Long-term follow-up of early treatment of unilateral forced posterior cross-bite. Orofacial status

Panagiota Tsarapatsani, Marie Tullberg, Anders Lindner and Jan Huggare
Departments of Orthodontics and Clinical Oral Physiology, Institute of Odontology, Karolinska Institutet, Huddinge, Sweden

Tsarapatsani P, Tullberg M, Lindner A, Huggare J. Long-term follow-up of early treatment of unilateral forced posterior cross-bite. Orofacial status. Acta Odontol Scand 1999;57:97–104. Oslo. ISSN 0001-6357.

Twenty-nine subjects, 20 years old on average and all treated at 4 years of age for unilateral forced posterior dento-alveolar cross-bite by grinding or by expansion of the upper dental arch, were clinically examined to evaluate the long-term effects of their treatment. The frequency of successful treatment–indicated as stable correction of the cross-bite–by means of only 1 treatment sequence was 59%; by grinding, 57%; and by expansion, 60%. The 18 subjects that had only been treated at the age of 4 years formed the 'early group' in our study. Eleven of our subjects had been retreated later in the mixed or permanent dentition because of a relapse of the unilateral forced posterior cross-bite and formed the 'late group'. A significantly higher frequency of mouth breathing, breathing obstacles, and snoring was found in this group. According to our clinical investigation, 2 of the subjects in our cohort still had a unilateral forced posterior cross-bite. Our findings regarding masticatory performance, bite force, and endurance showed no significant differences between the initial cross-bite and the healthy sides or between the early and the late group subjects, which showed that the masticatory function of the treated subjects was symmetrical. Grinding and expansion treatments seem to display similar success rates in the long-term regarding correction of unilateral posterior forced cross-bite. □ *Malocclusion; nasal obstruction; orthodontic treatment; treatment stability*

Panagiota Tsarapatsani, Department of Orthodontics, Institute of Odontology, Karolinska Institutet, Box 4064, SE-141 04 Huddinge, Sweden. Tel: +46 8 7288361, fax. +46 8 6080834, e-mail. Panagiota.Tsarapatsani@ofa.ki.se

Unilateral posterior cross-bite usually develops in the primary dentition and high priority is given to children with this malocclusion when patients are being selected for orthodontic treatment. The prevalence of unilateral posterior cross-bite among preschool children has been reported to be 10–17% (1–7). Most cross-bites are functional, with a laterally forced occlusion (3, 8), and they rarely correct spontaneously (9–11). Factors involved in the etiology of the cross-bite, besides heredity, are sucking habits (3, 12–14) and impaired nasal breathing because of, for example, enlarged tonsils and adenoids (4, 15–17).

Occlusal disturbances characteristic of this type of cross-bite are believed to play a role in the development of temporomandibular disorders (TMD) (18, 19), and, among late consequences, asymmetrical masticatory muscle function (20–22), temporomandibular joint (TMJ) clicking (23), and an abnormally large variability in the masticatory pattern (24) have been reported.

Functional TMD and symptoms such as TMJ clicking and orofacial pain are more frequent in adults with a unilateral cross-bite than in adults with a normal transverse dento-alveolar relationship (2, 25). A higher frequency of arthrotic TMJ alterations was macroscopically observed in autopsies from young adults with cross-bite than in those without (18). Asymmetric growth of the temporomandibular eminence has been reported (26), even in those cases where cross-bite treatment had been performed (27, 28). Permanent asymmetry of the mandible due to untreated unilateral forced cross-bite has been suspected to occur (29, 30).

Among children with a mixed dentition, masticatory performance and maximal bite force were found to be reduced on the cross-bite side compared with the healthy side before treatment of the unilateral forced cross-bite. Such a difference between the right and the left sides was not found in the age-matched control group with a normal transversal relation (S Razavi, personal communication).

For all these reasons, early treatment of unilateral forced posterior cross-bite is advisable. However, so far there have been no studies following up children with treated unilateral forced posterior cross-bite after growth has ceased. It was therefore considered desirable to study the long-term effects of early unilateral cross-bite treatment performed with two different treatment modalities. For that purpose a cohort of early-treated children was acquired 16–19 years after the treatment.

