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The functional shift of the mandible in unilateral posterior crossbite and the adaptation of the temporomandibular joints: a pilot study

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SUMMARY Changes in the functional shift of the mandibular midline and the condyles were studied during treatment of unilateral posterior crossbite in six children, aged 7–11 years. An expansion plate with covered occlusal surfaces was used as a reflex-releasing stabilizing splint during an initial diagnostic phase (I) in order to determine the structural (i.e. non-guided) position of the mandible. The same plate was used for expansion and retention (phase II), followed by a post-retention phase (III) without the appliance. Before and after each phase, the functional shift was determined kinesiographically and on transcranial radiographs by concurrent recordings with and without the splint. Transverse mandibular position was also recorded on cephalometric radiographs.

Prior to phase I, the mandibular midline deviated more than 2 mm and, in occlusion (ICP), the condyles showed normally centred positions in the sagittal plane. With the splint, the condyle on the crossbite side was displaced 2.4 mm ($P < 0.05$) forwards compared with the ICP, while the position of the condyle on the non-crossbite side was unaltered. After phase III, the deviation of the midline had been eliminated. Sagittal condylar positions in the ICP still did not deviate from the normal, and the splint position was now obtained by symmetrical forward movement of both condyles (1.3 and 1.4 mm).

These findings suggest that the TMJs adapted to displacements of the mandible by condylar growth or surface modelling of the fossa. The rest position remained directly caudal to the ICP during treatment. Thus, the splint position, rather than the rest position should be used to determine the therapeutic position of the mandible.

Introduction

Posterior crossbite is defined as a malocclusion in the canine, premolar, and molar regions, characterized by the buccal cusps of the maxillary teeth occluding lingual to the buccal cusps of the corresponding mandibular teeth (Björk *et al.*, 1964). Crossbite may comprise one or more pairs of teeth, and be unilateral or bilateral. It occurs in 8–16 per cent of the population, most frequently unilaterally (Helm, 1968, 1970; Foster and Hamilton, 1969; Kutin and Hawes, 1969; Day and Foster, 1971; Ingervall *et al.*, 1972; Thilander and Myrberg, 1973; Rasmussen and Helm, 1975; Ravn, 1975; Kisling and Krebs, 1976; Heikinheimo, 1978; Järvinen, 1981). A unilateral posterior crossbite will often be accompanied by deviation of the lower dental arch midline to the crossbite side.

The most frequent cause of unilateral posterior crossbite is a reduction in width of the maxillary dental arch. Such a reduction may be induced by finger or dummy sucking (Köhler and Holst, 1973; Holm and Arvidsson, 1974; Larsson, 1975, 1986; Infante, 1976; Kisling and Krebs, 1976), by certain swallowing habits (Melsen *et al.*, 1979), or by obstruction of the upper airways due to adenoid tissue or nasal allergy (Linder-Aronson, 1970; Bresolin *et al.*, 1983; Corruccini *et al.*, 1985; Trask *et al.*, 1987). The resultant discrepancy between the maxillary and mandibular arch widths may elicit a neuromuscular guidance of the mandible (Haralabakis and Loutfy, 1964; Troelstrup and Møller, 1970; Ingervall and Thilander, 1975; Møller, 1981; Møller and Bakke, 1985), generated by the central nervous system, and probably based on feedback from mechanoreceptors in the periodontal membrane and in the periosteum of the alveolar bone (Bakke, 1993). The 'forced guidance' causing the lateral deviation of the mandible in unilateral posterior crossbite thus does not seem to be a mechanically forced displacement of the mandible due to interfering teeth, as has been sometimes assumed. There is a neuromuscular guidance of the mandible directly into the intercuspal position (ICP), with maximally obtainable intercuspation (Beyron, 1969), and characterized by unilateral posterior crossbite and a deviating lower arch midline. In fact, an initial deviation in the closing path of the mandible may be present even before intermaxillary tooth contact, as evidenced by predominance of postural activity in the posterior temporal muscle on the side of the crossbite (Troelstrup and Møller, 1970).

The concept of the structural position (SP) of the mandible was introduced by Møller (1981) to characterize the position that provides optimal functional conditions for the muscles of mastication and the temporomandibular joints (TMJs). The SP does not necessarily coincide with maximally obtainable intercuspation, and it has been argued that divergence between the ICP and the SP may induce physical strain into muscles and joints in adults (Møller, 1981). Moreover, unilateral posterior crossbite has been shown statistically to be associated with temporomandibular disorders (Pullinger *et al.*, 1993; Sonnesen *et al.*, 1998).

