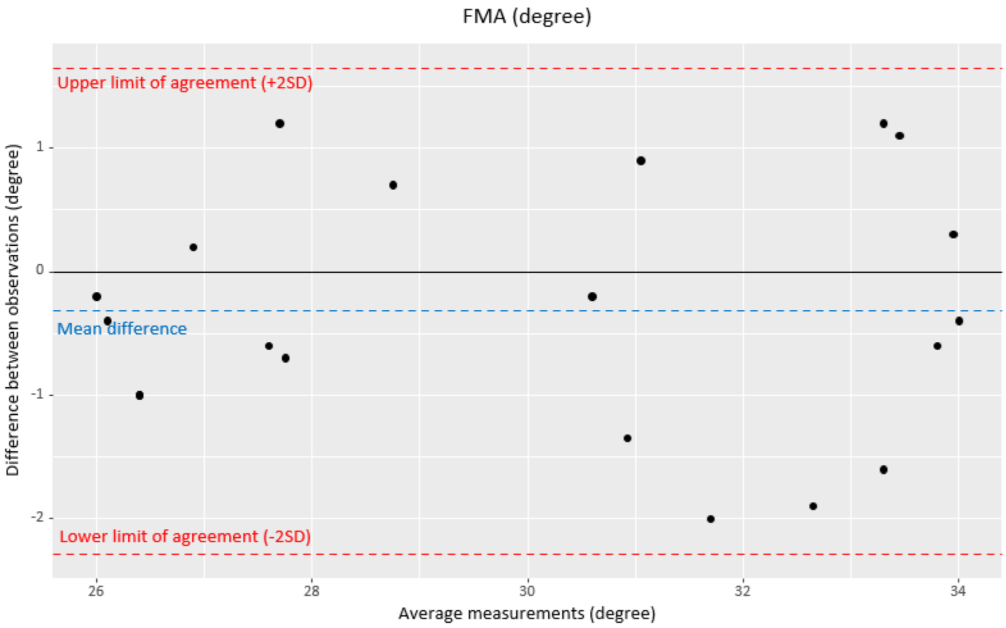

OB (mm)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (mm)
Average measurements (mm)
0.25
0.00
-0.25
-0.50
1
2
3
4
5

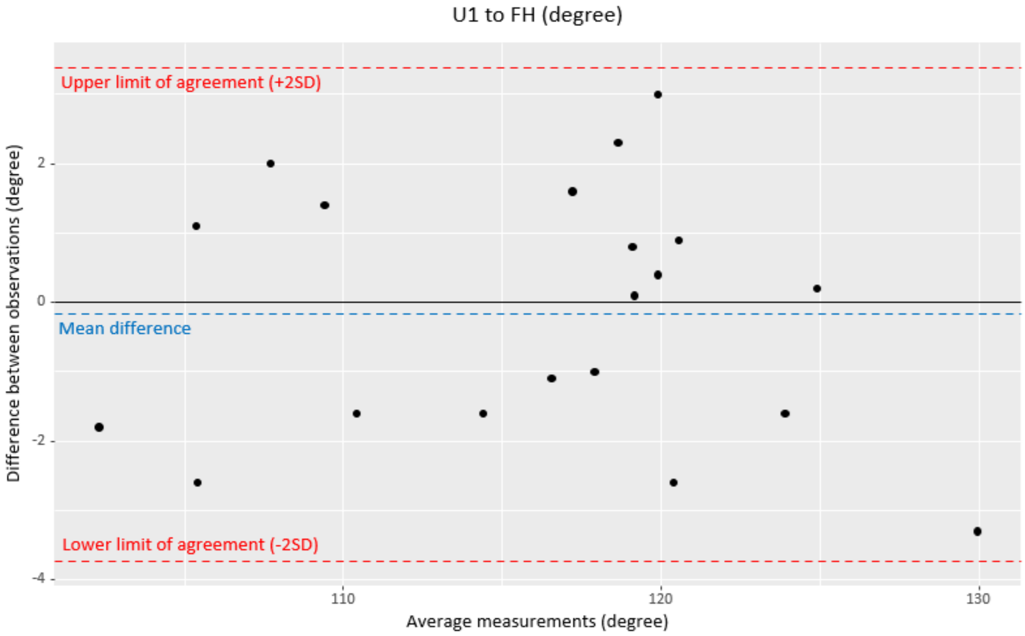

OJ (mm)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (mm)
Average measurements (mm)
0.5
0.0
-0.5
-1.0
-6
-4
-2
0
2
4

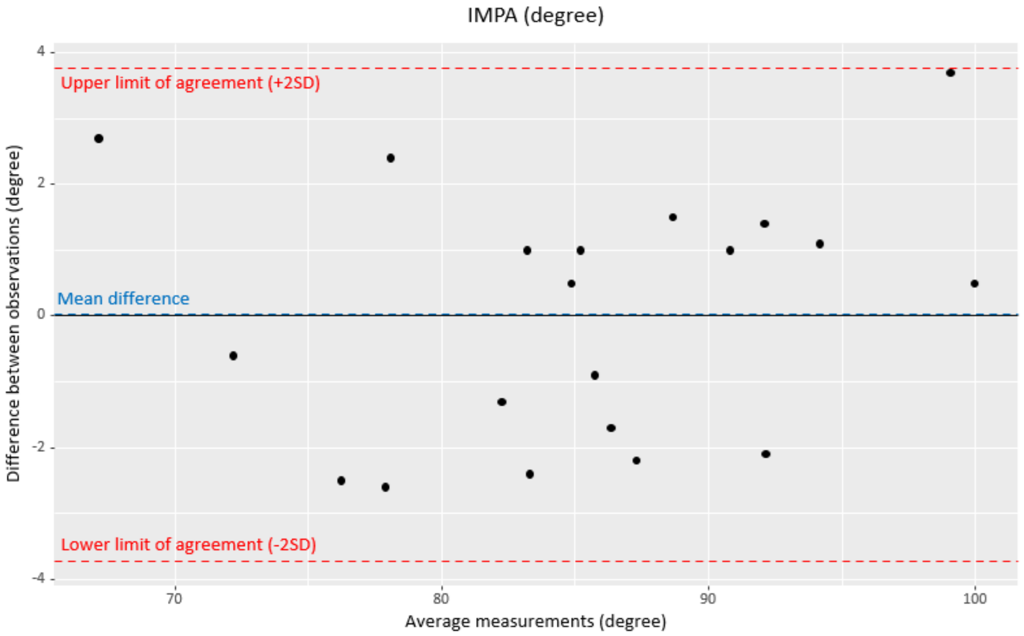

SNA (degree)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (degree)
Average measurements (degree)
2
0
-2
75
80
85