Subjects and methods

Selection of the subjects

The subjects were 29 Swedish young adults. As 4-year-olds they had been included in two studies. Twenty-nine participated in the first study (31) and 76 in the second (10). Of these 105 children, 67 had been treated early for unilateral posterior cross-bite and were chosen to be our cohort. Thirty-eight subjects could be reached, 29 (18 females and 11 males, with a mean age of 20 ± 2 years) of whom gave their consent to participate in the present study.

All subjects had had a unilateral forced posterior dento-alveolar cross-bite in the primary dentition and been treated by grinding or expansion of the upper dental arch (by means of a modified quad-helix appliance) as 4-year-olds. Eleven of them had also been treated later because of cross-bite in the mixed or permanent dentition.

The subjects received oral and written information about our study and a summary of the results from the study in which they had participated as 4-year-olds. They were asked to give their consent before entering the present study.

Anamnesis

The collected data contained the following information:

- Whether the subjects had received any additional orthodontic treatment between the age of 4 and the time of this study, and, if so, what kind of orthodontic treatment had been given and when and where it had taken place.
- In the opinion of the subjects, whether they were mouth breathers, whether they snored, and whether they had or still have a history of breathing obstacles such as nose-obstruction, enlarged tonsils, or adenoids.
- The handedness of the subjects and the preferred chewing side (right or left).

Collection of retrospective data

Data on any orthodontic treatment performed after the grinding or expansion therapy were collected. The subjects were asked which Public Dental Service Clinics or private dentists delivered their regular dental care and which clinic had performed orthodontic treatment. One of the authors (P.T.) contacted the clinics and dentists in question and asked for the dental records of the subjects. The records were studied and information about whether the subjects had received any late orthodontic treatment, and whether that treatment was because of a relapse of the unilateral forced posterior cross-bite, was gathered. Specifically, treatment due to a relapse of a unilateral forced posterior cross-bite was considered as 'late treatment' for our subjects.

Clinical investigation of the transversal relation. All cases with unilateral cross-bites were clinically examined by an orthodontist (A.L.) to find out whether the subject had a lateral forced bite. The criteria for a forced bite were based on an existing lateral shift of the mandible between retruded position (RP) and intercuspal position (IP). All cases with a lateral forced cross-bite were defined as failed. A normal lateral relationship or a stable morphological cross-bite was defined as a corrected case.

Model casts

Model casts were available from earlier studies when the subjects were 4 and 8 years old (model casts at 8 years were not available for the quad-helix appliance group). The inter-canine distance was measured on the casts taken before early treatment (at age 4 years). The measurement was made in the region of the canines (buccal prominence of the primary canines). New model casts were also made at this follow-up to confirm our morphological findings from the clinical investigation (P.T.). The model casts were then studied by an orthodontist (A.L.).

Assessment of masticatory performance. During assessment of masticatory performance, each subject was asked to chew one sheet (2.5×3.5 cm and weighing 5 g) consisting of Satous synthetic material (equal amounts carnauba wax and bariumsulphate) plus a color binder (Praestrol 655 BC), 10 strokes on each side. The subjects were asked to start on the subjectively preferred side of chewing. The particles were collected and separated from the liquid using a centrifuge and incubated with 30 ml of a standard erythrosin solution. After half an hour, sodium carbonate was added to bring the solution to a pH of 10. Finally, the difference in the spectrophotometrical absorbance between a standard solution and the supernatant was measured with a spectrophotometer at 526 nm (32). This difference in absorbance was used as an estimate of masticatory performance.

Assessment of bite force and endurance. The maximal voluntary lateral bite force at the first molars and the frontal bite force of the subjects were measured using a strain gauge bite fork [(5kHz—Carrier Frequency Measuring Amplifier KWS 3072, Hottinger Baldwin Messtechnik (HBM), Germany]. A digit was displayed on the device when the subject bit axially on the bite fork. That value was afterwards transformed into Newtons with the aid of standard diagrams.