The unilateral posterior crossbite with deviating arch midline, established and maintained by neuromuscular control, may be considered an ICP deviating from the SP. In order to assess whether such a neuromuscularly controlled displacement of the mandible is present in a patient, a so-called reflex-releasing stabilizing bite splint can be employed (Møller, 1981; Bakke and Møller, 1991). Such a splint has a flat occlusal plane without any transverse or sagittal guidance, and is assumed to eliminate the specific asymmetric stimuli from the ICP by an evenly distributed neural feedback in all positions of occlusal contact. If the ICP deviates from SP, the mandibular position on the splint (SPL) will then be expected to gradually change and eventually attain the SP (Møller, 1981; Bakke and Møller, 1992).

Although the lateral displacement of the mandible is mentioned in all accounts of the aetiology of unilateral posterior crossbite, there are only few analyses of the position of the mandibular condyles in this condition. Hesse *et al.* (1997) reported a change in the condylar position associated with maxillary expansion for correction of unilateral posterior crossbite. On tomograms taken before and after the 4–6-month treatment period, the condyles on the non-crossbite side were reported to have moved posteriorly and superiorly. So far, no analysis seems to have been made of changes in the functional shift at the mandibular midline and in the TMJs due to treatment of unilateral posterior crossbite.

The aim of the present study, therefore, was to describe the functional shift of the mandible and its changes, as evidenced in the temporomandibular joints and by the changes in the dental arch midline relationship during treatment of unilateral posterior crossbite with a removable expansion plate.

Subjects and methods

The study group comprised six sequentially admitted patients, three girls and three boys, who fulfilled the criteria of unilateral dentoalveolar posterior crossbite with a midline deviation to the crossbite side greater than or equal to 2 mm. The mean age was 8 years 7 months, with a range from 7 years 3 months to 11 years 3 months. Dental maturity at the start of the study varied from DS1, M1 to DS3, M1 (Björk *et al.*, 1964). All the patients had right-sided unilateral posterior crossbite, ¼–½ cusp distal molar occlusion on the crossbite side and neutral molar occlusion on the contralateral side. The midline of the mandibular dental arch deviated, on average, 2.5 mm to the crossbite side. All patients were healthy, and there were no symptoms or signs of temporomandibular disorders (TMD). In all patients there was an evenly distributed multi-point contact in the ICP.

Phases of treatment

The course of the treatment comprised three clinical phases: (I) a period with the use of an unactivated expansion plate acting solely as a reflex-releasing stabilizing splint in order to eliminate the reflex-controlled guidance of the mandible into the ICP; (II) a period with transverse expansion of the maxilla and subsequent retention with the plate; and (III) a post-retention observation period without any appliance. The duration of these periods and the timing of the registrations (Series 1–4) are shown in Table 1.

The same appliance was used for phases I and II, a removable expansion plate in the maxilla with covered occlusal surfaces. The base of the expansion plate and the occlusal coverage extended from the first permanent molars forwards to the deciduous canines, leaving the area behind the incisors free for the patient's comfort. The occlusal plane was flat without any transverse or sagittal guidance, and was adapted to have point contact by all facial cusps in the mandible. The plate was fitted with Adams' or ball clasps, a labial arch, an expansion screw, and springs for the labial movement of the upper deciduous canines (Figure 1). It was worn constantly, except when eating or brushing the teeth.

Table 1 Clinical phases and registrations.

	Duration (months)	
	Mean	Range
Registrations: Series 1		
Phase I: diagnostic splint	4.3	2–7
Registrations: Series 2		
Phase II: orthodontic treatment and retention	13.0	11–17
Registrations: Series 3		
Phase III: post-retention period	11.6	9–15
Registrations: Series 4		

Registrations in all series comprised malocclusion, dental arch widths and cephalometric radiographs. Mandibular kinesiographic recordings and transcranial TMJ radiographs were included in Series 1, 2, and 4 for assessment of the functional shift from the ICP to the SPL.

