Recovery pattern of masticatory function following surgical or non-surgical correction of skeletal Class III malocclusion

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Recovery pattern of masticatory function following surgical or non-surgical correction of skeletal Class III malocclusion

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Mei Ling Fang

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감사의 글

이 논문이 완성되기까지 항상 따뜻하고 세심하게 지도해주신 이기준 교수님께 진심으로 감사 드리며, 귀중한 시간을 내주시어 함께 고민해주시고 세심한 지도와 조언을 해주신 유형석 교수님, 최성환 교수님, 김희진 교수님, 정복영 교수님께도 깊은 감사를 드립니다. 또한 저에게 교정학을 공부할 수 있도록 기회를 주시고 많은 조언과 가르침을 주신 황충주 교수님, 김경호 교수님, 차정열 교수님, 정주령 교수님, 최윤정 교수님, 박선형 교수님께도 감사 드립니다.

학위 기간 동안 가장 많은 시간을 함께 하고 서로 격려하며 연구실에서 동고동락한 두개안면기형연구소 연구실 식구들에게도 감사 드립니다.

항상 아낌없이 지지해주시고 변함없이 사랑으로 지켜봐 주시는 외할아버지, 외할머니, 부모님, 그리고 사랑스러운 아들 승재와 언제나 내 편이 되어주는 든든한 남편에게 감사의 마음을 전합니다. 기꺼이 힘과 위로가 되어준 주변 지인 분들에게 이 글을 빌어 감사의 마음을 전합니다.

2021 년 12 월

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ABSTRACT

Recovery pattern of masticatory function following surgical or non-surgical correction of skeletal Class III malocclusion

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The converntional treatment for skeletal Class III malocclusion had commonly been accompanied by orthognathic surgey for the improvement of facial profile and occlusion. However, in terms of the cost-effectiveness, risk of surgery and non-surgical treatment techniques have been developed, lots of patients prefer non-surgical orthodontic treatment. The aim of this study was to evaluate differences in masticatory function and recovery pattern of masticatory function following surgical or non-surgical correction of skeletal Class III malocclusion, and correlation between dynamic and static variables. Non-surgical group comprised 9 male patients (mean age 23.75 ± 3.01), surgical group comprised 8 male patients (mean age 26.25 ± 4.27). The variables were recorded immediately after the fixed appliance was removed (T0), 1 month post-treatment (T1), 6 months post-treatment (T2), 12 months post-treatment (T3).

Maximum bite force, occlusal contact area were measured with Dental Prescale II system, and mixing ability were measured with Viewgum software. Repeated ANOVA was used to test the variations in maximum bite force, occlusal contact area and mixing ability (20 cycles) in each group during the study. The results are as follows:

The maximum bite force and occlusal contact area showed a time-dependent gradual increase in the non-surgical group and the surgical group after treatment ($P < 0.001$). There was no significant difference in the maintenance period.

The mixing ability showed a slow recovery pattern, but there was no statistically significant difference, and there was no significant difference of mixing ability comparison between two groups.

The correlation coefficient between occlusal force and occlusal area was 0.944 ($P < 0.001$) in the non-surgical group and 0.807 ($P < 0.05$) in the surgical group. There was no significant correlation between mixing ability and maximum bite force, mixing ability and occlusal contact area.

According to this study, the mean values of maximum bite force and occlusal contact area were higher in the non-surgical group, but the surgical group recovered faster than the non-surgical group. The above results are considered to be helpful in explaining changes in masticatory function in borderline skeletal Class III malosslusion.

Key words: bite force, masticatory efficiency, recovery pattern, Class III malocclusion

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I. INTRODUCTION

The conventional treatment for skeletal Class III malocclusion included orthognathic surgery for obtaining an improvement in facial profile and occlusion. Orthognathic surgery reduces the time required for orthodontic treatment. However, it may not be cost-effective. Various non-surgical treatment techniques have developed, which are preferred by patients because of the absence of surgical risk. On the contrary, non-surgical treatment is associated with limited esthetic improvement and longer treatment duration. Eisenhauer et al. (Stellzig-Eisenhauer et al., 2002) compared Class III patients who can be treated using non-surgical orthodontics only and those who required orthognathic surgery. Previous studies have described a specific method for identifying borderline skeletal Class III malocclusion (Georgalis and Woods, 2015; Rabie et al., 2008).

Clinical examinations, dental model and radiographic analyses are used to diagnose and treat malocclusion. Such analyses can be used to evaluate the degree of malocclusion, normal occlusion, and changes occurring before and after treatment. However, only morphological and esthetic evaluations can be performed. In addition to esthetic problem, impaired masticatory function is often a chief complaint of patients requesting treatment for mandibular prognathism. The evaluation of masticatory function is divided into static evaluation and dynamic evaluation. Assessment of bite force is the most important method for the objective evaluation of masticatory function. Several studies have analyzed functional changes in occlusion during the retention period after orthodontic treatment (Choi et al., 2010; Sultana et al., 2002; Yoon et al., 2017). Most studies have shown that the maximum bite force and occlusal contact area gradually increase and approach with values observed in individuals with a normal occlusion (Islam et al., 2017; Sultana et al., 2002; Yoon et al., 2017). These studies have used the Dental Prescale System (FujiFilm Corp., Tokyo, Japan) to measure the maximum bite force and occlusal contact area.