An index was calculated for each subject to determine which side was stronger in bite force. The index was obtained by dividing the difference of the bite force values of the initial cross-bite and the initial healthy sides by the average of the two sides and then multiplying by 100. The mean and the standard deviation of the indexes of the 29 subjects in the early and late groups were then calculated. An index that differed more than 1 standard deviation from the mean of the group was considered to be an indication of asymmetric bite force. The time (in seconds) that the subjects were able to maintain their bite force at a level of 2/3 of their maximal voluntary bite force (= endurance) was also measured.

Assessment of mandibular asymmetry. En face photos were taken with a digital camera (Casio LCD Digital Camera

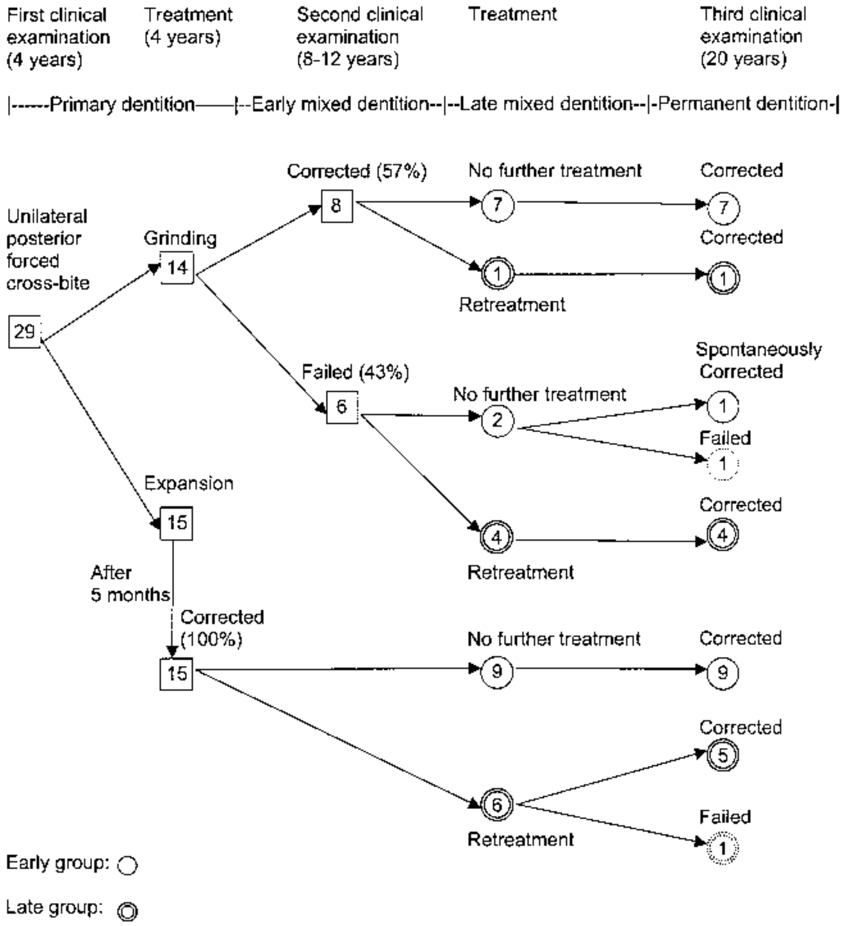

Fig. 1. Overview of our cohort from 4 years of age on average to 20 years of age on average.

QV-300). As the camera was fixed on a tripod, the height and distance to the subjects were therefore standardized. The photographs were taken in the frontal position. They were saved in the 'Adobe Photoshop™' computer program. A perpendicular line to the interpupillary axis was drawn through the interpupillar midpoint. The mandibular asymmetry was assessed by visual inspection of the position of the chin point in relation to this line. The photographs were evaluated blind by three of the authors (P.T., A.L., and J.H.) and any asymmetry was decided in consensus if the chin point obviously deviated from the line. Mandibular asymmetry was also assessed by 9 undergraduate dental students unaware of the subject's previous treatment. The students were asked individually to report which subjects they considered to be asymmetric at two different times, with an interval of 1 day. A subject was given the tag 'mandibular asymmetry' when a majority of the students found that person to have mandibular asymmetry both times.