SNB (degree)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (degree)
Average measurements (degree)
2
0
-2
-4
75
80
85


ANB (degree)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (degree)
0.5
0.0
-0.5
-1.0
-8
-4
0
4
Average measurements (degree)


FMA (degree)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (degree)
1
0
-1
-2
26
28
30
32
34
Average measurements (degree)


U1 to FH (degree)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (degree)
2
0
-2
-4
110
120
130
Average measurements (degree)


IMPA (degree)
Upper limit of agreement (+2SD)
Mean difference
Lower limit of agreement (-2SD)
Difference between observations (degree)
4
2
0
-2
-4
70
80
90
100
Average measurements (degree)

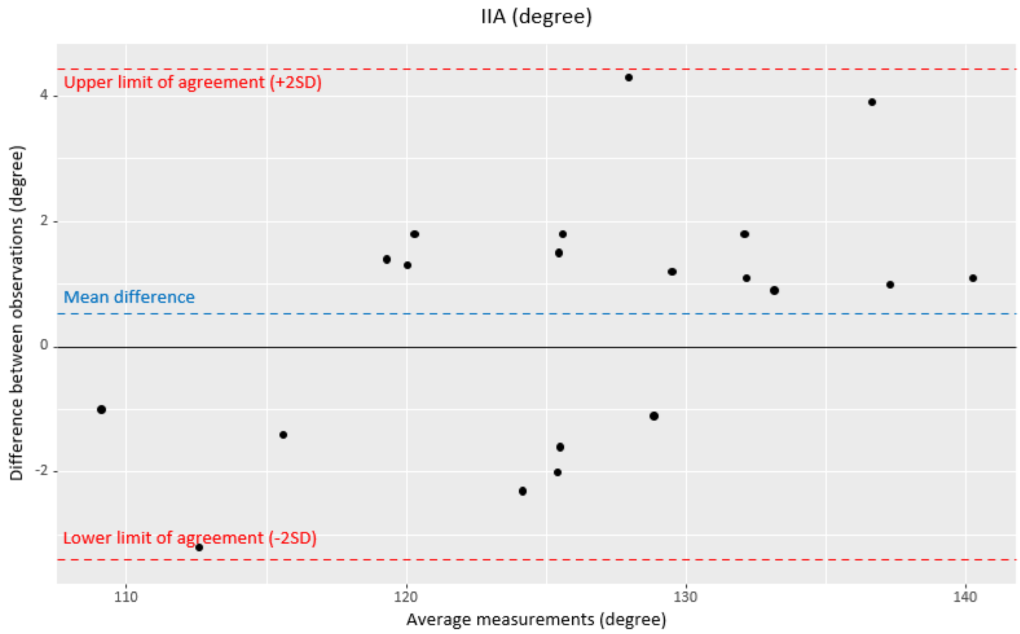


Figure 5. Bland-Altman Plot.

III. Results

At T0, the ANB, IMPA, overbite, and overjet were significantly lower in the camouflage and surgery group than in the control group ($P < .001$, Table 1). At T0 and T1, significant increases in the ANB, IMPA, and overjet in the surgery group and in the overjet in the camouflage group were observed ($P < .001$, Table 2). At T1, the OGS scores of casts were not significantly different among the 3 groups (Table 3).

There were no significant differences in the total OF among the 3 groups at T0, T1, and T2 ($P > .05$, Table 4 and Figure 6). However, the total OCA was significantly lower in the surgery group than in the camouflage and control group at T0 ($P < .05$). Also, the total OCA was significantly lower in the surgery group than in the and control group at T2 ($P < .05$). At T0, the absolute value of total OF in the camouflage and surgery groups was 95.2 % and 79.0 %, respectively, of that in the control group, while the absolute value of total OCA was 97.9 % and 70.1 %, respectively. The anterior OF and OCA were significantly lower in the camouflage and surgery groups than in the control group at T0 ($P < .01$, Table 5 and Figure 7). However, no significant difference was observed at T2 ($P > .05$). There were no significant differences in the posterior OF among the 3 groups at T0, T1, and T2 ($P > .05$, Table 6 and Figure 8). However, the posterior OCA was significantly lower in the surgery group than in the camouflage and control group at T0 ($P < .05$). Also, the posterior OCA was significantly lower in the surgery group than in the and control group at T2 ($P < .05$).

Depending on time, the total and posterior OF and OCA of the 3 groups showed decreases during treatment but increases during retention, with significantly lower values at T1 compared to those at T0 and T2 ($P < .05$, Tables 4,6 and Figures 6,8). The anterior OF and OCA showed the same trend in the control group, while they continued to increase with the highest values at T2 in the camouflage and surgery groups (Table 5 and Figure 7).

At T0, the anterior/total OF ratio was 3.8 % and 3.1 % in the camouflage and surgery groups, respectively, which was significantly lower than in the control group (8.9 %) ($P < .001$, Table 7 and Figure 9). However, the ratio increased at T1 in the camouflage and surgery groups, resulting in no significant differences among the three groups ($P > .05$). At T2, it remained lower in the camouflage and surgery groups than in the control group ($P < .01$). Meanwhile, the anterior/total OCA ratio was significantly lower in the camouflage and surgery groups than in the control group at T0 ($P < .001$), but showed no significant differences at T1 and T2 ($P > .05$).

