

Clinical study of frontal chewing patterns in various crossbite malocclusions

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Introduction: The purpose of this study was to clarify the frontal chewing patterns of various crossbite malocclusions. **Methods:** A mandibular kinesiograph was used to record the masticatory movements of 106 subjects (ages, 12-35 years) with crossbite malocclusion and 22 subjects (ages, 16-30 years) with normal occlusion. The chewing patterns were classified into 8 chewing types according to the cycle shape of the frontal incisor point movement. The crossbite subjects were divided into 5 groups by the anteroposterior position of the crossbite, and then the subjects with posterior crossbite were divided into 3 groups by the transverse position of the crossbite. The Mann-Whitney U test was used to compare the frequency of each chewing type between any crossbite group and the control group; and between the various crossbite groups. **Results:** In the crossbite groups, normal chewing occurred much less often than in subjects with normal occlusion. In the posterior crossbite group, reverse chewing was greater ($P = 0.002$), and normal chewing was less frequent ($P = 0.001$) compared with the anterior crossbite group. When accompanied by mandibular shift, mandibular prognathism, arch crossbite, in the crossbite or shift side, reverse type, and reverse-crossing type occurred more often than in contralateral side. **Conclusions:** In the frontal plane, patients with posterior crossbite might have more abnormal chewing types than those with anterior crossbite, and posterior crossbite could contribute to the high frequency of reverse and reverse-crossing chewing types, especially when accompanied by mandibular shift, mandibular prognathism, or arch crossbite. (Am J Orthod Dentofacial Orthop 2010;138:323-9)

Crossbite, either anterior or posterior, is a common malocclusion that has been reported to be associated with abnormal function of the masticatory muscles^{1,2} and signs and symptoms of temporomandibular disorders (TMD).³⁻⁵ It is important to know whether crossbite has a specific effect on masticatory movement, especially the cycle shape of incisal point movements on the frontal plane (frontal chewing patterns).

Ahlgren⁶ established a morphologic classification of frontal chewing patterns; however, the relationship

between chewing patterns and malocclusion type including crossbite was not found, even after analyzing the chewing types of 290 subjects with malocclusion and 30 with normal occlusion.⁷ Although the chewing patterns of crossbite malocclusion (especially posterior crossbite) have been investigated by others, the results were inconsistent.⁸⁻¹² Some studies found that reverse, cross, chopping, or other abnormal chewing types had higher frequencies in posterior crossbite or crossbite patients.⁸⁻¹⁰ In addition, Pröschel and Hofmann¹¹ found a different chewing pattern distribution in subjects with mandibular prognathism compared with Class I and Class II Division 2 patients, but no difference was found in any parameter studied during the masticatory cycle between the unilateral posterior crossbite group and the normal group in the study of Martin et al.¹²

The inconsistency of the results could be assigned to the differences in sample selection and methods for measurement and analysis. For example, the ages of the samples were different, including mixed dentition, early permanent dentition, adults, or mixed dentition to early permanent dentition, and so on. Studies of chewing patterns of normal occlusion have shown that the typical chewing patterns of subjects aged 12 to 14—characterized by sagittal opening and wide lateral closing movements—had changed completely compared with patterns in the deciduous and mixed dentitions.¹³ Hence, it might be more reasonable to analyze

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the effect of occlusion on chewing patterns of subjects in the same age range. Moreover, some authors noticed that some TMD patients had different chewing patterns,^{14,15} but it was unclear in the selected subjects with or without TMD features in some previous studies.^{7,10,11} Probably, this was another reason that caused the inconsistent, and even controversial, results.

The purposes of this study were to analyze the frontal chewing patterns in patients (aged 12-35 years) with various crossbite malocclusions without signs and symptoms of TMD and then to study the effect of different positions of crossbite on chewing patterns in the anteroposterior and transverse directions.