Ethical requirements

The study was approved by the Medical Ethics Committee at Huddinge Hospital, Huddinge, Sweden, before initiation of the study.

Statistical analysis. A normality test (Kolmogorov-Smirnov) was performed for the investigated variables. Student's t test was used to analyze the variables bite force, masticatory performance, and maxillary/mandibular (max./mand.) arch width difference. The Mann-Whitney U test was used to analyze the variable endurance, which showed a skewed distribution. The chi squared test (fourfold table corrected for small numbers) was used to analyze the variables mouth-breathing, breathing obstacles, snoring, initial cross-bite side (right or left), and mandibular asymmetry.

Results

The 29 subjects are distributed in accordance with type of treatment and outcome of treatment from 4 years of age in Fig. 1. In our clinical examination, we found that 2 (7%) of the 29 subjects still had unilateral forced posterior cross-bites. Furthermore, 5 subjects (17%) had a morphological

Table 1. Frequency (%) of mouth-breathing, breathing obstacles, and snoring in each group

	Early group ($n = 18$)	Late group ($n = 11$)	P
Mouth-breathing	33%	73%	NS
Breathing obstacles	17%	55%	NS
Snoring	11%	64%	<0.05

cross-bite. Both the forced and the morphological cross-bites were located on the same side as the initial forced unilateral cross-bite. The frequency of a successful treatment—indicated as stable correction of the cross-bite—by means of only 1 treatment sequence was 59%; by grinding (1 spontaneously corrected subject was included), 57%; and by expansion, 60%.

All 18 subjects (62%), 17 corrected and 1 failed, who had received only early treatment of the unilateral forced cross-bite at the age of 4 years formed the first group in our study. This group is referred to here as the 'early group'. The treatment performed consisted of grinding in 9 subjects and expansion of the upper dental arch in 9 subjects.

Eleven subjects (38%), 10 corrected and 1 failed, had, in addition, received orthodontic treatment in the mixed or permanent dentition because of a relapse of the unilateral forced cross-bite. This group is referred to as the 'late group'. The early treatment performed at the age of 4 years consisted of grinding in 5 subjects and expansion of the upper dental arch in 6 subjects. Six of the initially corrected cases in the expansion group and 1 in the grinding group had relapsed in the late mixed dentition.

In the early group, 1 (6%) of the 18 subjects still had a unilateral forced posterior cross-bite, and in the late group we found 1 failed case in 11 (9%). Furthermore, morphological cross-bites were found in 3 (17%) of the 18 subjects in the early group and in 2 (18%) of the 11 subjects in the late group.

Mouth-breathing, breathing obstacles, and snoring

Mouth-breathing, breathing obstacles, and snoring were found to occur more frequently in the late group. In the early group, 6 (33%) of the 18 subjects considered themselves to be mouth-breathers, while 2 were unsure. In the late group, 8 (73%) of the 11 subjects considered themselves to be mouth-breathers while 1 was unsure. A history of breathing obstacles was reported in the early group by 3 (17%) of the 18 subjects and in the late group by 6 (55%) of the 11 subjects. Two (11%) of 18 subjects reported snoring in the early group, while 2 were unsure; 7 (64%) of the 11 in the late group reported snoring, which was statistically significant ($P < 0.05$; Table 1).

All subjects in the late group reported at least one of these signs indicating impaired nasal breathing, whereas in the early group this was reported by 7 of 16 (2 subjects were uncertain). This difference was significant ($P < 0.05$).

Relationship between initial cross-bite side and preferred chewing side and handedness. A significantly higher number ($P < 0.05$) of subjects with an initially right-sided cross-bite (66%) was found in our cohort. The handedness and preferred chewing side of the subjects with an initially right- or left-sided cross-bite are given in Table 2.

A unilateral preference of a chewing side was reported by 24% of our subjects: 28% in the early group and 18% in the late group. A bilateral preference of a chewing side was more frequently reported (59%) than unilateral: 50% in the early and 73% in the late group. The remaining subjects were uncertain.

Model casts analysis

We found that the mean value of the max./mand. arch width difference (on the casts taken at the age of 4 years) in the early group was slightly larger (3.03 mm) than the corresponding mean value in the late group (2.80 mm). The difference, however, was not statistically significant.