The anterior OF was significantly lower in the patient group with five teeth in ACB than in the patient group with four teeth in ACB ($P < .001$, Table 8). However, there were no significant differences in the total OF and OCA according to the number of teeth in ACB ($P > .05$).

The linear mixed model analysis showed that total OF was significantly influenced by time, while total OCA was affected by both group and time ($P < .01$, Table 9). However, none of the nine cephalometric covariates showed a significant correlation with changes in total OF or OCA ($P > .05$).

Table 1. Cephalometric measurements before treatment (T0) in the camouflage, surgery and control groups

Variables	Camouflage (n = 32)	Surgery (n = 34)	Control (n = 56)	P-value
Age (y)	22.3 ± 5.3	20.6 ± 4.2	21.6 ± 5.4	0.391
Treatment period (m)	21.8 ± 7.9	24.6 ± 7.0	21.2 ± 7.4	0.100
SNA (°)	80.2 ± 3.0	80.8 ± 3.1	80.2 ± 3.2	0.621
SNB (°)	80.1 ± 3.4^{B}	83.2 ± 4.0^{C}	77.8 ± 3.9^{A}	<0.001***
ANB (°)	0.1 ± 2.0^{B}	- 2.3 ± 2.7^{A}	2.4 ± 2.4^{C}	<0.001***
FMA (°)	30.2 ± 3.0	30.4 ± 3.2	29.9 ± 2.9	0.745
U1 to FH (°)	115.2 ± 7.4	115.3 ± 6.2	112.9 ± 9.0	0.261
IMPA (°)	88.6 ± 7.8^{B}	81.7 ± 8.3^{A}	94.6 ± 5.9^{C}	<0.001***
Interincisal (°)	124.5 ± 8.4	127.5 ± 8.8	125.4 ± 10.8	0.100
A'-Ptm' (mm)	42.9 ± 2.7	43.1 ± 2.7	43.3 ± 2.2	0.726
Body length (mm)	72.6 ± 4.7^{A}	78.4 ± 6.3^{B}	71.1 ± 3.8^{A}	<0.001***
OB (mm)	0.6 ± 0.8^{A}	1.5 ± 1.6^{A}	3.1 ± 1.7^{B}	< 0.001***
OJ (mm)	- 1.4 ± 0.5^{B}	- 3.1 ± 2.4^{A}	3.0 ± 1.2^{C}	< 0.001***

Data are presented as mean ± standard deviation.

One-way ANOVA and Bonferroni correction for post-hoc test were performed. The different superscript letters indicate that there were statistically significant differences among groups (A < B < C).

y, years; m, months; ANB, A point-nasion-B point angle; FMA, Frankfort to mandibular plane angle; U1 to FH, Frankfort to the maxillary central incisor angle; IMPA, mandibular plane to the mandibular central incisor angle; Interincisal, interincisal angle; A'-Ptm', A point to vertical line with Ptm; Body length, mandibular body length; OB, overbite; OJ, overjet.

*** P < .001.

Table 2. Changes in cephalometric measurements before (T0), immediately after (T1) and two years after treatment (T2) in the camouflage, surgery and control groups

Variables	Camouflage (n = 32)				Surgery (n = 34)				Control (n = 56)			
	T0	T1	T2	P-value	T0	T1	T2	P-value	T0	T1	T2	P-value
SNA (°)	80.2 ± 3.0	80.0 ± 3.1	80.1 ± 3.1	0.611	80.8 ± 3.1^{A}	82.4 ± 3.7^{B}	82.4 ± 3.6^{B}	<0.001***	80.2 ± 3.2^{B}	80.0 ± 3.1^{B}	79.7 ± 3.3^{A}	0.001**
SNB (°)	80.1 ± 3.4	79.6 ± 3.4	79.7 ± 3.6	0.072	83.2 ± 4.0^{B}	78.5 ± 3.5^{A}	78.6 ± 3.4^{A}	<0.001***	77.8 ± 3.9^{C}	77.5 ± 3.9^{B}	77.2 ± 4.0^{A}	<0.001***
ANB (°)	0.1 ± 2.0	0.4 ± 1.9	0.4 ± 1.9	0.086	- 2.3 ± 2.7^{A}	3.9 ± 2.2^{B}	3.8 ± 2.2^{B}	<0.001***	2.4 ± 2.4	2.5 ± 2.3	2.5 ± 2.3	0.181
FMA (°)	30.2 ± 3.0	30.8 ± 3.3	30.6 ± 3.5	0.139	30.4 ± 3.2^{A}	35.3 ± 4.2^{B}	35.3 ± 4.4^{B}	<0.001***	29.9 ± 2.9	30.0 ± 3.2	29.9 ± 3.0	0.886
U1 to FH (°)	115.2 ± 7.4^{A}	118.3 ± 6.3^{B}	117.5 ± 6.6^{B}	0.0106*	115.3 ± 6.2^{B}	110.5 ± 5.7^{A}	110.4 ± 4.9^{A}	<0.001***	112.9 ± 9.0	113.2 ± 7.1	112.9 ± 7.1	0.381
IMPA (°)	88.6 ± 7.8^{C}	84.5 ± 7.4^{A}	85.6 ± 7.2^{B}	<0.001***	81.7 ± 8.3^{A}	86.1 ± 7.1^{B}	87.2 ± 6.9^{C}	<0.001***	94.6 ± 5.9	91.9 ± 8.4^{A}	94.8 ± 7.3^{B}	0.001**
Interincisal (°)	124.5 ± 8.4	125.5 ± 8.1	125.2 ± 8.1	0.138	127.5 ± 8.8^{A}	128.6 ± 8.7^{B}	128.0 ± 8.6^{A}	0.027*	125.4 ± 10.8	125.9 ± 8.7	125.7 ± 9.1	0.904
A'-Ptm' (mm)	42.9 ± 2.7	42.6 ± 3.1	42.8 ± 3.1	0.683	43.1 ± 2.7^{A}	44.9 ± 2.4^{B}	44.7 ± 2.5^{B}	<0.001***	43.3 ± 2.2^{B}	42.7 ± 2.4	42.7 ± 2.6^{A}	0.029
Body length (mm)	72.6 ± 4.7	72.9 ± 4.5	73.0 ± 4.5	0.169	78.4 ± 6.3^{B}	71.3 ± 5.4^{A}	71.5 ± 5.4^{A}	<0.001***	71.1 ± 3.8	71.1 ± 3.8	70.9 ± 3.8	0.324
OB (mm)	0.6 ± 0.8^{A}	2.2 ± 0.5^{C}	1.7 ± 0.7^{B}	<0.001***	1.5 ± 1.6^{A}	2.6 ± 0.7^{B}	2.0 ± 0.9^{A}	<0.001***	3.1 ± 1.7^{B}	2.5 ± 0.6^{A}	2.6 ± 0.6	0.019*
OJ (mm)	- 1.4 ± 0.5^{A}	2.7 ± 0.6^{C}	2.1 ± 0.6^{B}	<0.001***	- 3.1 ± 2.4^{A}	2.8 ± 0.7^{C}	2.4 ± 0.7^{B}	<0.001***	3.0 ± 1.2	2.7 ± 0.6	2.6 ± 0.5	0.092