Phase I: diagnostic splint. In phase I the appliance was used exclusively as a reflex-releasing stabilizing splint in order to identify the mandibular displacement and to determine the sagittal and transverse location of the SP. The contact points were marked on the splint and copied onto transparent foil to provide a graphical record. The adaptation and the graphical registration on foil were repeated at each monthly

(a) (b)

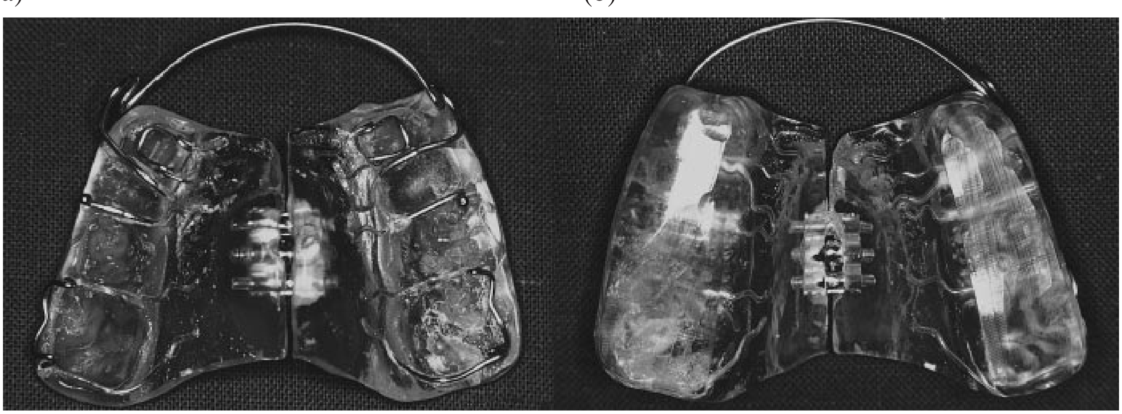

Figure 1 Appliance used as a diagnostic reflex-releasing stabilizing splint, as expansion plate, and for retention. (a) Palatal surface. (b) Occlusal surface.

follow-up visit until the location of the contact points no longer changed. The repeated grinding to adapt contact points sometimes resulted in the occlusal covering becoming so thin that a new layer of acrylic had to be added. When there was no change in the contact marks on the splint at two consecutive sessions, phase I was terminated.

Three patients lost their splints before period I was finished. In these cases, a new splint was fabricated, material corresponding to Series 1 was recorded again, and phase I as described above was repeated.

Phase II: orthodontic treatment and retention. The expansion treatment was started after phase I. The patient and the parents were instructed how to activate the expansion screw twice a week. The tooth contacts on the splint were checked, if necessary corrected, and transferred to foil at each visit. When the expansion of the maxilla was complete, the retention period commenced. The occlusal covering was ground away, the clasps were cut off if they interfered with the occlusion, and the patient was instructed to stop the expansion and only to wear the splint at night. When the recordings of contact points between the teeth subsequently showed stable and evenly distributed occlusal contacts, phase II was terminated.

Phase III: post-retention period. After expansion and retention there followed an observation period without the appliance. For technical reasons the project was terminated at a specific date. At this time the post-retention period had lasted from 9 to 17 months. In order to determine the SPL and the SP as a control, a new diagnostic splint was fabricated in the form of a plate for the maxilla with covered cusps as in Series 1, but without expansion screw and labial arch. Immediately after adapting the plate as a reflex-releasing splint, as described above, Series 4 was recorded.

Recordings

The recordings comprised four series: Series 1 and 2 at the start and at the end of the diagnostic splint period; Series 3 after the orthodontic expansion and retention period; and Series 4 one year post-retention.

Tooth contacts. Contact points on the plate were recorded with horseshoe articulating paper, and occlusal contacts between teeth were recorded in the ICP with Hawe transparent strips (0.05 mm thick and 6.0 mm wide).

Dental arch widths. The width of the dental arches in the maxilla and mandible was measured with sliding callipers on dental casts as the distance between the midpoints of the mesial marginal crests of the first permanent molars on the right and left sides.

Mandibular kinesiographic recordings. The positions and movements in relation to the ICP of a magnet placed on the lower central incisors were recorded kinesiographically by means of a jaw tracking device (Sirognathograph type D 3175, Siemens AG, Bensheim, Germany). The sagittal and transverse recordings were simultaneously traced on graph paper with a double pen recorder (Kipp and Zonen *x–y* recorder, type BD 91, Delft, The Netherlands).

The kinesiographic recordings comprised a series of movements and positions as described by Michler *et al.* (1987). Of these, this study made use of the recording of the splint position (SPL) in relation to the intercuspal position (ICP), and recording of the transverse location of the rest area in relation to the ICP (Bakke and Møller, 1991). The rest area was represented by the midpoint between its maximum contralateral and ispilateral deviation (MRA) from the ICP. These positions were determined for each patient as the mean of three recordings.