Masticatory performance. There was no significant difference in masticatory performance between the initial cross-bite and the healthy sides in either group. Neither was there a difference in their mean masticatory performance.

Bite force. The mean voluntary lateral bite force was 393 N (SD = 81) on the initial cross-bite side and 445 N (SD = 116) on the initial healthy side in males. In females, the corresponding figures were 266 N (SD = 122) and 283 N (SD = 125). The mean frontal bite force was 139 N (SD = 78) in males and 90 N (SD = 35) in females.

One male subject was excluded from our bite-force measurements since the measured bite forces were extremely high compared with those of the other subjects. The maximal bite force recorded in this case was 830 N.

There was no significant difference in bite force between the initial cross-bite and the healthy sides in either group. Neither was there a difference in their mean bite forces.

Table 2. Handedness and preferred chewing side of the subjects ($n = 29$) according to the initial cross-bite side

	Handedness		Preferred chewing side		
Initial cross-bite side	Right	Left	Right	Both	Unsure
Right ($n = 19$, 66%)	95% (18)	5% (1)	26% (5)	58% (11)	16% (3)
Left ($n = 10$, 34%)	80% (8)	20% (2)	20% (2)	60% (6)	20% (2)

Table 3. Frequency (%) of a stronger side, as determined by bite force values overall in 28 subjects and in each group

	Stronger side		
	Initial cross-bite side	Initial healthy side	No sidedness
Overall (*n* = 28)	4% (1)	14% (4)	82% (23)
Early group (*n* = 17)	6% (1)	18% (3)	76% (13)
Late group (*n* = 11)	0%	9% (1)	91% (10)

No significant difference was found between the groups concerning bite force in the front. However, there was one subject in the early group in whom the initial cross-bite side was stronger than the contralateral side. In 4 subjects (3 in the early group and 1 in the late group), the initial healthy side was stronger than the contralateral side. Hence, asymmetric bite force was detected in 18% of our subjects, while in 82% the bite force values of the two sides did not significantly differ from each other (Table 3).

Endurance. In general, females showed a higher endurance than males. The mean lateral endurance in males was 14 sec (SD = 10) on the initial cross-bite side and 13 sec (SD = 12) on the initial healthy side. In females, the corresponding figures were 22 sec (SD = 14) and 21 sec (SD = 16). The mean frontal endurance was 28 sec (SD = 18) in males and 21 sec (SD = 16) in females.

There was no significant difference in endurance between the initial cross-bite and the initial healthy sides in either group or between the mean endurances of the groups. No significant difference concerning endurance in the front was found between the groups.

Mandibular asymmetry

According to the authors' evaluation, the majority of our subjects (86%) showed no obvious mandibular asymmetry. Only 2 subjects in the early and 2 in the late group had obviously asymmetric mandibles. There was no significant difference in the mandibular asymmetry between the groups. An asymmetry to the initial cross-bite side was found in 50%. According to the students, 76% showed no obvious mandibular asymmetry and no significant difference in the mandibular asymmetry was found between the groups. The students' agreement between the 2 times they evaluated the photographs was on average 76% (22 of 29). The same 4 subjects with asymmetric mandibles in the authors' evaluation were also evaluated as asymmetric by the students and the mandible asymmetry too was reported on the same side. An asymmetry to the initial cross-bite side was reported for 57% of the subjects with asymmetric mandibles.

Discussion

The majority of our subjects (93%) exhibited a normal transverse occlusion in the permanent dentition. A unilateral forced posterior cross-bite was found in only 2 subjects in our cohort, 1 in the early and 1 in the late group. The subject in the early group had experienced a trauma in the TMJ area prior to his visit to our clinic, which could have had an influence on his occlusion. The subject in the late group was a complex case with a basal open bite for which surgical treatment had been advised, but the patient had rejected this option. In the remaining 27 subjects, the forced cross-bite had been treated successfully. Nevertheless, morphological cross-bite was found in 5 subjects; 3 in the early and 2 in the late group. The forced and the morphological cross-bites were localized on the same side, as had been the initial forced unilateral cross-bites for all 7 subjects.