Data are presented as mean ± standard deviation.
Repeated-measures ANOVA and Bonferroni method for post-hoc test were performed. The different superscript letters indicate that there were statistically significant differences among times (A < B < C).

* P < .05; ** P < .01; *** P < .001.
Please refer to Table I for abbreviations of the cephalometric measurements.

Table 3. OGS scores immediately after treatment (T1) in the camouflage, surgery and control groups

Variable	Camouflage (n=32)	Surgery (n=34)	Control (n=56)	P-value
OGS score	20.1 ± 6.5	19.6 ± 7.2	21.3 ± 6.8	0.486

Data are presented as the mean ± standard deviation.
One-way ANOVA was performed.
OGS score, objective grading system scores of casts.

Table 4. Total occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery and control groups

Measurements	Time	Camouflage (G1)	Surgery (G2)	Control (G3)	P-value (Significance†)	Overall P-values
Total OF (N)	T0	366.2 (28.4)	303.7 (27.6)	384.5 (21.5)	0.069	Group: P = 0.091 Time: P < 0.001*** Group × time: P = 0.513
	T1	261.6 (18.2)	240.2 (17.6)	287.9 (13.7)	0.099	
	T2	352.7 (23.3)	330.1 (22.6)	357.1 (17.6)	0.627	
	P-value (Significance$^{\Delta}$)	<.001*** (T1 < T0***, T1 < T2***)	<.001*** (T1 < T2***)	<.001*** (T1 < T0***, T1 < T2***)		
Total OCA (mm^2)	T0	9.5 (0.8)^{B}	6.8 (0.8)^{A}	9.7 (0.6)^{B}	0.006** (G2 < G1*, G2 < G3**)	Group: P = 0.001** Time: P < 0.001*** Group × time: P = 0.051
	T1	5.5 (0.4)	4.9 (0.4)	5.9 (0.3)	0.152	
	T2	8.8 (0.6)	7.4 (0.6)^{A}	9.3 (0.5)^{B}	0.005** (G2 < G3*)	
	P-value (Significance$^{\Delta}$)	<.001*** (T1 < T0***, T1 < T2***)	<.001*** (T1 < T0*, T1 < T2**)	<.001*** (T1 < T0***, T1 < T2***)		

Data are presented as the estimated mean (standard error).
The linear mixed model and Bonferroni corrected post-hoc test were performed. The different superscript letters indicate that there were statistically significant differences among groups (A < B < C).
†, P-values obtained by comparing three groups (G1, G2, and G3) at the same time point.
Δ, P-values obtained by comparing three time points (T0, T1, and T2) within the same group.
T0, before treatment; T1, immediately after treatment; T2, two years after treatment.

* P < .05; ** P < .01; *** P < .001.

Table 5. Anterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery and control groups

Measurements	Time	Camouflage (G1)	Surgery (G2)	Control (G3)	P-value (Significance†)	Overall P-values
Anterior OF (N)	T0	14.3 (3.0)^{A}	9.1 (2.9)^{A}	33.1 (2.3)^{B}	<.001*** (G1 < G3***, G2 < G3***)	
	T1	21.7 (2.4)	20.3 (2.3)	21.7 (1.8)	0.879	Group: P < 0.001*** Time: P < 0.004** Group × time: P < 0.001***
	T2	23.4 (2.5)	24.3 (2.4)	30.8 (1.9)	0.290	
	P-value (Significance$^{\Delta}$)	0.041* (T0 < T2*)	<.001*** (T0 < T1**, T0 < T2***)	<.001*** (T1 < T0***, T1 < T2**)		
Anterior OCA (mm^2)	T0	0.4 (0.1)^{A}	0.2 (0.1)^{A}	0.8 (0.1)^{B}	<.001*** (G1 < G3** G2 < G3***)	
	T1	0.4 (0.1)	0.4 (0.1)	0.5 (0.1)	0.176	Group: P < 0.001*** Time: P < 0.001*** Group × time: P < 0.001***
	T2	0.7 (0.1)	0.5 (0.1)	0.7 (0.1)	0.203	
	P-value (Significance$^{\Delta}$)	<.001*** (T0 < T2** T1 < T2***)	0.012* (T0 < T2*)	<.001*** (T1 < T0***, T1 < T2**)		

Data are presented as the estimated mean (standard error).

The linear mixed model and Bonferroni corrected post-hoc test were performed. The different superscript letters indicate that there were statistically significant differences among groups (A < B < C).

†, P-values obtained by comparing three groups (G1, G2, and G3) at the same time point.

Δ, P-values obtained by comparing three time points (T0, T1, and T2) within the same group.

T0, before treatment; T1, immediately after treatment; T2, two years after treatment.

* P < .05; ** P < .01; *** P < .001.