The factors affecting masticatory efficiency are occlusal contact area (Horie et al., 2014), bite force, malocclusion (Bae et al., 2017; Choi et al., 2014; Iwase et al., 2006), number of teeth, and temporomandibular dysfunction. Most studies have focused on postsurgical bite force recovery, but not on changes in bite force of patients after orthodontic treatment (Iwase et al., 2006; Ohkura et al., 2001).

Another dynamic method of assessing masticatory function is to assess the color change in chewing gums after chewing The Sieving method (Manly and Braley, 1950) and assessment of color change in chewing gum after chewing (Hama et al., 2014; Ishikawa et al., 2007; Kamiyama et al., 2010) have been developed to evaluate masticatory efficiency. Thereinto, the Sieving method is highly reliable but requires equipment, time and expertise. Halazonetis et al. (Halazonetis et al., 2013) and Schimmel et al. (Schimmel et al., 2015) showed that the ViewGum software is reliable and accurate for the assessment of mixing ability.

Therefore, the aim of this study was to evaluate the differences in masticatory function and recovery pattern of masticatory function following surgical or non-surgical correction of skeletal Class III malocclusion and the correlation between dynamic and static variables. Our null hypothesis was that there would be no differences in recovery pattern of masticatory function between the two groups.

II. Materials and methods

1. Subjects

The subjects for this prospective study were selected patients who had completed orthodontic treatment at the Department of Orthodontic, Yonsei University Dental Hospital, between April 2019 and October 2020. The inclusion criteria were: 1) with skeletal Class III malocclusion 2) aged between 18 and 40 years 3) ANB angle between -1 º and -5 º 4) without severe dentofacial deformity 5) without temporomandibular joint disordered patients 6) and with pre- and post-treatment lateral cephalograms. The inclusion and exclusion criteria were presented in Figure 1. Previous studies, ra nge of ANB angle were between -1 º and -5 º (Georgalis and Woods, 2015); (Ra bie et al., 2008).

The included patients were categorized in surgical and non-surgical groups. The non-surgical group comprised 9 men (mean age, 23.75 ± 3.01 years) while the surgical group comprised 8 men (mean age, 26.25 ± 4.27 years) (Table 1). The intraoral photos pre- and post treatment in both groups are as shown in Figure 2. The details of the extraction protocols for patients in both groups are presented in Table 2. According to the pilot study, the maximum bite force and occlusal contact area were not significantly different between non-extraction and extraction groups. Therefore, the premolar existence was not considered.

The patients who satisfied the inclusion and exclusion criteria received oral information about this study and provided written informed consent. This study conf ormed to the tenets of the Declaration of Helsinki on medical protocols and et hics and was approved by our Institutional Review Board (IRB 2-2021-0011).

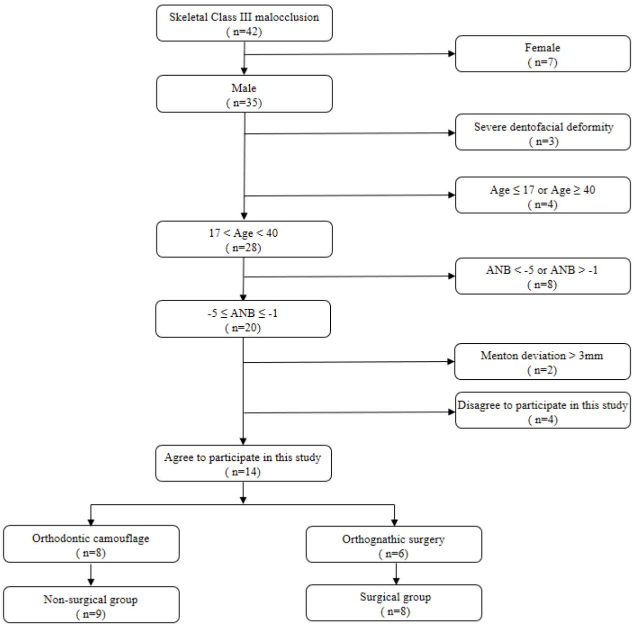


Figure 1. Flow diagram illustrating the process of participant selection and group allocation

Table 1. Demographic features of the subjects

	Non-surgical group (n=9)	**Surgical group** (n=8)	
Variable	Mean ± SD	Mean ± SD	*P* - Value
Age (years)	23.71±3.55	26.67±4.97	.144
Treatment duration (months)	32.22±8.24	19.86±6.85	.000***

Figure 2. Intraoral photos in the non-surgical (A, B, C) and surgical groups (D, E, F)

(A), (D) Pre-treatment; (B), (E) During treatment; (C), (F) Post-treatment

Table 2. Details of extraction protocols in the non-surgical and surgical groups

Non-surgical group	**Extracted teeth**
Patient 1	Non-Ex
Patient 2	Non-Ex
Patient 3	Non-Ex
Patient 4	15,34
Patient 5	Non-Ex
Patient 6	Non-Ex
Patient 7	Non-Ex
Patient 8	34,44
Patient 9	34,44
Surgical group	
Patient 1	Non-Ex
Patient 2	Non-Ex
Patient 3	13,24,34,44
Patient 4	Non-Ex
Patient 5	14,24
Patient 6	14,24,34,44
Patient 7	34,44
Patient 8	Non-Ex