MATERIAL AND METHODS

The sample for this study comprised 106 subjects with crossbite malocclusion (ages, 12-35 years; 70 female, 36 male) and 22 subjects with normal occlusion (ages, 16-30 years; 15 female, 7 male; dental and skeletal Class I relationship according to molar relationship, ANB angle, and convexity; less than 3 mm of crowding and less than 3 mm of anterior overjet and overbite). The malocclusion subjects were selected from a consecutive group of 917 patients visiting the First Orthodontic Department, Tokyo Medical and Dental University. We checked their data, including pretreatment casts, clinical examination records, questionnaire data and raw pretreatment mandibular kinesiograph recordings. Subjects with normal occlusion were chosen from nursing students and dental postgraduate and graduate students in this university. In the entrance criteria established for this study, subjects with crossbite and normal occlusion were excluded if they had clinical signs and symptoms of TMD according to clinical examination and questionnaire, a history of orthodontic treatment, extensive restorations, cast restorations, pathologic periodontal conditions, or missing teeth. Subjects with functional crossbites were excluded by clinical examinations in this study. For patients with posterior crossbite, the presence or absence of mandibular shift and or mandibular prognathism was not an entrance criterion. All subjects were informed and agreed to participate in this study. Ethics approval was given by this university before the start of this research. First, all patients with crossbite were divided into 5 groups according to the anteroposterior position of crossbite.

Group 1 included those with only individual anterior crossbite, without posterior crossbite; group 2, those with at least 4 anterior teeth in crossbite, without posterior crossbite; group 3, those with continuous anterior and posterior crossbites (eg, arch crossbite involving 1 side); group 4, those with individual posterior crossbite,

without anterior crossbite; and group 5, similar to groups 1 and 2, but with individual posterior crossbite simultaneously.

Then the patients with posterior crossbite (groups 3-5) were divided into 3 groups according to the transverse position of crossbite: group A, left posterior crossbite; group B, right posterior crossbite; and group C, bilateral posterior crossbite.

The distribution of malocclusion details of groups A through C is shown in Table I, considering the possible effect of mandibular shift, mandibular prognathism, position of the teeth in crossbite, individual posterior crossbite, or posterior crossbite involving more than 2 teeth of 1 side or bilateral arch (arch crossbite) on the chewing patterns of subject with posterior crossbite.

Pretreatment masticatory movements of the patients and the subjects with normal occlusion were recorded with a mandibular kinesiograph system (K6-I cranio-mandibular evaluation system, Myotronics-Noro Med, Seattle, Wash). This system allow 3-dimensional recording of mandibular movements without interfering with the motion of the jaw. The masticatory recordings of all subjects were done by 2 examiners (Q.N. and Z.K.), who carefully complied with the manufacturer's protocol. The masticatory movements of 5 randomly selected patients were examined twice by the same examiners; statistical tests showed no significant difference for the results of mandibular kinesiograph recordings between the 2 times (linear parameters, maximum opening, maximum lateral displacement, Student *t* test, $P > 0.05$; the distribution of chewing types described in the next paragraph and the statistical analysis, Mann-Whitney U test, $P > 0.05$). Similar tests were performed between the 2 examiners for 5 other randomly selected patients, with similar results. The accuracy and reliability of the mandibular kinesiograph meets the needs of a clinical study as the study of Keeling et al¹⁶ demonstrated.

Chewing gum was selected as the experimental food because it could form a more consistent bolus than natural food to produce a consistent masticatory pattern over many cycles, and its size and solidity were stable during mastication so that the occlusal condition was easily reflected by chewing.^{17,18} Before we recorded the masticatory movements, the subjects were instructed to chew the gum until it was sufficiently soft. Then, free chewing, right-side chewing, and left-side chewing were recorded. For chewing on either side, 10 strokes, from the fifth to the 14th, were analyzed because they had the least variability in both path and rhythm.¹⁹⁻²¹ The chewing type of each stroke was classified by visual examination according to the cycle shape of incisor point movement on the frontal plane as shown in the Figure. The chewing types were as follows.

Table I. Distribution of malocclusion manifestations in the 3 posterior crossbite groups

		Right crossbite, n (%)	Left crossbite, n (%)	Bilateral crossbite, n (%)
1	Individual crossbite	8 (53.3)	20 (95.2)	4 (21.1)
	Arch crossbite	7 (46.7)	1 (4.8)	15 (79.9)
2	Only premolar	1 (6.7)	4 (19.0)	3 (15.8)
	First molar involved	11 (73.3)	10 (47.6)	15 (78.9)
	Only second or third molar	3 (20)	7 (33.3)	1 (5.3)
3	Right shift	7 (46.7)	0 (0)	1 (5.3)
	Left shift	0 (0)	6 (28.6)	8 (42.1)
	No shift	8 (53.3)	15 (71.4)	10 (52.6)
4	Mandibular prognathism	8 (53.3)	4 (19.0)	15 (78.9)
	No mandibular prognathism	7 (46.7)	17 (71)	4 (11.1)

1, Individual or arch crossbite: chi-square test, right and left, $P = 0.003$; left and bilateral, $P = 0.000$; right and bilateral, $P = 0.051$.