Table 6. Posterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery and control groups

Measurements	Time	Camouflage (G1)	Surgery (G2)	Control (G3)	P-value (Significance†)	Overall P-values
Posterior OF (N)	T0	352.0 (27.0)	294.6 (26.2)	351.4 (20.4)	0.187	Group: P = 0.153 Time: P < 0.001*** Group × time: P = 0.544
	T1	240.0 (16.8)	219.9 (16.3)	266.3 (12.7)	0.078	
	T2	329.3 (21.8)	305.8 (21.1)	326.3 (16.5)	0.683	
	P-value (Significance^Δ)	<.001*** (T1 < T0***, T1 < T2***)	<.001*** (T1 < T0**, T1 < T2***)	<.001*** (T1 < T0***, T1 < T2**)		
Posterior OCA (mm^2)	T0	9.1 (0.7)^{B}	6.5 (0.7)^{A}	8.9 (0.5)^{B}	0.013* (G2 < G1*, G2 < G3*)	Group: P = 0.002** Time: P < 0.001*** Group × time: P = 0.066
	T1	5.1 (0.4)	4.5 (0.4)	5.4 (0.3)	0.176	
	T2	8.0 (0.6)	6.9 (0.6)^{A}	8.6 (0.4)^{B}	0.006** (G2 < G3*)	
	P-value (Significance^Δ)	<.001*** (T1 < T0***, T1 < T2***)	<.001*** (T1 < T0**, T1 < T2**)	<.001*** (T1 < T0***, T1 < T2***)		

Data are presented as the estimated mean (standard error).

The linear mixed model and Bonferroni corrected post-hoc test were performed. The different superscript letters indicate that there were statistically significant differences among groups (A < B < C).

†, P-values obtained by comparing three groups (G1, G2, and G3) at the same time point.

Δ, P-values obtained by comparing three time points (T0, T1, and T2) within the same group.

T0, before treatment; T1, immediately after treatment; T2, two years after treatment.

* P < .05; ** P < .01; *** P < .001.

Table 7. Anterior/Total ratios of the occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery and control groups

Measurements	Time	Camouflage (G1)	Surgery (G2)	Control (G3)	P-value (Significance†)	Overall P-values
Anterior/Total ratio of the OF (%)	T0	3.8 (0.6)^A	3.1 (0.6)^A	8.9 (0.5)^B	<.001*** (G1 < G3***, G2 < G3***)	Group: P < 0.001*** Time: P < 0.001*** Group × time: P < 0.001***
	T1	7.8 (0.6)	8.3 (0.6)	7.9 (0.5)	0.829	
	T2	6.9 (0.6)^A	7.0 (0.5)^A	9.1 (0.4)^B	<.001*** (G1 < G3** , G2 < G3**)	
	P-value (Significance^Δ)	<.001*** (T0 < T1***, T0 < T2**)	<.001*** (T0 < T1***, T0 < T2***)	0.082		
Anterior/Total ratio of the OCA (%)	T0	4.5 (0.6)^A	3.4 (0.6)^A	7.8 (0.5)^B	<.001*** (G1 < G3***, G2 < G3***)	Group: P = 0.001** Time: P < 0.001*** Group × time: P < 0.001***
	T1	7.5 (0.6)	7.3 (0.6)	8.5 (0.5)	0.209	
	T2	8.2 (0.6)	7.0 (0.6)	7.4 (0.5)	0.566	
	P-value (Significance^Δ)	<.001*** (T0 < T1***, T0 < T2**)	<.001*** (T0 < T1***, T0 < T2***)	0.199		

Data are presented as the estimated mean (standard error).

The linear mixed model and Bonferroni corrected post-hoc test were performed. The different superscript letters indicate that there were statistically significant differences among groups (A < B < C).

†, P-values obtained by comparing three groups (G1, G2, and G3) at the same time point.

Δ, P-values obtained by comparing three time points (T0, T1, and T2) within the same group.

T0, before treatment; T1, immediately after treatment; T2, two years after treatment.

* P < .05; ** P < .01; *** P < .001.

Table 8. Effect of the number of maxillary anterior crossbite teeth on OF and OCA at T0

Variables	0 crossbite (n=56)	4 crossbite (n=27)	5 crossbite (n=33)	6 crossbite (n=6)	P-value
Anterior OF	31.6 (2.4)^{C}	20.4 (3.3)^{B}	8.2 (3.0)^{A}	5.4 (6.7)^{AB}	<0.001***
Anterior OCA	0.7 (0.1)^{B}	0.5 (0.1)	0.3 (0.1)^{A}	0.2 (0.2)	0.002**
Total OF	389.0 (24.2)	332.3 (33.0)	342.8 (29.8)	252.2 (66.4)	0.205
Total OCA	9.7 (0.7)	8.6 (0.9)	8.2 (0.8)	5.5 (1.8)	0.106

Data are presented as the estimated mean (standard error).

Multivariable linear regression was performed. The different superscript letters indicate that there were statistically significant differences among groups (A < B < C).

OF, occlusal force; OCA, occlusal contact area; T0, before treatment.

** P < .01; *** P < .001.

Table 9. P-values for fixed effects and covariates in the linear mixed model

Variables	Total OF		Total OCA	
	Univariable	Multivariable	Univariable	Multivariable
Group	0.04*	0.091	<.001***	0.001**
Time	<.001***	<.001***	<.001***	<.001***
Group × Time	0.422	0.513	0.079	0.051
ANB	0.199	0.916	0.072	0.537
FMA	0.145	0.217	0.289	0.719
U1 to FH	0.153	0.732	0.303	0.473
IMPA	0.217	0.751	0.398	0.659
Interincisal angle	0.204	0.791	0.228	0.341
A'-Ptm'	0.371	0.721	0.226	0.667
Body length	0.513	0.849	0.684	0.504
OB	0.434	0.735	0.348	0.628
OJ	0.150	0.717	0.283	0.771

The linear mixed model with regression analysis and Bonferroni corrected post-hoc test were performed.

OF, occlusal force; OCA, occlusal contact area.

