European Journal of Orthodontics 28 (2006) 480–484
doi:10.1093/ejo/cjl014
Advance Access publication 13 June 2006

Reverse-sequencing chewing patterns before and after treatment of children with a unilateral posterior crossbite

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SUMMARY The aim of this study was to compare the percentage of reverse-sequencing chewing cycles in 22 children [9 boys and 13 girls; mean age ± SD, 8.6 ± 1.3 and 8.8 ± 1.5 years, respectively), with a unilateral right or left posterior crossbite, before and after therapy.

The chewing cycles were recorded using a kinesiograph while the subjects masticated a soft and a hard bolus on both the crossbite and non-crossbite side. Chewing data were acquired before and 6 months after orthodontic treatment of the crossbite with an orthodontic functional appliance, the 'Function Generating Bite'.

The results showed that, before therapy, the percentage of reverse-sequencing chewing cycles on the crossbite side was significantly higher than that on the normal side ($P < 0.001$) with both the soft and hard bolus. In addition, the percentage of reverse-sequencing chewing cycles on the crossbite side before therapy was significantly greater than after therapy with both a soft and hard bolus ($P < 0.001$). No significant differences were found in the percentage of reverse-sequencing chewing cycles on the non-crossbite side, before or after therapy, either with a soft or hard bolus.

Introduction

A posterior unilateral crossbite is considered a serious asymmetric malocclusion (Moller and Troelstrup, 1975; Pinto *et al.*, 2001; Bracco *et al.*, 2002; Harrison and Ashby, 2003). It may develop during eruption of the primary dentition and can involve the permanent dentition at a later stage of development. It may originate from a skeletal or dental malrelationship, or both, and may lead to a mandibular displacement (Daskalogiannakis, 2002).

It is well established that children with a unilateral posterior crossbite exhibit unusual chewing patterns when chewing on the affected side, and this is characterized by an increased frequency of reverse sequencing (Lewin, 1985; Ben-Bassat *et al.*, 1993; Brin *et al.*, 1996; Pinto *et al.*, 2001; Throckmorton *et al.*, 2001; Saitoh *et al.*, 2002). Usually, the mandible deviates laterally, towards the bolus side, and then, during closure, medially, through the trans-cuspal and intercuspal phases of mastication. In reverse sequencing, the mandible first deviates medially and then laterally, thus ensuring overlap of opposing dental occlusal surfaces (Figure 1). This reverse chewing pattern is dependent on central motor control.

Reverse-sequencing chewing cycles occur on the crossbite side only; this is the reason why a unilateral posterior crossbite is characterized by both dental and functional asymmetry. Moreover, this malocclusion occurs at an early stage in development and has a significant influence on the developing motor control of mastication in the central nervous system (Throckmorton *et al.*, 2001). Asymmetric masticatory function during growth has a biological impact on the growing structures and may lead to asymmetric anatomical structures (bones, temporomandibular joint, muscles, and teeth) on completion of growth. Such asymmetries may be prevented by orthodontic therapy at an early stage in development. (Enlow, 1986; Pirttiniemi *et al.*, 1990, 1991; Lam *et al.*, 1999; Nerder *et al.*, 1999; Santos Pinto *et al.*, 2001; Gazit-Rappaport *et al.*, 2003).

The aim of this study was to investigate the prevalence of reverse-sequencing chewing cycles in children with a unilateral posterior crossbite, when chewing on the crossbite and non-crossbite sides, before and after therapy.

Subjects and methods

Twenty-two children (9 boys, 13 girls; mean age ± SD, 8.6 ± 1.3 and 8.8 ± 1.5 years, respectively), with a posterior unilateral crossbite, were selected from patients referred to the Department of Orthodontics, University of Turin, Italy. Before entering the study, informed consent was obtained from all parents.

The inclusion criteria were as follows: a functional unilateral right or left posterior crossbite; mixed dentition; no signs or symptoms of dental or myofacial disorders; and no previous orthodontic therapy.

Each patient was treated with a functional appliance: the 'Function Generating Bite' (Figure 2; Bracco and Solinas, 1979; Castroflorio *et al.*, 2004). The appliances were

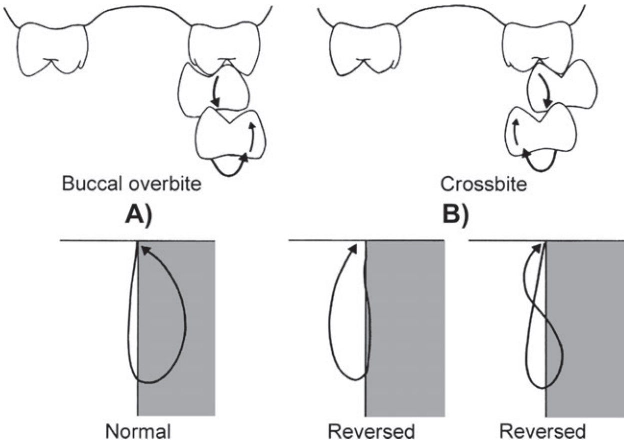

Figure 1 In subjects without a crossbite, the mandible, in the majority of chewing cycles, deviates to the bolus side on opening, especially if the bolus is known to offer resistance. It then moves medially on closure to approximate and traverse the opposing occlusal tooth surfaces during the close–open transition (above left). In subjects with a unilateral posterior crossbite, the sequence is reversed on the bolus side in order to facilitate opposition of the tooth surfaces during the close–open transition (above right). (Reproduced with the permission of Lewin 'Electrognathographics' and the Quintessence Publishing Co.)