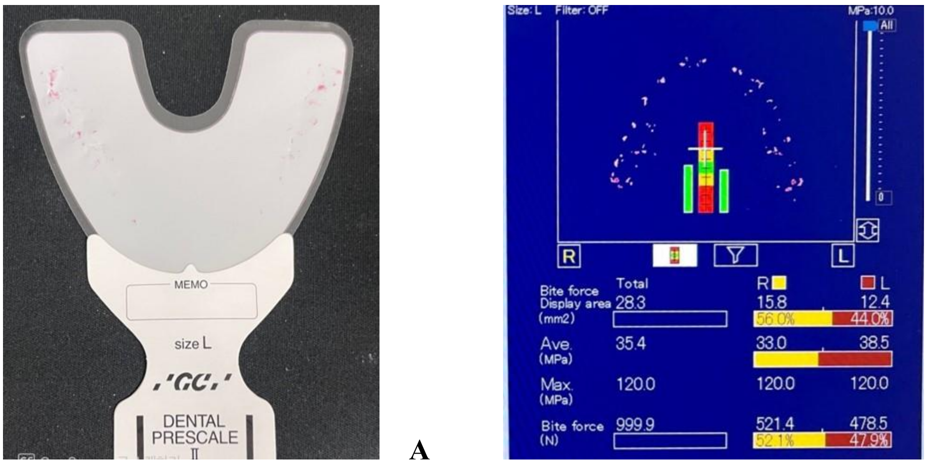
13, Maxillary right canine ; 14, Maxillary right first premolar; 15, Maxillary right second premolar; 24, Maxillary left premolar; 34, Mandibular left first premolar; 44, Mandibular right first premolar .

2. Measurements

Occlusal contact area, maximum bite force and mixing ability were recorded immediately after the fixed appliance was removed (T0), 1 month post-treatment (T1), 6 months post-treatment (T2) and 12 months post-treatment (T3).

2-1) Maximum bite force & Occlusal contact area

The maximum bite force and occlusal contact area were recorded using a pressure-sensitive film (Dental Prescale II System, FujiFilm Corp., Tokyo, Japan). A prescale sheet of appropriate size was selected to fit the dental arch of each subject. Then, the participants were instructed to bite on the sheet for about 5 s while sitting in the upright position. The maximum bite force and occlusal contact area were calculated using an occlusal force analyzing system (GC, Seoul, Korea; Figure 3).



A B

Figure 3. The Dental Prescale II system
(A) Pressure-sensitive sheet, (B) Scan result

2-2) Mixing ability

The mixing ability were taken using Hubba-Bubba Tape Gums (WM. Wrigley Jr. Company, Chicago, USA) of two different colors (azure and pink). Both types of gums were cut in dimensions of 30 mm × 18 mm × 3 mm and soaked in water for 2 s before they were stacked together. During the test, the patients were instructed to sit in the upright position and chew 5, 10, and 20 times (Figure 4). Then, they were asked to spit the gums in a transparent plastic bag marked with a random number. Each gum was flattened to achieve a thickness of 1 mm by pressing with a stamp on a custom-made milled depression with dimensions of 1 × 50 × 50 mm. Both sides of the flattened gum were scanned using an Epson scanner, and the data were assessed using the ViewGum software (2017, dHAL Software; version 1.4; Figure 5). These experimental methods are based on analytical methods described by Halazometis et al. (Halazonetis et al., 2013) and Aquilabti, L. et al. (Aquilanti et al., 2020)

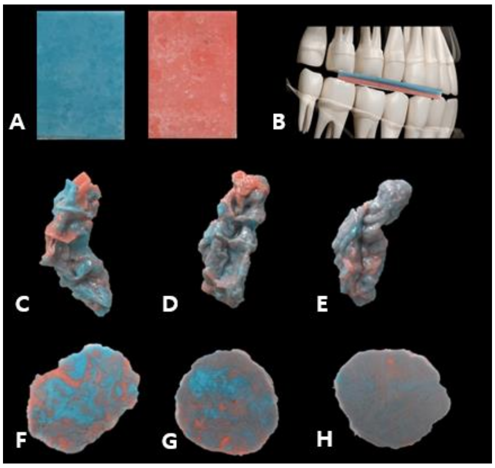


Figure 4. Chewing gum specimens
A, chewing gums of two different colors; B, chewing gums stuck together; C-E, chewing gum boluses after 5,10 and 20 masticatory cycles, respectively; F-H, flattened chewing gum

3. Statistical analysis

All statistical analyses were performed using the SPSS software (IBM SPSS Statistics Version 26). Using the G*Power 3.1 program (Dusseldorf, Germany), we determined that with the total sample size of 14, the analysis would be sufficiently powered, with a significance level of (*P* value) less than 0.05, 90% power, and 0.4 effect size. The Shapiro-Wilk test was used to assess the normality of the distributions. Repeated analysis of variance was used to test the variations in occlusal contact area, maximum bite force, and mixing ability (20 cycles) between the two groups. The independent *t*-test were used to compare changes over time between two groups. Further, Pearson's correlation coefficients were calculated to verify the association between occlusal contact area, maximum bite force and mixing ability (20 cycles). Statistical significance was defined as a probability value of less than 0.05.