The treatment was considered successful when no further orthodontic intervention was needed based on findings (2, 11) that a forced cross-bite is prone to later TMD.

The degree of success in the elimination of the cross-bite (functional success) found in this study (93%) is higher than that reported earlier in the literature, with a follow-up in permanent dentition. Purcell (33) found that 69% of the patients treated for the correction of posterior cross-bite in the mixed dentition had been successfully treated when an evaluation of the permanent dentition was made later. A success rate of 67% was reported by Thilander et al. (34) in an examination of the permanent dentition of subjects who as children had been treated early for posterior cross-bite by grinding and expansion. Herold (35) found that 56% of the cross-bites treated by expansion were corrected on the long-term. However, it is difficult to conclude whether the discrepancy indicates a real difference in treatment success or is due to a difference in the definition of the criteria for success.

The frequency of a successful treatment—indicated as stable correction of the cross-bite in our clinical examination—by means of only 1 treatment sequence was 59%: by grinding, 57%; and by expansion, 60%. Although the two treatment modalities were investigated in 2 different studies, their subjects were the same age, were diagnosed to exhibit the same malocclusion, were living in the same geographic area, and all had a history of sucking habits, which had been discontinued before the start of treatment. In addition, the same investigator performed both studies. Consequently, the 2 cohorts should be comparable. Both treatment modalities seem to have effected similar long-term results regarding the correction of unilateral posterior forced cross-bite.

The early and late groups. Our subjects were categorized into an early and a late group. All those in the late group experienced a relapse of their cross-bite. A higher frequency of mouth-breathing, breathing obstacles, and snoring was found in this group. Furthermore, all subjects with a history of failed cross-bite treatment (at the second investigation and also at our third investigation) exhibited one or more of the above variables, which could be the explanation for their relapse. The presence of breathing problems might interfere with an otherwise successful treatment.

In fact, mouth-breathing and breathing obstacles have been blamed for regression of cross-bite. Enlarged tonsils can, over a period of time, contribute to the development of a lateral cross-bite, and their removal might inhibit, or even reverse, this development. Compared to control children, the children with enlarged tonsils displayed an increased frequency of lateral cross-bite and mouth-breathing. The effect of a tonsillectomy was associated with a reduction in the tendency to develop a lateral cross-bite, mainly due to a decrease in the lower inter-molar distance and a change from mouth to nose breathing (36).

In a group of adenoidectomized children (and hence a change to nose-breathing), Linder-Aronson (37) also found a reduction in cross-bite tendency and an increase in upper inter-molar width in the operated group compared with a control group.

The diagnosis of the mode of breathing in our study was based on the patient's history and clinical observations. It is difficult to find appropriate methods and equipment suitable for the registration of breathing function. No technical device was used in our study. It was considered reliable enough to ask the patients to give information about their breathing habits.

Rhinometry has been used to assess nasal oral breathing, often by application of a pressure flow technique to estimate nasal cross-sectional area (38). The reliability obtained with this device is questionable, however, since the correlations between repeated assessments are very low (39). Besides the technical difficulties (e.g., partially blocking the mouth catheter with the tongue), the momentary mode of breathing does not necessarily represent the patient's true mode of breathing.

In the original study (10), where our subjects (treated by grinding) participated, the max./mand. arch width difference at age 4 was found to be the only variable differing significantly between a successful and a non-successful treatment outcome. The subjects with a large max./mand. arch width difference exhibited a successful outcome of the grinding treatment. We were interested to find out whether this could predict the long-term outcome at age 20. The mean value was only slightly larger (3.03 mm) in the early group than in the late group (2.80 mm). However, since the difference was not significant, this variable cannot be used as a predictive factor for the late outcome.

Measurements on masticatory performance, bite force, and endurance were made to evaluate the functional condition of the masticatory system of our subjects. Our findings regarding these parameters showed no significant difference between the initial cross-bite and the initial healthy side or between the early and the late group subjects, which indicated that the masticatory function of the treated subjects was symmetrical.