2, Position of crossbite teeth: chi-square test, right and left, $P = 0.284$; left and bilateral, $P = 0.33$; right and bilateral, $P = 0.062$.

3, Mandibular shift: chi-square test, right and left, $P = 0.001$; left and bilateral, $P = 0.381$; right and bilateral, $P = 0.001$.

4, Mandibular prognathism: chi-square test, right and left, $P = 0.031$; left and bilateral, $P = 0.001$; right and bilateral, $P = 0.113$.

- I. Normal: smooth opening toward the working side and smooth convex closing. This often occurred in normal occlusion including types I and III in the classifications of Akiyama et al.²¹
- II. Concave closing: opening similar to I, but concave closing.
- III. Concave opening: closing similar to I, but concave opening.
- IV. Reverse: shape similar to I, but opening and closing directions were contrary to I.
- V. Positive crossing: opening and closing paths were crossed; in the occlusal phase, the directions of opening and closing were the same as I.
- VI. Reverse crossing: opening and closing paths were crossed, but, in the occlusal phase, the directions of opening and closing were the same as IV.
- VII. Superimposition: the closing path almost superposes with the opening path.
- VIII. Irregular: opening and closing movements with no consistent pattern and frequent crossing of the opening and closing phases.

Statistical analysis

Contingency statistics (chi-square test) were used to compare the distribution of malocclusion manifestations between the right, left, and bilateral posterior groups. The level of significance was set at 0.05.

The number of strokes of each chewing type in the 10 strokes in either side was counted and considered as the frequency of each chewing type in either side. The average of the number of strokes in the right and left sides was used to represent unilateral chewing. The Mann-Whitney U test (a nonparametric test) was used to compare the frequency of each chewing type in the 10 strokes between the crossbite and normal

occlusion groups, between the crossbite groups (including comparisons of crossbite groups 1 to 5, and between the anterior and posterior crossbite groups), and between the crossbite and contralateral sides for patients with posterior crossbite. The level of significance was set at 0.05.

RESULTS

The distribution of malocclusion manifestations of the right, left, and bilateral posterior crossbite groups is shown in Table I. The position distribution of the crossbite teeth in each group was similar, but the ratios of arch crossbite and mandibular prognathism were higher in the right and bilateral posterior groups than in the left posterior crossbite group ($P = 0.003$ and $P = 0.000$ for arch crossbite; $P = 0.031$ and $P = 0.001$ for mandibular prognathism, respectively). For the percentage of shift, the ratio of right shift in the right group was not significantly different from that of left shift in the left group, and the distribution of shifts in the bilateral crossbite group was similar to that of the left group ($P > 0.05$).

Table II shows the frequency of each chewing type in different anteroposterior positions of the crossbite groups. In all crossbite groups, type I occurred significantly less often than in normal occlusion. In addition, groups 3, 4, and 5 had higher frequencies of type IV than in normal occlusion ($P < 0.01$ or $P < 0.001$). Moreover, group 4 (individual posterior crossbite) had a higher frequency of reverse-crossing chewing and superimposition types than in normal occlusion. Comparisons between any 2 crossbite groups showed no significant difference for the frequency of any chewing type between groups 1 and 2 ($P > 0.05$) and between groups 3, 4, and 5 ($P > 0.05$). In addition, groups 1 and 2 had anterior crossbite without posterior crossbite.