Radiographs. The radiographic material comprised cephalometric lateral and postero-anterior (P-A) radiographs recorded in the ICP, and transcranial radiographs of both temporomandibular joints. For the cephalometric exposures the focus-to-median plane distance was 180 cm, the median plane-to-film distances were 10 cm for the lateral, and 15 cm for the P-A exposures. No correction was made of the radiographic enlargement of 5.6 and 8.3 per cent, respectively. On the lateral films 17 variables were used to describe the craniofacial morphology (Björk, 1961), and on the P-A films (Figure 2) the transverse positions of the maxillary and mandibular midlines and

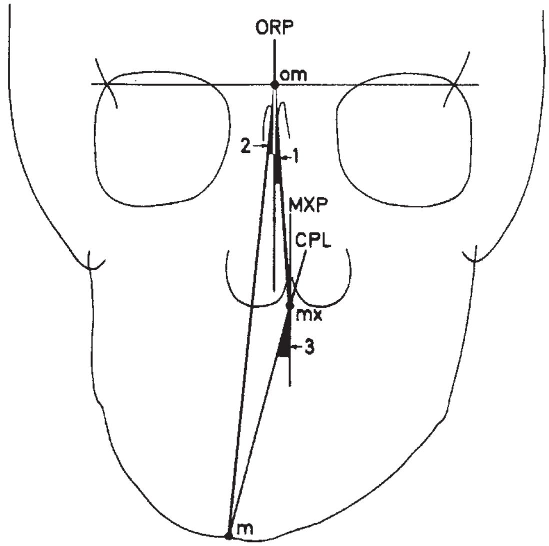

Figure 2 Variables recorded on the postero-anterior cephalometric films. 1: mx-om/ORP = transverse maxillary position. 2: m-om/ORP = transverse mandibular position. 3: CPL/MXP = transverse jaw relationship. For definitions of reference points and lines, see Svanholt and Solow (1977).

the transverse jaw relationship were determined (Svanholt and Solow, 1977).

In each series, oblique transcranial TMJ radiographs were recorded concurrently with and without the splint, i.e. in the SPL and the ICP, with the patient kept seated with the head fixed to a head rest by means of a forehead band. The central beam was directed from 20 degrees above and 10 degrees behind the condyles. The focus-to-film distance was approximately 100 cm and the condyle-to-film distance about 4 cm.

The horizontal displacement of the condyle from the ICP to the SPL was measured by superimposing the two TMJ exposures from each series by a method analogous to that used in structure-based cephalometric superimpositions (Björk and Skieller, 1983). The anterior part of the external acoustic meatus, the articular fossa, and the articular tubercle were used as reference structures. No correction was made for radiographic enlargement.

Statistical methods. Differences in means were assessed by paired or unpaired *t*-tests after testing for differences in variances.

Method errors. For assessment of method errors, a remeasurement of all radiographs was undertaken 6 months after the first measurement. There were no significant differences between the two series of measurements. The error of the method, $s(i)$, was 0.1–1.5 degrees for the cephalometric variables and 0.2–0.4 mm for the transcranial radiographs.

Results

Series 1, at the start of the diagnostic splint phase

The craniofacial morphology of the subjects was assessed from the lateral cephalometric films by comparison with the reference data used in the Björk cephalometric analysis (Björk, 1961). Apart from a slightly reduced mean overjet of 2.2 mm, none of the variables on the lateral radiographs differed significantly from the reference data. Neither did the P-A films (Table 2) show statistically significant transverse deviations of the maxillary or mandibular midpoints or the transverse jaw relationship.

On the kinesiographic registration (Table 3) the mandibular rest area was located directly below the ICP. With the splint, in the SPL, there was a mean contralateral displacement, i.e. to the non-crossbite side, of 2.0 mm ($P < 0.05$) from the ICP (Figure 3, SPL1).

The joint structures showed no erosions, sclerosis, or flattening, and the sagittal positions of the condyles on both sides showed no deviation from normally centred positions on the transcranial radiographs. With the splint, in the SPL (Table 4), the ipsilateral condylar head, i.e. the condylar head on the crossbite side, was displaced on average 2.4 mm forwards ($P < 0.05$) compared with the ICP, while the mean sagittal location of the contralateral condylar head did not change significantly. On average, the ipsilateral condylar head was displaced 2.5 mm further forward than the contralateral ($P < 0.05$).