Many attempts to measure the effectivity of mastication by the use of test foods have been carried out (40). The use of different kinds of test foods makes standardization and interstudy comparisons difficult. In addition, most of these methods are unsuitable for routine clinical use because of their complexity (40, 41).

One method addressing the above-mentioned problems in the assessment of masticatory performance was developed by Huggare & Skindhöj (32) and has been tested both in vitro and in vivo for selectivity and reproducibility.

Using the same method as ourselves, Razavi found statistically significant differences in masticatory performance and maximal bite force between the cross-bite side and the healthy side in children with an untreated unilateral forced cross-bite. This difference was not found in the age-matched control group with a bilateral normal transversal relation (S Razavi, personal communication).

Interestingly, our subjects showed bilateral symmetric masticatory performance and maximal voluntary bite force. It could be assumed that a normalization of the bite force and the masticatory performance was achieved after our subjects had received treatment, since no significant asymmetric function between the sides was found. However, the results from our different groups suggest the need for caution when viewing those findings.

In addition, no significant difference was detected between the early and the late groups regarding masticatory performance and bite force. Since symmetric function was earlier found in subjects with a normal transversal relation (S Razavi, personal communication), it could be presumed that symmetric function is gained when the subject's cross-bite is corrected. The amount of treatment sequences or retreatment seems not to have an effect on the above parameters.

The possibility of comparing the results of different studies regarding bite force has been limited mainly by differences in experimental conditions and in the methods and appliances used. In accordance with earlier studies, we also found differences between males and females; we found that the forces at the incisors were approximately one-third of those measured at the molars (42–44). Maximal voluntary bite force registrations presented by different investigators average 380–490 N on molars and 176–190 on incisors in males. In females, the average on molars was 216–470 N (42, 43, 45).

Unilateral chewing is more frequent in individuals with an unequal distribution of residual teeth on both sides of the mouth (46). Our subjects had an even distribution of teeth. Unilateral chewing was reported by 24% of our subjects. This frequency was the same as in the Agerberg (46) study of a normal population.

In accordance with earlier studies (7, 8, 34, 47), we also found that unilateral cross-bite was most common on the right side. Possibly, there is a tendency from the beginning of the existence of a cross-bite to 'correct' the bite to the right side, since the handedness is also to the right. The right side is generally more prominent, since the left brain hemisphere usually dominates in humans. According to a hypothesis of Annett (48), the origin of directional asymmetry or laterality in the brain and cranium is a genetic factor that favors left hemisphere dominance, in the absence of which, laterality would be determined by random effects (48).

None in our cohort preferred to chew on the left side, but 34% had initially left-sided cross-bites (among those was 1 failed subject at our examination), which means that there is no correlation between cross-bite side and preferred chewing side. Similarly, 1 left-handed subject was found among those 19 with initially right-sided cross-bites and 8 right-handed subjects among the 10 with initially left-sided cross-bites. Consequently, neither can a correlation between cross-bite side and handedness be made.

The endurance of our subjects was measured to obtain a second tool for describing their orofacial muscular functional status. No asymmetric function regarding endurance between the sides was found in our subjects. This could also be explained as a normalization of the muscular functional status after treatment.

Obvious mandibular asymmetry was found for only a minority of our subjects, revealing a predominant morphological symmetry in this cohort. All human faces have some degree of asymmetry, which often goes unnoticed by the general public. Measurable skeletal asymmetry at the mandible gonion was reported in subjects with esthetically pleasing faces (49).

In conclusion, the mode of breathing and breathing obstacles seem to play an important role in the origin and persistence of a cross-bite and have an effect on the success rate of treatment. Elimination of factors that hamper normal nasal breathing is of paramount importance in providing optimal conditions for stable cross-bite correction.

Grinding and expansion treatments display similar success rates in the long-term regarding correction of unilateral posterior forced cross-bite. From a cost-benefit point of view, grinding is an easy treatment, less expensive and less time-consuming and could be recommended as the first choice among early treatment modalities.

Acknowledgments.—This study has been supported by Karolinska Institutet, Stockholm, Sweden.

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Received for publication 26 November 1998
Accepted 6 April 1999