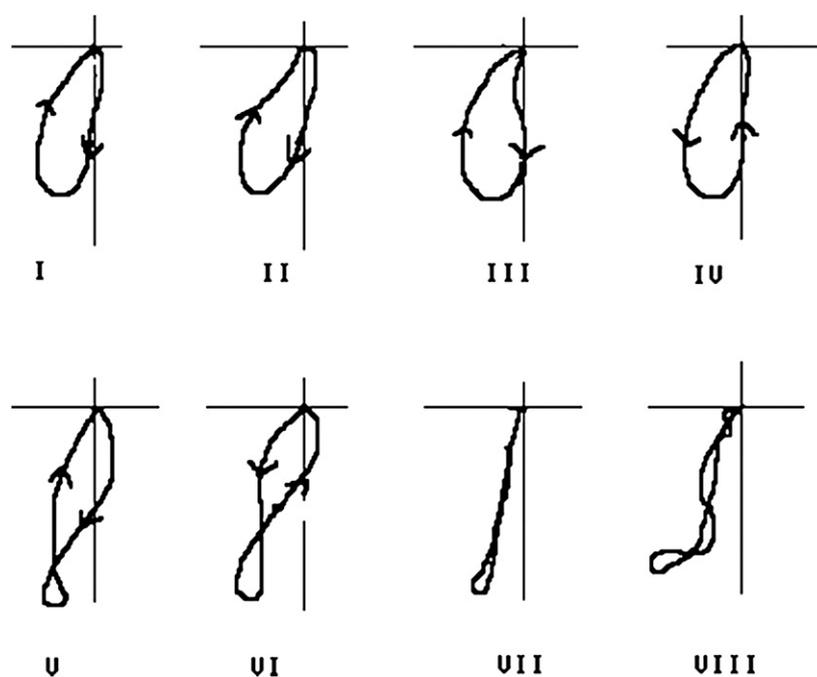


Fig. Classifications of chewing types (opening toward the nonworking side and closing in the nonworking side can occur in types II to VIII; the opening path and, in particular, the closing path approximately in the median plane can occur in types II to VIII).

Groups 3, 4, and 5 included patients with posterior crossbite; thus, groups 1 and 2 were combined as the anterior crossbite group, and groups 3, 4, and 5 were combined as the posterior crossbite group.

As shown in Table III, for the anterior crossbite group, the frequencies of types I and IV were different from the normal occlusion group, whereas, in the posterior crossbite group, the frequencies of types I, IV, VI, and VII were different from the normal occlusion group. But when compared with the anterior crossbite group, there were a significantly lower type I frequency ($P = 0.001$) and a higher type IV frequency ($P = 0.002$) in the posterior crossbite group.

Table IV shows the frequency of each chewing type between the right and left sides in the posterior crossbite group divided by the transverse position of the crossbite teeth. In the right posterior crossbite group, type IV had a higher frequency in the right side than in the left side ($P = 0.036$), whereas types II and V had lower frequencies in the right side ($P = 0.035$, $P = 0.022$, respectively). In the left posterior crossbite group, there was no significant difference for the frequency of each chewing type between the 2 sides. In the bilateral posterior crossbite group, type IV occurred more often, and type I occurred much less in the left side than in the right side.

DISCUSSION

The chewing pattern of each subject had unique characteristics, and there were great individual variations. Akiyama et al²¹ investigated the average pattern of masticatory paths from 5 to 14 strokes in 78 normal subjects using a sirognathograph and an automatic masticatory analyzing system, and 8 chewing patterns were classified. The most frequent pattern on the habitual side, the nonhabitual side, and both sides was type I, followed by type III. This was confirmed in our study by the frequency of type I (normal): 88.4% in normal occlusion. Simultaneously, our results agreed well with the study of Ahlgren⁷; ie, normal occlusion had a simple and regular chewing pattern that was smoothly opened on the chewing side and smoothly closed on the contact point of the teeth. The individual variations in malocclusion were greater than in normal occlusion.

Kuwahara et al¹⁴ found that the concave opening type, called types III, IV, and VI in our study, was frequently observed in subjects with closed lock and osteoarthritis with sclerosis or erosive bone change (early stages of organic changes). This indicated a characteristic chewing pattern in some TMD patients. Sato et al¹⁵ reported similar results for TMD patients. Hence, it might be more reasonable to separate patients with and without TMD for analysis of the effect of

Table II. Frequency of each chewing type in various anteroposterior positions of crossbite patients

Group	Subjects (n)		Means of the numbers of each chewing type in the 10 strokes							
			I	II	III	IV	V	VI	VII	VIII
1	37	Mean	5.76 [†]	.54	.76	.90	.61	1.11	.23	.09
		SD	3.39	1.37	1.43	1.57	1.19	1.92	.49	.31
2	14	Mean	6.82 [†]	.36	.07	.64	1.22*	.43	.47	.00
		SD	2.56	.93	.27	.95	1.48	0.94	1.05	.00
3	25	Mean	3.78 [‡]	1.12*	.38	2.00 [‡]	1.00	1.36	.26	.10
		SD	2.95	1.93	1.10	1.92	1.45	2.38	.54	.29
4	16	Mean	3.91 [‡]	.31	.97	1.94 [‡]	.19	1.28*	1.38 [†]	.03
		SD	3.36	1.25	2.11	2.50	.36	1.63	2.75	.13
5	14	Mean	4.82 [‡]	.18	.86	1.89 [†]	.57	1.21	.43	.04
		SD	2.93	.67	1.68	2.38	.76	1.72	.78	.13
Normal occlusion	22	Mean	8.84	.09	0.34	.09	.34	.33	.07	.00
		SD	1.23	0.25	0.89	0.20	0.58	0.46	0.15	0.00

Significantly different from normal occlusion: * $P < 0.05$; [†] $P < 0.01$; [‡] $P < 0.001$.
There were no significant differences for the frequency of any chewing type between groups 1 and 2, and between groups 3, 4, and 5, $P > 0.05$.