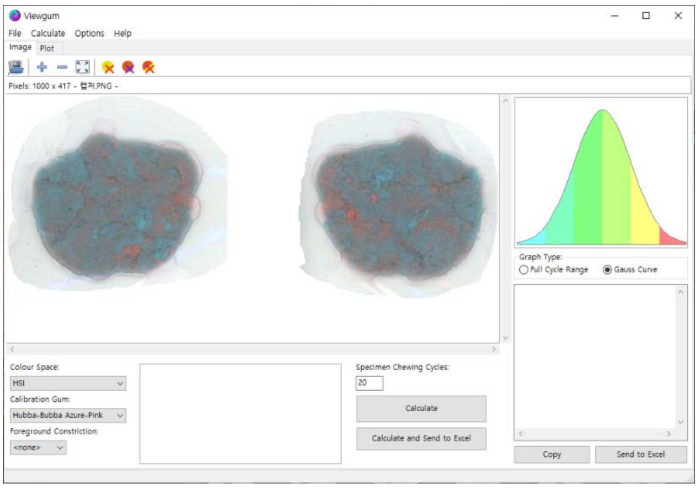


Figure 5. User interface after importing the scanned images of the flattened gum chewed for 20 cycles

III. Results

1. Characteristics of study subjects

The mean treatment duration for patients in the non-surgical group (32.22 ± 8.24 months) was significantly greater than that for those in the surgical group (19.86 ± 6.85 months; $P < 0.001$; Table 1).

No difference was observed in skeletal variables between the surgical and non-surgical groups, implying that all patients met the requirements for borderline Class III malocclusion (Table 3).

Comparing the skeletal changes during the treatment period, there were significant differences in SNB ($P < 0.01$), ANB ($P < 0.01$), and mandibular plane angles ($P < 0.05$) between the two groups. SNB increased by a mean of 0.42° ± 1.32° in the non-surgical group and -3.63° ± 2.53° in the surgical group. ANB decreased by a mean of 1.06° ± 0.66° in the non-surgical group and 4.14° ± 2.08° in the surgical group. The mandibular plane angle increased by a mean of 1.68° ± 2.20° in the non-surgical group and decreased by a mean of 3.54° ± 3.05° in the surgical group (Table 3).

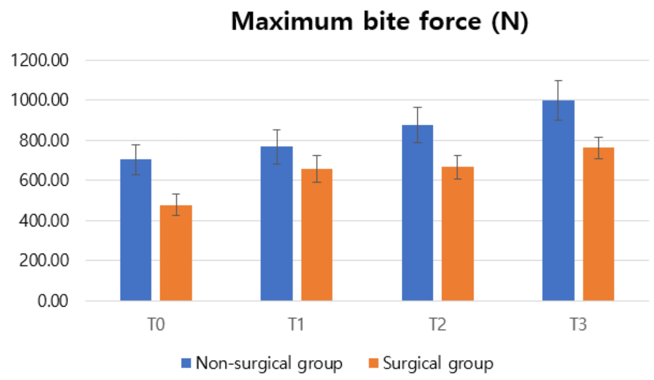
Table 3. Characteristics of the subjects

	Pre-treatment			Post-treatment			Post-Pre treatment		
	Non-surgical group	Surgical group		Non-surgical group	Surgical group		Non-surgical group	Surgical group	
Variable	Mean ± SD	Mean ± SD	*P* - Value	Mean ± SD	Mean ± SD	*P* - Value	Mean ± SD	Mean ± SD	*P* - Value
SNA (deg)	81.26±3.30	78.76±3.42	.193	81.90±3.61	79.28±2.81	.168	0.64±0.94	0.52±1.56	.857
SNB (deg)	83.91±2.79	82.09±3.73	.316	83.49±3.11	78.47±3.51	.015*	-0.42±1.32	-3.63±2.53	.009**
ANB (deg)	-2.65±0.98	-3.33±1.01	.234	-1.59±0.67	0.82±2.00	.031*	1.06±0.66	4.14±2.08	.002**
Wits (mm)	-8.68±2.84	-10.85±4.12	.265	-6.03±1073	-5.45±3.05	.658	2.65±2.50	5.40±2.20	.054
Mandibular plane angle (deg)	32.50±5.38	38.26±6.17	.087	30.82±6.10	41.79±6.84	.008*	-1.68±2.20	3.54±3.05	.003**
AFH (mm)	137.44±6.21	143.45±3.05	.051	137.65±7.17	141.26±3.50	.282	0.21±1.78	-2.20±2.76	.070
U1 to SN (deg)	115.17±7.33	111.97±7.87	.449	115.54±5.00	109.30±6.81	.071	0.37±6.56	-2.67±7.90	.446
IMPA (deg)	85.45±7.50	80.77±8.94	.308	85.36±4.24	81.06±3.74	.072	-0.09±7.46	0.29±8.61	.931
U1 to VRP (mm)	72.40±3.59	64.18±10.42	.058	73.85±6.76	66.98±4.98	.058	1.45±5.14	2.81±10.31	.750
L1 to VRP (mm)	74.76±5.28	68.80±12.71	.251	72.56±6.59	64.50±5.55	.033*	-2.20±3.39	-8.16±16.24	.327
U1 to HRP (mm)	71.73±4.41	76.08±1.54	.041*	74.46±4.21	75.61±1.69	.545	2.73±5.23	-0.47±0.88	.167
L1 to HRP (mm)	91.41±5.25	97.44±2.29	.023*	90.56±5.39	93.81±1.08	.175	-0.85±1.68	-3.63±2.41	.026*
U6 to VRP (mm)	48.33±4.42	46.03±5.32	.395	48.90±5.64	43.47±5.27	.092	-0.08±4.33	-2.57±4.13	.300
L6 to VRP (mm)	50.87±5.97	50.38±7.26	.892	49.88±5.95	43.16±5.74	.055	-0.99±5.08	-7.22±5.06	.042*
U6 to HRP (mm)	76.97±2.93	76.76±3.00	.896	77.04±3.83	76.21±1.46	.587	0.08±2.37	-0.54±1.98	.615
L6 to HRP (mm)	81.95±4.77	86.39±2.51	.062	82.79±3.91	82.88±3.48	.967	0.84±2.76	-3.51±2.22	.008**