* $P < .05$; ** $P < .01$; *** $P < .001$.

Please refer to Table I for abbreviations of the cephalometric measurements.

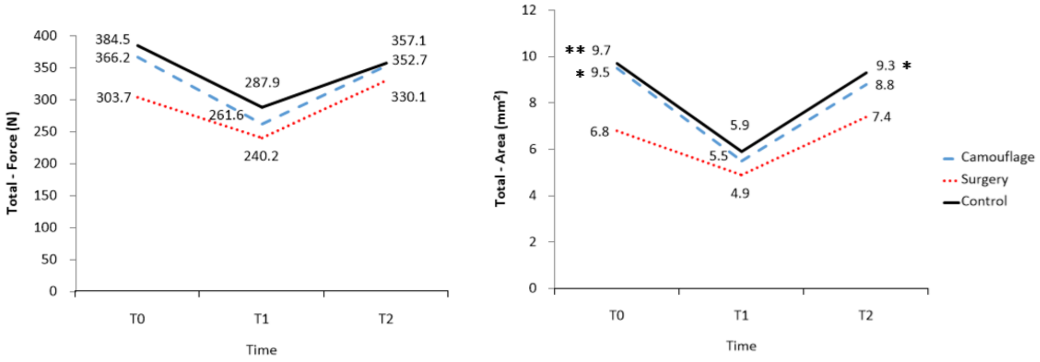


Figure 6. Changes in total occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups.

OF and OCA decreased immediately after treatment (T1) but increased thereafter. Before treatment (T0), total OF showed no statistically significant differences among the three groups, whereas total OCA was significantly lower in the camouflage and surgery groups. Two years after treatment (T2), only total OCA in the surgery group remained significantly lower compared to the control group.

*P<0.05; **P<0.01.

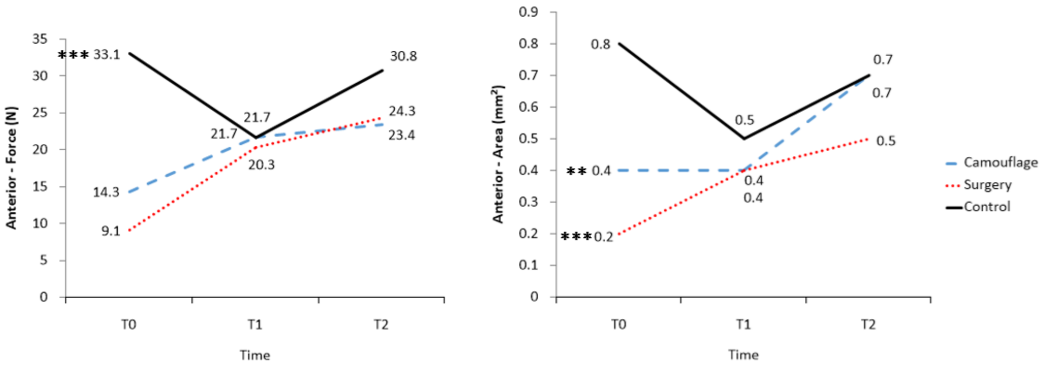


Figure 7. Changes in anterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups.

Before treatment (T0), anterior OF and OCA were significantly lower in the camouflage and surgery groups than in the control group. However, they increased immediately after treatment (T1) and continued to increase two years after treatment (T2), resulting in no significant differences among the three groups at T1 and T2.

**P<0.01; ***P<0.001.

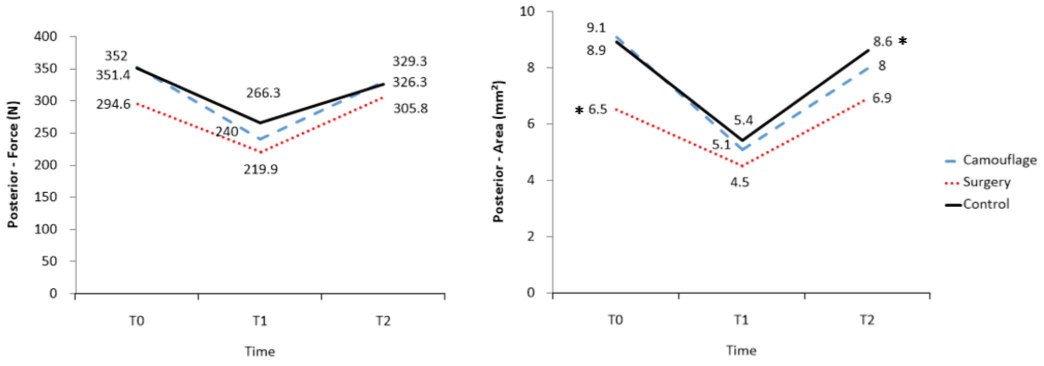


Figure 8. Changes in posterior occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups.

Posterior OF and OCA showed the same trend in the three groups: they decreased immediately after treatment (T1) but increased thereafter. Posterior OF did not show significant differences before treatment (T0) and two years after treatment (T2), while posterior OCA was significantly lower in the surgery group than in the control group at T0 and T2.

*, significant difference obtained by comparing three groups (camouflage, surgery, and control groups) at the same time point.

*P<0.05.

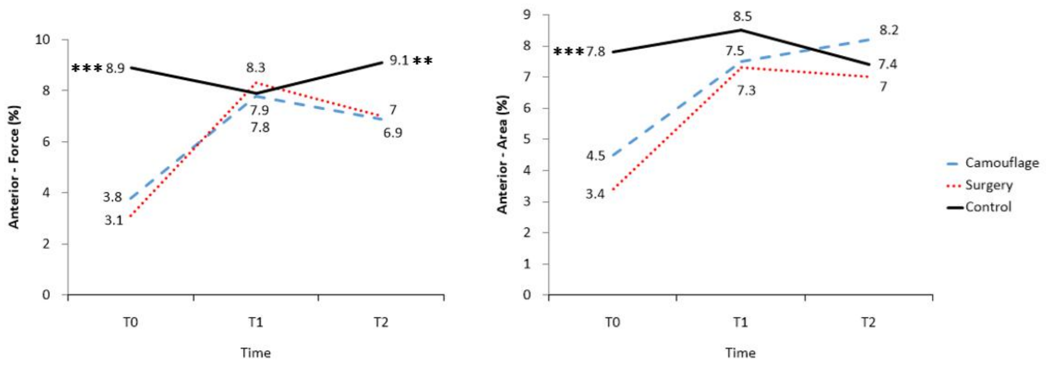


Figure 9. Changes in the anterior/total ratios of occlusal force (OF) and occlusal contact area (OCA) in the camouflage, surgery, and control groups.