Series 2, at the end of the diagnostic splint phase

In the ICP, the crossbite, the dental arch width (Table 5) and the midline deviation were almost unchanged, though the crossbite on the first

Table 2 Postero-anterior cephalometric analysis.

	Transverse jaw position				Transverse jaw relationship	
	Maxilla		Mandible			
	Mean	SD	Mean	SD	Mean	SD
Position (deviation):						
Series 1	0.8 NS	0.8	–0.6 NS	0.9	–1.3 NS	1.3
Series 2	0.6 NS	0.9	–0.7 NS	1.0	–1.4*	1.1
Series 3	0.6 NS	0.9	0.2 NS	0.9	–0.1 NS	1.0
Series 4	0.8 NS	1.0	0.2 NS	1.1	0.0 NS	1.1
Change (displacement):						
Series 1–2	–0.2 NS	0.7	–0.1 NS	0.6	–0.1 NS	0.5
Series 1–3	–0.2 NS	0.7	0.8**	0.4	1.3*	0.9
Series 1–4	0.1 NS	0.4	0.8*	0.5	1.3*	1.1

Sample size = 6. Values are given in degrees. The variables are defined in Figure 2.
Zero mean: symmetry or no change. Negative values: ipsilateral deviation or displacement. Positive values: contralateral deviation or displacement.
NS: $P > 0.05$, *$P \le 0.05$, **$P \le 0.01$.

Table 3 Mandibular transverse displacement from the ICP (mm) assessed kinesiographically.

	Series 1		Series 2		Series 4	
	Mean	SD	Mean	SD	Mean	SD
Midpoint of rest area (ICP – MRA)	0.1 NS	0.6	0.1 NS	0.3	–0.3 NS	0.5
Splint position (ICP – SPL)	2.0*	1.8	1.4*	1.0	0.2 NS	0.7

Sample size = 6. NS: $P > 0.05$, *$P \le 0.05$.
ICP: intercuspal position. SPL: splint position. MRA: midpoint of rest area.
Negative values: ipsilateral displacement. Positive values: contralateral displacement.

molars had become normalized in two patients during the splint phase.

The kinesiographic registration (Table 3) showed that the rest area was still located directly below the ICP. With the splint, in the SPL, there was now a mean contralateral displacement of the mandible of 1.4 mm ($P < 0.05$) in relation to the ICP (Figure 3, SPL2).

On the transcranial radiographs with the splint, SPL (Table 4), the ipsilateral condylar head was displaced on average 2.0 mm forwards ($P < 0.001$) compared with the ICP, while the contralateral condylar head was displaced 0.7 mm forwards ($P < 0.05$). Thus, the forward displacement of the condylar head was now 1.3 mm greater ipsilaterally than contralaterally ($P < 0.05$).

Series 3, after the orthodontic treatment and retention

The unilateral crossbite in the ICP was eliminated on all tooth pairs in five subjects, while one subject still had a transverse cusp-to-cusp relationship on the first upper molars. On

Table 4 Sagittal displacement of the condylar head from the ICP to the SPL (mm) assessed from oblique transcranial TMJ radiographs.

Case no.	Ipsilateral displacement			Contralateral displacement			Difference (ipsilateral – contralateral)		
	Series 1	Series 2	Series 4	Series 1	Series 2	Series 4	Series 1	Series 2	Series 4
1	3.5	2.5	1.5	1.0	0.5	2.0	2.5	2.0	0.5
2	3.5	1.0	1.0	1.0	0.5	1.0	2.5	0.5	0.0
3	2.0	2.0	1.0	–1.5	0.5	0.0	3.5	1.5	1.0
4	1.5	2.0	1.0	0.0	1.5	0.5	1.5	0.5	0.5
5	0.0	1.5	1.5	–0.5	0.5	3.0	0.5	1.0	–1.5
6	4.0	3.0	2.0	–0.5	0.5	2.0	4.5	2.5	0.0
Mean	2.4*	2.0**	1.3***	0.1 NS	0.7***	1.4*	2.5*	1.3*	–0.1 NS
SD	1.5	0.7	0.4	1.0	0.4	1.1	1.6	0.8	0.9

Series 1: at the start of the diagnostic splint phase. Series 2: at the end of the diagnostic splint phase. Series 4: 1 year after expansion and retention. NS: $P > 0.05$; *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$. Positive values: forward displacement.