U1, center of resistance of the upper central incisor; L1, center of resistance of the lower central incisor; HRP, horizontal reference plane was set on sella and oriented 7° below to the sella-nasion line; VRP, vertical reference plane was set to the plane that passed the sella and perpendicular to the HRP

P value with independent *t* -test were performed

* $P < 0.05$; ** $P < 0.01$;



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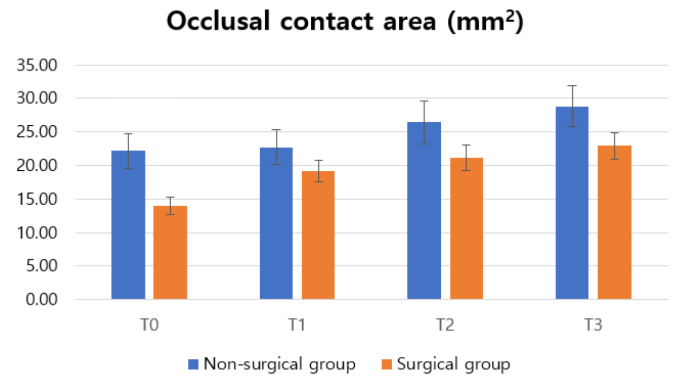

B

Figure 6. Changes in maximum bite force (A) and occlusal contact area (B) in the non-surgical and surgical groups

T0, immediately after the fixed appliance was removed; T1, 1 month post-treatment; T2, 6 months post-treatment; T3, 12 months post-treatment

2. Time-dependent changes in maximum bite force and occlusal contact area since the removal of the fixed appliance

The means and standard deviations for maximum bite force, occlusal contact area and mixing ability in both groups at T0, T1, T2 are show in Table 4.

The maximum bite force and occlusal contact area showed similar trends in both groups during the repeated observation period (P < 0.001) (Figure 6). The mean maximum bite force (standard deviation) measured at T0 and T3 in the non-surgical and surgical groups increased significantly and gradually from 702.87 (± 210.70) N to 1021.39 (± 299.23) N and 476.95 (± 131.64) N to 762.45 (± 133.14) N, respectively (Table 4).