Before treatment (T0) the ratios of OF and OCA were significantly lower in the camouflage and surgery groups than in the control group. Immediately after treatment (T1) there were no significant differences among the three groups. However, two years after treatment (T2) the ratio of OF remained lower in the camouflage and surgery groups than in the control group.

*, significant difference obtained by comparing three groups (camouflage, surgery, and control groups) at the same time point.

**P<0.01; ***P<0.001.

IV. Discussion

This study was aimed to investigate changes in OF and OCA after ACB correction to assess effects of initial malocclusion and treatment outcomes. Total OF was not significantly different among three groups from T0 to T2. Anterior OF and OCA in the camouflage and surgery groups increased after treatment. Total and posterior OCA in the surgery group also increased after treatment, although these values could not reach the values of the control group. The findings suggest that mild Class III malocclusion with anterior crossbite has no functional problems except the anterior teeth. However, severe Class III malocclusion may have functional impairments.

The camouflage group exhibited total OF and OCA levels comparable to those of the control group from T0 to T2, likely due to its relatively good skeletal and occlusal status, aside from ACB. This finding suggests that posterior occlusion was favorable, despite significantly lower anterior OF and OCA at T0 in the camouflage group compared to the control group due to ACB. After orthodontic treatment for ACB, these differences were no longer significant at T1 and T2, indicating that ACB reduces anterior OF and OCA.

In contrast, total OCA was significantly lower in the surgery group than in the control group at T0 and T2. Although the average number of maxillary teeth in ACB was slightly higher in the surgery group than in the camouflage group, the significant differences in total OCA between the surgery and control groups may be attributed to other factors. In the surgery group, which consisted of more severe Class III malocclusion, the mandible was positioned more anteriorly relative to the maxilla. As a result, the rearmost second molars of the maxilla may have lacked proper occlusal contact with the opposing mandibular teeth. Additionally, a transverse discrepancy, often observed due to relatively greater basal arch width of the mandible,(Koo YJ, Choi SH et al. 2017) may have contributed to poor interdigitation. These findings suggest that skeletal discrepancies in severe Class III malocclusion may contribute to reduced posterior OCA followed by total OCA, independent of the number of maxillary teeth in ACB. After treatment, the difference in posterior OCA between the two groups decreased at T2 but remained significantly lower in the surgery group, indicating persistent interdigitation deficiency.

Meanwhile, posterior and total OF were slightly lower in the surgery group compared to the control group throughout the observation period, although the differences were not statistically significant—possibly due to insufficient statistical power. Masticatory function tends to decrease in patients with skeletal Class III malocclusion, likely due to reduced masticatory muscle volume and activity,(Sforza C, Peretta R et al. 2008, Lee DH, Yu HS. 2012) as well as mal-aligned teeth,(Choi YJ, Lim H et al. 2014) with the latter being a more critical factor.(Islam I, Lim AAT et al. 2017) Although OF and OCA are generally proportional (OF [N] = bite pressure [MPa] × OCA [mm^2]), OF is directly influenced by masticatory muscle forces, while OCA is determined by occlusion. This distinction may explain why posterior OCA differed significantly between the two groups.

Depending on time point, all three groups exhibited a decrease in OF and OCA at T1 compared to T0, followed by an increase at T2. At T1, OF and OCA did not significantly increase despite improved occlusion following orthodontic treatment, as previously reported.(Lee J, Choi YJ et al. 2024, Yoon W, Hwang S et al. 2017, Choi YJ, Lim H et al. 2014) The decrease in OF may be attributed to reduced masticatory muscle activity during the approximately two-year orthodontic treatment period, potentially leading to muscle atrophy.(Varga S, Spalj S et al. 2017) Additionally, occlusal settling may not have been fully achieved at T1.(Lee J, Choi YJ et al. 2024, Yoon W, Hwang S et al. 2017, Lee H, Kim M et al. 2015) At T2, after two years of retention, OF and OCA increased but did not exceed T0 values, possibly due to insufficient occlusal settling. The time required for occlusal settling varies among studies, with some suggesting that it may take more than three years.(Edward Ellis III, Throckmorton GS et al. 1996, Ohkura K, Harada K et al. 2001, Yamashita Y, Otsuka T et al. 2011) Therefore, longer follow-up periods are necessary to monitor changes in OF and OCA over time.

The anterior–posterior balanced distribution of OF and OCA is essential for optimal occlusal function.(Rubió-Ferrer G, Rovira-Lastra B et al. 2024) The anterior/total ratios of OF and OCA vary slightly depending on the sample population and measurement method. Previous studies using the same system have reported that in adults with normal occlusion, these ratios range from 6% to 14%.(Kumagai H, Suzuki T et al. 1999, Sultana MH, Yamada K et al. 2002) In this study, the anterior/total ratios at T0 were 3.1 – 4.5% in the camouflage and surgery groups, approximately half the values observed in the control group. However, these ratios increased to 6.9–8.2% at T1 and T2, suggesting that ACB correction helps restore a more balanced occlusal function between the anterior and posterior teeth.

When OF and OCA were compared based on the number of maxillary teeth in ACB at T0, anterior OF and OCA tended to decrease significantly as the number of affected teeth increased. Therefore, when treating patients with ACB, special attention should be given to ensuring stable anterior occlusion.