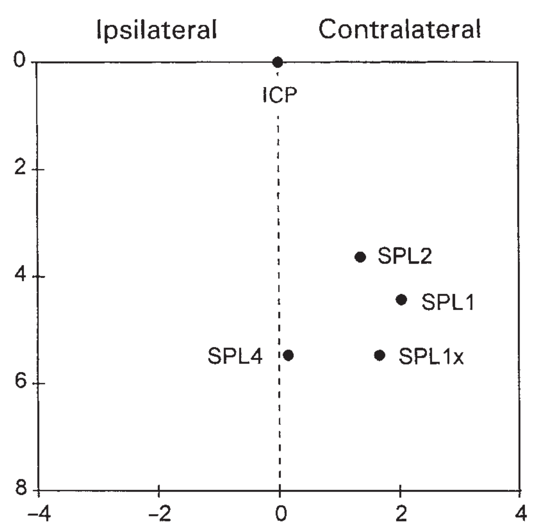

Figure 3 Average displacement of the mandibular central incisors (mm) from the intercuspal (ICP) to the splint (SPL) position assessed by kinesiography. Sample size = 6. SPL1: displacement immediately after the insertion of the reflex-releasing stabilizing splint at the beginning of the diagnostic period. SPL1x: displacement at insertion of the replacement splint (n = 3). SPL2: displacement after the period with a diagnostic splint. SPL4: displacement after expansion treatment and retention. Notice the gradual reduction of SPL-ICP displacement. The lower positions at SPL1x and SPL4 were due to the somewhat higher replacement splints used on these occasions.

Table 5 Intermolar dental arch widths measured on casts (mm).

	Maxillary first molars		Mandibular first molars	
	Mean	SD	Mean	SD
Series 1	41.2	2.7	40.8	1.9
Series 2	41.3	3.0	41.0	2.3
Series 3	44.8	2.6	41.7	2.6
Series 4	45.3	2.3	41.5	2.3
Changes:				
Series 1–2	0.2 NS	0.4	0.2 NS	0.4
Series 1–3	3.7***	1.0	0.8*	0.8
Series 1–4	4.2***	1.3	0.7*	0.5

Sample size = 6, NS: $P > 0.05$; *$P \leq 0.05$; ***$P \leq 0.001$.

average the widths of the dental arches (Table 5) had increased 3.7 mm ($P < 0.001$) in the maxilla and 0.8 mm ($P < 0.05$) in the mandible.

Assessed from the P-A radiographs (Table 2) the mandibular midpoint had been displaced on average 0.8 degrees contralaterally compared with the position before treatment ($P < 0.01$), and the transverse jaw relation had increased by 1.3 degrees ($P < 0.05$). The displacement from the ICP to the SPL could not be evaluated at this stage because the occlusal covering had been ground away by the end of the expansion phase.