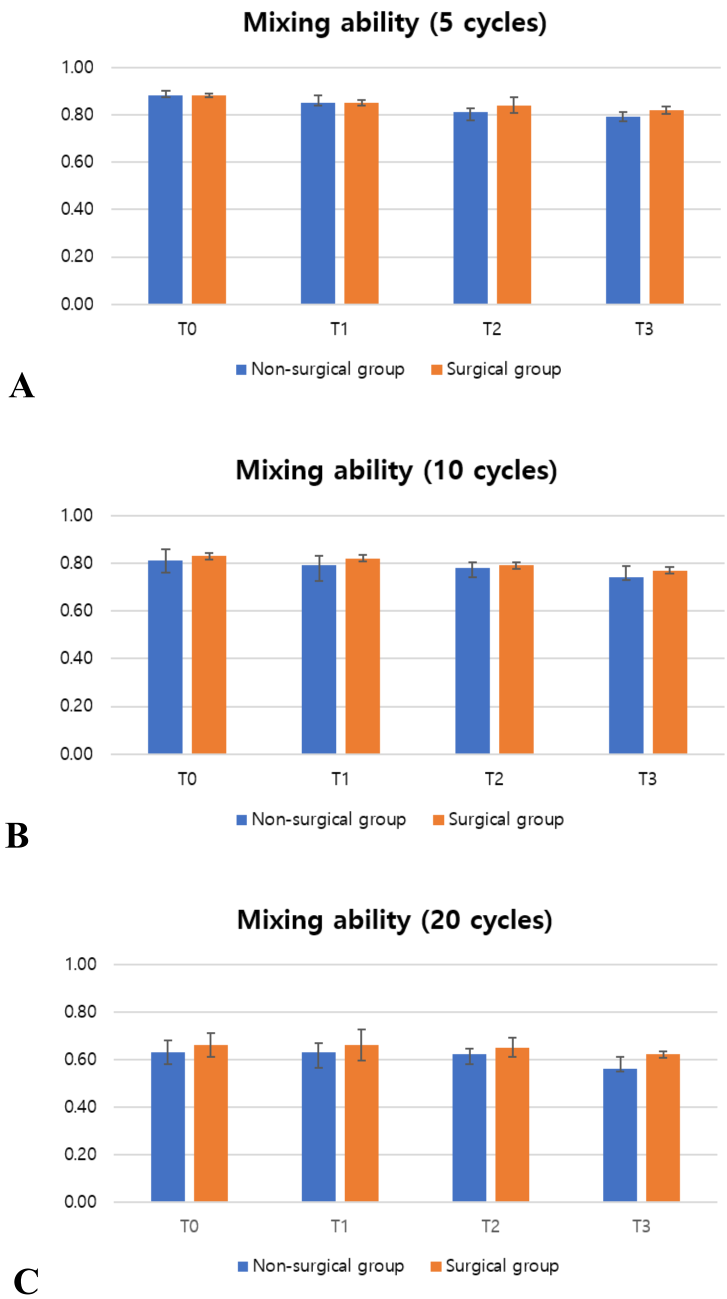

Figure 7. Changes in mixing ability in the non-surgical and surgical groups at T0, T1, T2, T3

T0, immediately after the fixed appliance was removed; T1, 1 month post-treatment; T2, 6 months post-treatment; T3, 12 months post-treatment

3. Time-dependent changes in the mixing ability from after removed fixed appliance

With the increase in the number of chewing cycles, the hue variation decreased significantly that indicated a higher degree of color mixing. The 5 and 10 chewing cycles were not high discriminative for mixing ability. (Figure 7 A, B) Instead, the 20 chewing cycles was more discriminative than 5 and 10 chewing cycles for mixing ability. (Figure 7 C)

Time-dependent changes in mixing ability in the non-surgical and surgical group showed no significantly difference (*P* > 0.05; Table 5)

Table 4. Time-dependent changes in the bite force, maximum bite force contact area and mixing ability from after removed fixed appliance

	Non-surgical group (n=9)					Surgical group (n=8)				
	T0	T1	T2	T3	*P* - Value	T0	T1	T2	T3	*P* - Value
Maximum bite force (N)	702.87±210.70	767.81±244.54	876.69±248.69	1021.39±299.23	.002**	476.95±131.64	658.57±162.02	665.78±140.50	762.45±133.14	.001**
Occlusal contact area (mm^2)	22.17±7.31	22.70±7.39	26.41±8.90	28.84±8.70	.019*	13.97±3.29	19.15±3.95	21.18±4.60	22.90±4.78	.000***
Mixing ability (20)	0.63±0.14	0.63±0.11	0.62±0.07	0.56±0.14	.108	0.66±0.12	0.66±0.16	0.65±0.10	0.62±0.03	.999

T0, immediately after the fixed appliance was removed; T1, 1 month post-treatment; T2, 6 months post-treatment; T3, 12 months post-treatment
Comparison among the timing of different measurements using the repeated ANOVA.
* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 5. Comparison of the maximum bite force, occlusal contact area and mixing ability between non-surgical and surgical group

	T0			T1			T2			T3		
	Non-surgical group	Surgical group	*P* - Value	Non-surgical group	Surgical group	*P* - Value	Non-surgical group	Surgical group	*P* - Value	Non-surgical group	Surgical group	*P* - Value
Maximum bite force (N)	702.87±210.70	476.95±131.64	.034	767.81±244.54	658.57±162.02	.332	876.69±248.69	665.78±140.50	.088	1021.39±299.23	762.45±133.14	.085
Occlusal contact area (mm^2)	22.17±7.31	13.97±3.29	.036	22.70±7.39	19.15±3.95	.281	26.41±8.90	21.18±4.60	.216	28.84±8.70	22.90±4.78	.146
Mixing ability (20)	0.63±0.14	0.66±0.12	.668	0.63±0.11	0.66±0.16	.620	0.62±0.07	0.65±0.10	.699	0.56±0.14	0.62±0.03	.193

T0, immediately after the fixed appliance was removed; T1, 1 month post-treatment; T2, 6 months post-treatment; T3, 1 year post-treatment
P value with independent *t*-test were performed.
* $P < 0.00833$;

4. Comparison of the recovery ratio in maximum bite force, occlusal contact area and mixing ability between two groups

During the treatment period of 12 months, the increase rate of maximum bite force and occlusal contact area was higher in the surgical group than in the non-surgical group, but there was no significant difference between the two groups. ($P > 0.05$; Table 6)

The increase rate of mixing ability was higher in the non-surgical group tha n in the surgical group, there was no significant difference between the two gr oups. ($P > 0.05$; Table 6)

5. Correlation between maximum bite force, occlusal contact area and mixing ability.

The correlation coefficient between maximum bite force and occlusal contact area was 0.944 ($P < 0.001$) in the non-surgical group and 0.807 ($P < 0.001$) in the surgical group. However, the mixing ability was not associated with maximum bite force or occlusal contact area in any groups ($P > 0.05$; Table 7)