This study found no correlation between the nine cephalometric covariates and OF or OCA, which contrasts with previous studies reporting an association between skeletal patterns and occlusal function. Specifically, patients with a skeletal Class III tendency(Islam I, Lim AAT et al. 2017) or a hyperdivergent skeletal pattern have been shown to exhibit reduced OF or OCA.(Throckmorton GS, Finn RA et al. 1980, Proffit WR, Fields HW et al. 1983) Although pre-treatment OF and OCA values may be influenced by cephalometric characteristics, changes in OF and OCA during and after orthodontic treatment appear to be primarily driven by occlusal factors.

Quantitative measurements of OF and OCA can be obtained using T-scan (Tekscan Inc., Boston, MA, USA) or the Dental Prescale System. T-scan detects OF changes through a sensor that measures electrical resistance under pressure and allows real-time evaluation of dynamic occlusion during mandibular movement. It displays OF distribution within the arch as relative proportions. In contrast, the Dental Prescale System uses a thin, soft film (0.097 mm) that reacts to pressure by breaking microcapsules between two polyethylene terephthalate sheets, producing red markings of varying intensity based on OF magnitude. Unlike T-scan, it expresses OF distribution and magnitude as absolute values, making it suitable for cohort studies comparing absolute OF across different subjects and time points.(Islam I, Lim AAT et al. 2017, Huang YF, Wang CM et al. 2022, Zhao Z, Wang Q et al. 2023)

This study has several limitations. First, only female patients aged 18–40 years were included to eliminate the effects of sex and age on occlusal function. Future studies should include both male and female patients to examine whether sex influences change in OF and OCA. Additionally, facial growth may continue beyond puberty, particularly in late adolescence,(Fudalej P, Kokich VG et al. 2007) and its potential impact on OF was not considered over the two-year orthodontic period. Second, although the average OGS scores—indicating finishing quality—did not differ significantly among the three groups, the finishing quality of each case might still have influenced OF and OCA. Third, this study assessed only static occlusal function by measuring OF and OCA in maximal intercuspal position. Since anterior guidance is also critical in ACB treatment, further research incorporating dynamic occlusal function is needed. Last, to more accurately evaluate occlusal function after ACB treatment, studies with a retention period of over two years are needed. Long-term research, multi-center studies would provide better insight into occlusal changes resulting from occlusal settling or relapse.

V. Conclusion

ACB reduces anterior OF and OCA, and in cases of severe skeletal Class III malocclusion, posterior OCA is also reduced. Surgical and nonsurgical treatment of ACB can increase anterior OF and OCA, although they contribute only a small portion to overall occlusal function. Additionally, ACB treatment increases posterior and total OCA in the surgery group, making them comparable to those in the camouflage group. These findings suggest that ACB treatment helps to achieve a more balanced anterior–posterior occlusion.

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국문요약

전치부 반대교합 환자의 수술적 및 비수술적 교정치료 후 교합기능 변화 : 2 년 추적

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이 준 구

전치부 반대교합은 전치부의 부적절한 교합으로 인한 저작 효율 감소와 같은 기능적 장애를 유발한다. 본 연구에서는 전치부 반대교합의 치료가 전치부, 구치부, 그리고 전체 치아의 교합력 및 교합면적에 미치는 영향을 평가했다.

본 후향적 연구는 18 세에서 40 세 사이의 여성 환자 122 명을 전치부 반대교합을 교정치료만으로 치료한 군(G1, 절충치료군, n=32), 악교정수술을 동반한 교정치료로 치료한 군(G2, 수술치료군, n=34), 그리고 전치부 반대교합이 없는 구치부 I 급 부정교합을 교정치료만으로 치료한 군(G3, 대조군, n=56)의 세 군으로 나누었다. 교합력과 교합면적은 교정치료 전(T0), 치료종료(T1), 그리고 치료종료 2 년 후(T2)의 세 시점에 Dental Prescale System 을 사용하여 측정했다. 동시에, 골격 및 치아 변화를

평가하기 위해서 측모두부방사선계측사진을 촬영했다. 그리고 다음과 같은 결과를 얻었다.

1. T0 에서는 전치부 반대교합을 치료한 두 군(절충치료군, 수술치료군)의 전치부 교합력 및 교합면적은 대조군보다 낮았다($P < .01$). 수술치료군의 구치부 교합면적은 절충치료군보다 낮았고($P < .05$), 대조군보다 낮았으나($P < .05$), 구치부 교합력은 유의차가 없었다. 수술치료군의 전체 교합면적은 절충치료군보다 낮았고($P < .05$), 대조군보다 낮았으나($P < .01$), 전체 교합력은 유의차가 없었다.
2. T1 에서는 전치부 반대교합을 치료한 두 군(절충치료군, 수술치료군)의 전치부, 구치부 그리고 전체 교합력 및 교합면적은 대조군과 유의차가 없었다.
3. T2 에서는 전치부 반대교합을 치료한 두 군(절충치료군, 수술치료군)의 전치부 교합력 및 교합면적은 대조군과 유의차가 없었다. 수술치료군의 구치부 교합면적은 대조군보다 낮았으나($P < .05$), 구치부 교합력은 유의차가 없었다. 수술치료군의 전체 교합면적은 대조군보다 낮았으나($P < .05$), 전체 교합력은 유의차가 없었다.

결론적으로, 전치부 반대교합 환자는 전치부 교합력과 교합면적이 낮았지만 절충치료 후 증가했다. 반면, 전치부 반대교합을 가진 골격성 III 급 환자는 구치부 교합면적과 전체 치아의 교합면적이 낮았으며, 악교정수술 후 절충치료군만큼 증가했다. 이러한 치료를 통해 환자는 전치부와 구치부 사이의 더욱 균형 잡힌

교합을 얻을 수 있으나, 기능적으로 대조군 수준으로 회복하기 위해서는 2 년 이상의 관찰이 필요할 것으로 보인다.

핵심이 되는 말: 전치부 반대교합, 교정치료, 악교정수술, 교합력, 교합면적, 전치부, 구치부