Table III. Chewing pattern distribution between anterior and posterior crossbite group

Group	Subjects (n)		Means of the numbers of each chewing type in the 10 strokes							
			I	II	III	IV	V	VI	VII	VIII
I	51	Mean	6.05 [†]	.49	.57	.83*	.77	.92	.29	0.07
		SD	3.20	1.26	1.26	1.42	1.29	1.73	.69	.26
II	55	Mean	4.08 [†]	.65	.67	1.95 [†]	.65	1.30*	.63*	0.06
		SD	3.04	1.54	1.59	2.18	1.11	1.99	1.62	.22
Normal occlusion	22	Mean	8.84	.09	0.34	.09	.34	.33	.07	.00
		SD	1.23	0.25	0.89	0.20	0.58	0.46	0.15	0.0

Significantly different from normal occlusion: * $P < 0.05$; [†] $P < 0.001$.
Group I, Anterior crossbite; group II, posterior crossbite.
Between 2 malocclusion groups: type I, $P = 0.001$; type IV, $P = 0.002$.

malocclusion on chewing patterns. To simplify our study, only the chewing patterns of crossbite patients without signs and symptoms of TMD were analyzed.

Crossbite is a malocclusion with the buccal cusps or incisal edges of the maxillary teeth occluding lingually to the buccal cusps or incisal edges of the corresponding teeth. Is the direction of the chewing cycle in crossbite patients also the reverse of that in the normal occlusion group? Previous studies reported that the reverse type was one of the abnormal chewing types in crossbite malocclusions.^{7-9,11} This study showed that, in the anterior crossbite group, in either individual anterior crossbite or 4-incisors crossbite, 58% to 68% of the chewing cycles were normal, and the rest were a combination of other chewing types with similar frequencies except for the irregular chewing type. This indicated that there is not 1 obvious characteristic of abnormal frontal chewing type that is different from normal occlusion in the anterior crossbite group.

However, in the posterior crossbite groups (groups 3-5), type IV (reverse chewing) occurred more often

than in normal occlusion. In addition, the results of comparisons showed no significant differences in the frequency of any chewing type between groups 1 and 2, or between groups 3, 4, and 5. The crossbite subjects were divided into 2 groups: anterior crossbite with no posterior crossbite, and posterior crossbite with anterior crossbite. The results showed significant differences in the frequencies between the 2 groups in type I (40.8% of the strokes in the posterior crossbite group, and 60.5% of the strokes in the anterior crossbite group) and type IV (19.5% of the strokes in the posterior crossbite group, and 8.3% of the strokes in the anterior crossbite group). In addition, 13% of the strokes in the posterior crossbite group were the reverse-crossing type (type VI); this was significantly different from normal occlusion. Thus, it demonstrated that posterior crossbite played an important role in the occurrence of the reverse-chewing and reverse-crossing types. Normal chewing had a lower frequency in the posterior crossbite group when compared with the anterior crossbite group. But it cannot be concluded that the bad effect of an

Table IV. Frequency of each chewing type between the right and left sides in the posterior crossbite groups divided by the transverse position of the crossbite teeth

Group	Subjects (n)	Side		Means of the numbers of each chewing type in the 10 strokes							
				I	II	III	IV	V	VI	VII	VIII
A	15	R	Mean	4.27	.00	.00	2.53	.27	1.80	1.00	.13
			SD	4.13	.00	.00	3.02	.59	2.54	2.33	.52
		L	Mean	4.00	1.87	.20	.80	1.07	1.07	1.00	.00
			SD	3.53	3.40	.77	1.70	1.16	2.46	2.14	.00
B	21	R	Mean	4.14	.00	1.05	2.38	.19	1.52	.71	.00
			SD	3.77	.00	1.77	3.71	.40	2.58	1.85	.00
		L	Mean	3.90	.00	.67	2.43	.620	1.43	.86	0.09
			SD	3.77	.00	1.82	2.62	1.12	2.34	2.15	.30
C	19	R	Mean	5.42	1.05	1.21	.68	1.16	.37	.00	.11
			SD	3.95	2.99	3.14	2.14	1.98	1.38	.00	.46
		L	Mean	2.79	1.21	.63	2.68	.68	1.63	.32	0.05
			SD	3.24	2.64	1.92	3.00	1.53	2.95	.82	.23
Normal	22	R	Mean	9.13	0.09	.14	0.04	.32	.23	0.04	.00
			SD	1.04	.29	.47	.21	.72	.53	.21	.00
		L	Mean	8.54	0.09	.55	.14	.36	.27	0.04	.00
			SD	1.99	.43	1.53	.35	.73	.77	.21	.00