Table 6. Comparison of the recovery ratio in maximum bite force, occlusal contact area and mixing ability between non-surgical and surgical group

	Non-surgical group (n=9)	Surgical group (n=8)	*P*-value
Maximum bite force (N)	45.3 ± 25.4 %	67.7 ± 48.9 %	.245
Occlusal contact area	37.8 ± 19.9 %	70.8 ± 56.0 %	.093
Mixing ability	-11.3 ± 28.3 %	-7.2 ± 22.2 %	.245

Table 7. Pearson's correlation coefficients between maximum bite force, occlusal contact area, mixing ability

	Non-surgical group		Surgical group	
	Occlusal contact area	**Mixing ability (20)**	**Occlusal contact area**	**Mixing ability (20)**
Maximum bite force (N)	0.944**	-0.219	0.807**	-0.249
Occlusal contact area (mm^2)	-	-0.260	-	0.073

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

III. Discussion

This prospective study was to evaluate differences in masticatory function and recovery pattern of masticatory function following surgical or non-surgical correction of skeletal Class III malocclusion, and correlation between dynamic and static variables. With the relation to our hypothesis, there was significant differences in recovery pattern of masticatory function between the two groups.

The Dental Prescale System has been widely used to evaluate maximum bite force and occlusal contact area. Bachus et al. (Bachus et al., 2006) and Sultana et al. (Sultana, Yamada et al.,2002) reported that high accuracy and good reproducibility of the measurements using this system. The Dental Prescale System measures the maximum bite force and occlusal contact area within a 5% error range. This is an excellent way to measure static assessments and it is easy to objects assessment of occlusal function (Bachus et al., 2006)

According to a previous study, the bite force and occlusal contact area were not significant difference between non-extraction and extraction groups (Yoon-Jeong Choi 2010). Therefore, the premolar existence was not considering in surgical and non-surgical groups in present study. The occlusal contact area was reported to be larger in patients aged 40 years than orther ages (Yoon et al., 2010). We had planned to compare the differences between men and women, but few female patients we willing to participate in the study and therefore, were not included in the study. According to the results of previous studies, which showed that the participants' age and sex are important, 17 to 40-year-old male patients were enrolled in this study.

Temporomandibular joint disorders are known to affect maximum bite force and masticatory efficiency (Todic et al., 2019). Therefore, patients diagnosed with temporomandibular joint dysfunction were excluded.

In this study, the maximum bite force and occlusal contact area of the non-surgical and surgical groups of Class III patients showed the lowest values at T0, and has been steadily recovering since bracket debonding. This means that the muscles are damaged due to the operation, and this damage seems to have affected the recovery of maximum occlusal force and occlusal area.

Recovery of masticatory function may require more than 2 years after orthodontic treatment (Yoon et al., 2010). In the present study, the mean maximum bite force of patients in the non-surgical group was 1021.39 ± 299.23 N at T3, which achieved the mean maximum occlusal force (1009.7 ± 308.4N) of patients with a nomal occlusion (Shiga et al., 2020). The maximum bite force and occlusal contact area were achieved normal occlusion earlier in the non-surgical group than in the surgical group. This could be induced by bones, muscles, and teeth, as they settle in their new position after surgical treatment. In addition, patients are concerned about wound healing and therefore, reluctant to masticate actively after surgery (Iwase et al., 1998; Proffit et al., 1989).

Even though the masticatory function may recover at some extent during post-surgery orthodontic treatment, the occlusal force and occlusal area at T0 were significantly lower in the surgical group than in the non-operative group. Although the maximum bite force was not measured before surgery. However, compared with previous studies (Choi et al., 2014; Iwase et al., 2006), the maximum bite force of the surgical group at T0 was similar to the maximum bite force value of before treatment. Thus we presumed that the surgical process surely influenced the masticatory fu nction before T0. The rate of increase in maximum bite force and occlusal co ntact area were faster in the non-surgical group than in the surgical group (Ta ble 6).

Many methods have been developed to evaluate masticatory function. The two-color chewing gum mixing ability test was used in this study. It has been proposed as a reliable and accurate method to evaluate mastication efficiency; it is also indicated for patients with impaired masticatory function (Schimmel et al., 2007; Weijenberg et al., 2013). Through 20 chewing cycles, the volume of the gum decreased by 40%, the color of the chewing gum became uniform and there was almost no discernment between the subjects more than 20 cycles (Halazonetis et al., 2013). Additionally, several literatures have established that 20 cycles were sufficient to draw valid conclusions about mixing ability (Anastassiadou and Heath, 2001; Hirano et al., 2004)

To compare the differences in mixing ability after 5, 10, and 20 chewing cycles, we measured the masticatory efficiency of 25 patients with normal occlusion in a pilot study. We found that the mean mixing ability (20 cycles) was 0.4. In present study, the mixing ability (20 cycles) was 0.57 ± 0.15 for patients in the non-surgical group and 0.61 ± 0.03 for patients in the surgical group at T3, and there was no significant difference between the two groups. This indicated that mixing ability does not recover in a short period after orthodontic treatment with or without surgery. A previous study showed that masticatory muscles, such as the tongue and masseter muscles, exhibited atrophy and are maintained in a traumatic state because of mandible setback surgery (Islam et al., 2017; Trawitzki et al., 2010; Yamashita et al., 2011). These muscles require 3-4 years for regaining the preoperative muscle size. A similar pattern was observed in the present study; the recovery in the surgical group was slower than in the non-surgical group in dynamic evaluation (Table 6).