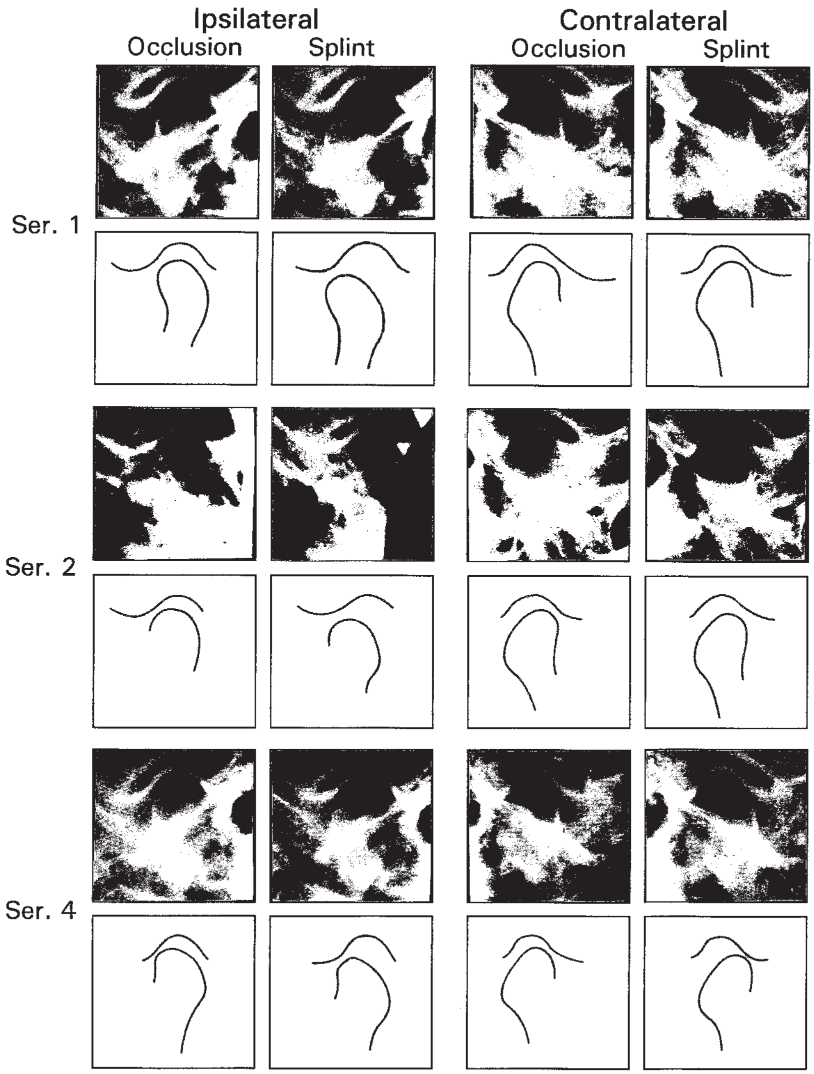

Figure 4 (a) Case No. 6. Displacement of the condylar head. Oblique transcranial TMJ radiographs of the joint structures in the intercuspal position and the splint position. Ipsilateral: crossbite side. Contralateral: non-crossbite side. Occlusion: ICP. Splint: SPL. Series 1: at the start of the diagnostic splint phase. Series 2: at the end of the diagnostic splint phase. Series 4: one year after expansion and retention.

Series 4, one year post-retention

The remaining crossbite in one subject was eliminated by 2 months' Quad-Helix treatment. After a control period without an appliance, lasting on average 11.6 months, the crossbite in the lateral regions remained eliminated in all patients. The widths of the dental arches (Table 5) had increased on average by 4.2 mm in the maxilla ($P < 0.001$) and by 0.7 mm in the mandible ($P < 0.05$).

Assessed on the P-A radiographs (Table 2), there was no mean change in the transverse location of the maxilla in relation to Series 1, but the mandible was displaced 0.8 degrees

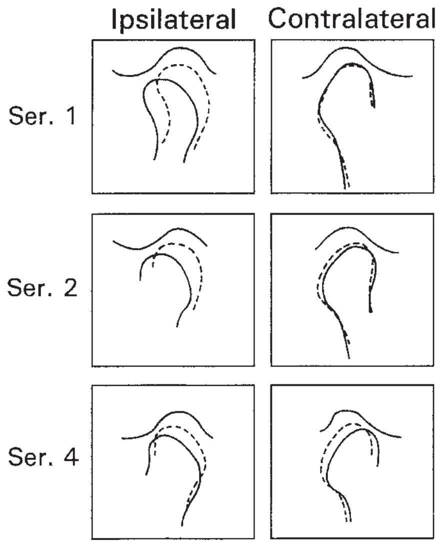

Figure 4 (b) Case No. 6. Condylar displacement from the intercuspal position (ICP: - - - - - -) to the splint position (SPL: ——). Tracings of radiographs in Figure 4(a) were superimposed by a method analogous to that used in structure-based cephalometric superimpositions (Björk and Skieller, 1983). (1) A cross serving as a fiducial marker was drawn on the first TMJ film. (2) The second TMJ film was superimposed on the first film using the anterior part of the external acoustic meatus, the articular fossa, and the articular tubercle as reference structures (Møller *et al.*, 1985). (3) The cross was copied onto the second film. (4) The crosses were included in the tracings (not shown) and were used for the superimposition.

($P < 0.05$) contralaterally in relation to Series 1, and the transverse jaw relation had increased by 1.3 degrees ($P < 0.05$) from –1.3 to 0.0 degrees.

The kinesiographic recording (Table 3) showed that the average transverse location of the resting area still did not deviate from the ICP. The displacement of the mandible from the ICP to the SPL was now eliminated (Figure 3, SPL4).