Group A, right posterior crossbite, right and left comparisons: type II, $P = 0.035$; type IV, $P = 0.036$; type V, $P = 0.022$.

Group B, left posterior crossbite, right and left comparisons: all types, $P > 0.05$.

Group C, bilateral posterior crossbite, right and left comparisons: type I, $P = 0.041$; type IV, $P = 0.004$.

R, Right; L, left.

anterior crossbite on mastication function was less than that of a posterior crossbite. More work is needed on the properties of chewing cycles in the sagittal and horizontal planes, chewing rhythms, the concentration of the end of chewing cycles, and other chewing parameters. In this study, only the frontal chewing pattern was studied.

In the posterior crossbite group, reverse-chewing (type IV) and reverse-crossing (type VI) were more prevalent than in normal occlusion. Does reverse-chewing type occur more often on the crossbite side than on the noncrossbite side? Few studies were available on this point.^{8,9} Our study showed that, in the right posterior crossbite group, the reverse type was more frequent, and the opening concave and positive crossing types were less frequent in the right side (ie, the crossbite side) than in the left side. But in the left posterior crossbite group, the frequency of each chewing type showed no significant differences between the right and left sides. In the bilateral posterior crossbite group, type I was significantly lower, and the reverse type was more frequent in the left side than in the right. This seemed that the results did not completely support the idea that, in the crossbite side, the reverse type occurred more often than in the noncrossbite side.

About 67% to 79% of patients with unilateral posterior crossbites in the deciduous and mixed dentitions had dental interferences that produced functional shifts

toward the crossbite side on closure.^{9,22} If it was not corrected in time, the mandibular functional shift could become a skeletal mandibular shift with obvious mandibular morphologic asymmetry. Did a mandibular shift affect the chewing type of posterior crossbite subjects, especially the difference of chewing pattern between the crossbite and noncrossbite sides, or between the shift and contralateral sides? In addition, Pröschel and Hormann¹¹ found that the chewing pattern distribution of Class III (mandibular prognathism) differed significantly from Class I and Class II Division 2, and type D had a high prevalence followed by the half-inverted and inverted types. In our study, the presence or absence of mandibular shift or mandibular prognathism was not an entrance criterion. So, the distributions of malocclusion manifestation in the right, left, and bilateral posterior groups were further analyzed, as shown in Table I.

The results showed that the position distributions of crossbite teeth in each group were similar, but arch crossbites accounted for 46.7% in the right group and 79.9% in the bilateral group, but only 4.8% in the left group. Similarly, mandibular prognathism was greatest in the right and bilateral groups and less in the left group. As to the percentage of shift, the ratio of right shift in the right group was not significantly different than left shift in the left group, and the distribution of shift in the bilateral crossbite group was similar to that of the left group. From these data, it can be explained

that, in the left group, since the percentages of mandibular prognathism and arch crossbite were relatively smaller than in the other 2 groups, no significant difference was found between right-side and left-side chewing. In the bilateral group, the left mandibular shift was 42.1%; this was similar to the 46.7% right shift in the right group, and the percentages of mandibular prognathism and arch crossbite were the highest in the 3 groups. This might explain the higher frequency of the reverse type in left-side chewing in the bilateral posterior crossbite group. Based on these results, it could be concluded that, for mandibular shift, prognathism, and arch crossbite, the reverse-chewing type was more likely in the crossbite side than in the noncrossbite side, or in the shift side than in the contralateral side.

CONCLUSIONS

In the frontal plane, the posterior crossbite group might have more abnormal chewing types than the anterior crossbite group, and a posterior crossbite might contribute to the high frequency of reverse and reverse-crossing chewing types, especially with mandibular shift, mandibular prognathism, or arch crossbite.

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