The Pearson's correlation coefficient for the association between maximum bite force and occlusal contact area was 0.944 in the non-surgical group and 0.807 in the surgical group, indicating a high correlation between the two parameters in both groups. However, there was no significant correlation between maximum bite force and mixing ability and between occlusal contact area and mixing ability in any group. Thus, there was no significant correlation between dynamic and static variables.

The gum chewing exercise was reported effective in improving masticatory efficiency and maximum bite force after surgery (Kato K et al., 2012). Muscular rehabilitation, such as by masticatory exercises using chewing gum, can hasten recovery.

There are a few limitations existing in this study. The masticatory function was not evaluated before treatment. Therefore, changes occurring before and after treatment could not be compared. Additionally, due to ethical constraints, computed tomography could not be performed after completion of orthodontic treatment. Therefore, the specific effect of muscles on masticatory function could not be evaluated. These points should be considered in further studies.

V. CONCLUSIONS

This study was performed to evaluate the differences in masticatory function and recovery pattern of masticatory function following surgical and non-surgical correction of skeletal Class III malocclusion. The results are as follows:

1. The maximum bite force and occlusal contact area showed a time-dependent gradual increase in the non-surgical group and surgical group after treatment ($P < 0.001$). There was no significant difference in the maintenance period between the two groups.

2. The mixing ability recovered slowly with time, but there was no statistically significant difference, and there was no significant difference of mixing ability between two groups.

3. The correlation coefficient between occlusal force and occlusal area was 0.944 ($P < 0.001$) in the non-surgical group and 0.807 ($P < 0.05$) in the surgical group. There was no significant correlation between mixing ability and maximum bite force, mixing ability and occlusal contact area.

According to this study, the mean values of maximum bite force and occlusal contact area were higher in the non-surgical group, but the surgical group recovered faster than the non-surgical group. The above results are considered to be helpful in explaining changes in masticatory function in borderline skeletal Class III malosslusion.

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국문 요약

골격성 III급 부정교합에서 수술 혹은 비수술 교정치료 후 저작 기능 회복 양상

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방 미 령

본 연구의 목적은 골격성 III급 부정교합에서 수술 혹은 비수술로 치료한 환자의 교정치료 후 시간에 따른 저작 기능 차이와 회복 양상을 비교하고 동적 평가인 저작 효율과 정적 평가인 교합력 및 교합면적 사이의 상관관계를 분석하는 것이다.

총 17명의 골격성 III급 부정교합 환자를 대상으로 비수술군 (9명, 평균 나이 : 23.75 ± 3.01), 수술군 (8명, 평균 나이 : 26.25 ± 4.27), 두 군으로 나누었다. 압력 감지 필름 시스템을 사용하여 교합력, 교합면적을 측정하였고 두가지 색상의 껌을 씹어 색상의 혼합 정도로 저작 효율을 측정 하였다. 고정식 교정장치를 제거 및 고정식 유지 장치 접착 직후, 그 후 1개월, 6개월, 12개월 되는 시기 각각 측정하였다. 두 군의 측정 값을 비교하고 정적

평가와 동적 평가의 상관관계를 조사하여 다음과 같은 결과를 얻었다.

1. 시간에 따른 변화에서 교합력과 교합면적은 치료 후 비수술군과 수술군에서 점진적으로 증가하는 양상을 보였지만 ($P < 0.001$) 군 간 비교시 교합력 교합면적은 교정장치를 제거한 직후 유의한 차이를 보였지만 그 후 유지기간 중 유의한 차이를 보이지 않았다 ($P > 0.05$).

2. 저작 효율은 시간에 따른 변화에서 느리게 회복되는 양상을 보였으나 통계적으로 유의한 차이를 보이지 않았고, 군 간 비교시 유의한 차이가 없었다 ($P > 0.05$).

3. 교합력, 교합면적, 저작 효율 사이의 상관관계를 분석한 결과, 교합력과 교합면적의 상관계수는 비수술군에서 0.944 ($P < 0.001$) 수술군에서 0.807 ($P < 0.05$) 였고 교합력과 저작 효율, 교합면적과 저작 효율 간 유의한 상관관계가 존재하지 않았다.

본 연구에 의하면 교정 치료 후 교합력과 교합면적은 각 시기별 평균적 수치가 비수술군에서 더 높게 나타났지만 수술군이 비수술군보다 회복이 빨랐다.반면, 저작 효율은 시기에 따른 전반적 향상에도 두 군간의 차이를 보이지 않았다. 위 결과는 경계성 골격성 III급 부정교합에서 저작 기능 변화를 설명하는데 도움이 될 수 있을 것으로 사료된다.

핵심이 되는 말: 교합력, 교합면적, 저작효율, 회복양상, 골격성III급 부정교합