On the transcranial radiographs (Table 4) the forward displacement of the condylar heads in the SPL compared with the ICP was now the same on both sides (ipsilaterally 1.3 mm, $P < 0.001$, contralaterally 1.4 mm, $P < 0.05$). An example of the changes in position of the condylar heads in an individual case is shown in Figure 4a and b.

Discussion

The recruitment of subjects for this study was undertaken sequentially as the patients were admitted to the department. The selection was accordingly unbiased with regard to any previously determined morphological and functional criteria. The average craniofacial morphology showed a slightly reduced horizontal maxillary overjet, but did not otherwise differ significantly from the reference values.

A prerequisite for the treatment of crossbite is a clearly defined treatment goal, both functionally and morphologically. This calls for the definition of a basic paradigm for the functioning of the craniomandibular system. Some authors (Ingervall, 1964a,b, 1968; Hamerling, 1991) employ the functional treatment goal defined by Posselt (1952) that the ICP should be located about 1 mm anterior to the retruded contact position. The present study, however, is based on the paradigm defined by Møller (1981) that the masticatory apparatus functions best biologically when there is positional concordance between the ICP, defined as the position of maximum occlusal stability, and SP, defined as the position most suitable for the loading of the masticatory muscles and the temporomandibular joints.

In order to determine the functional treatment goal it was therefore first necessary to decide where the muscles would place the mandible transversely when the neural feedback from the contact relationships in the ICP had been reduced. This was carried out by means of a reflex-releasing stabilizing splint, which eliminated the neuromuscular guidance of the mandible into the ICP (Møller, 1981). The SPL thus acted as a guide to the functional treatment goal, the structural position (SP) of the mandible.

The present study showed clearly by kinesiographic recordings and TMJ radiographs, that the maximum transverse displacement of the mandible from the ICP to the SPL occurred immediately after insertion of the splint, even though it was used diagnostically for a period of 3–6 months. The use of a splint for several months to diagnose the SP does not seem to be necessary for the type of patients without symptoms or signs of TMD examined in this study.

The kinesiographic recordings further showed that the transverse location of the rest position cannot be used to determine the SP. In all the kinesiographic recordings the rest area was situated directly caudally to the ICP. Thus, these observations suggest that the splint position rather than the rest position should be used to determine the therapeutic position for the mandible. Consequently, the simplest way to establish the functional treatment goal and to control whether it has been achieved is to perform the treatment by an expansion plate, shaped as a reflex-releasing stabilizing splint.

The radiographic examination of the TMJs showed that the contralateral displacement of the mandibular midline on biting on the reflex-releasing splint was due to a significantly greater forward displacement of the ipsilateral than of the contralateral condylar head, since the ipsilateral condylar head showed a significant forward displacement when biting on the splint, while the contralateral condylar head did not show any significant sagittal change. Although the transcranial radiographs give only a rough indication of the condylar position, the fact that the locations of both condylar heads were similar and did not deviate from normal at the start of the study indicates that the original lateral displacement of the mandible when the crossbite arose, to a large extent, must have been compensated in the TMJs. This may have occurred through increased growth of the contralateral condyle, reduced growth of the ipsilateral condyle, a corresponding surface modelling in the articular fossae, or a combination of these factors (Woodside *et al.*, 1987; Bakke and Paulsen, 1989).

Due to the longitudinal nature of the study, the changes in the parameters could be assessed individually for each patient. Despite the small sample size these changes were so unambiguous that the mean changes became statistically significant. Nevertheless, studies of a larger sample of subjects are warranted to cover the full range of biological variability in the unilateral posterior crossbite.

Conclusions

The changes in the functional shift of the mandible during treatment of unilateral posterior crossbite have not been studied previously. Despite the small sample size, the findings provide substantial indirect evidence that, in the patients studied, the functional shift and its correction were compensated by growth and surface modelling in the TMJs.

The use of a combined reflex-releasing splint and expansion plate led to a normalization of the occlusion in the functionally optimal position of the mandible. This manifested itself in that the transverse movement of the mandible from the ICP to the SPL did not differ significantly from zero, and that the forward displacement of the condyles when biting on the reflex-releasing splint was now the same on both sides. Presumably, a differentiated growth in the two TMJs during the treatment period had eliminated the former asymmetry.

The overall course of treatment in this study was of longer duration than traditional treatment with an expansion plate. This was mainly due to the research protocol. The normal treatment time would be considerably shorter, since the expansion phase can be started as soon as the appliance has been adapted into a reflex-releasing stabilizing splint.

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