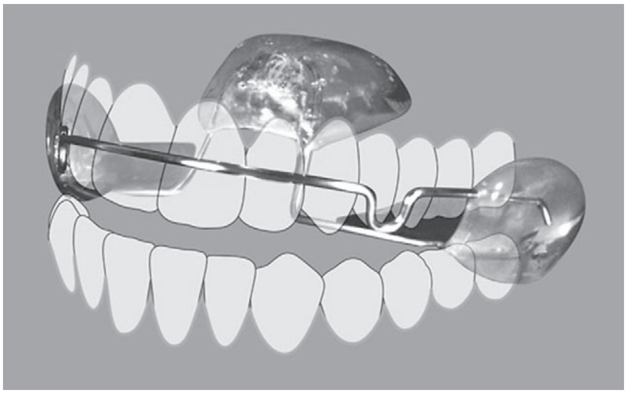

Figure 2 The Function Generating Bite appliance. The tooth cups compress the metalic bite plane which is made of a special resilient stainless steel. The resilience of the bite planes and the elasticity of the wires of the appliance permit the teeth to move slowly and gradually avoiding dental trauma.

individually manufactured and made of acrylic resin and resilient stainless steel, with posterior metallic bite planes preventing the teeth from intercuspal contact (Figures 3 and 4). At the end of treatment, the buccal cusps of the upper teeth, which were previously in crossbite, overlapped the lower teeth, thus providing the appropriate physiological stimuli from peripheral receptors and proprioceptors. The mean treatment time ± SD was 10.1 ± 8.9 months. The recordings of chewing cycles were carried out before treatment and after a retention period of 6 months.

The patients were instructed to chew a soft bolus (chewing gum) and then a hard bolus (wine gum), firstly non-deliberately and then deliberately on the right and left sides. The duration of each test was 10 seconds and each set was repeated three times.

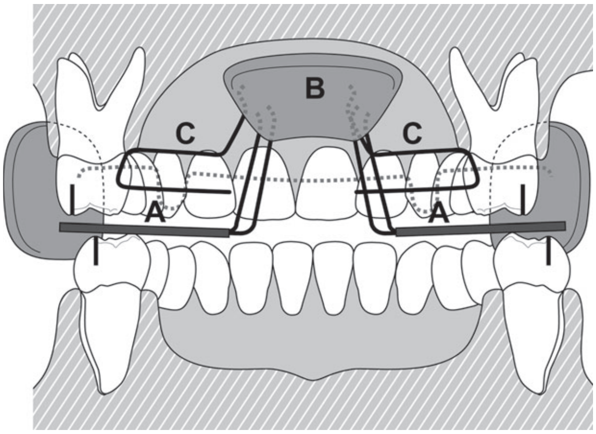

Figure 3 Schematic representation of the Function Generating Bite. (A) Posterior metallic bite planes (B) palatal resin plate, and (C) expansion spring.

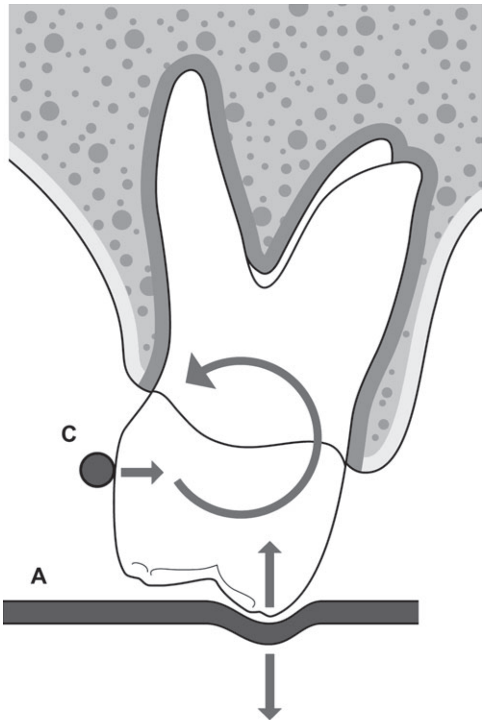

Figure 4 Schematic representation of the orthodontic movement which is the result of the action of the posterior metallic bite plane (A) and of the force of the expansion spring (C).

Mandibular movement was measured with a kinesiograph (K6-I, Myotronics Inc. Tukwila, Washington, USA) which measures jaw movements within an accuracy of 0.1 mm. Multiple sensors (Hall effect) in a lightweight array (4 oz) track the motion of a magnet attached to the midpoint of the lower incisors (Jankelson, 1980). The kinesiograph was interfaced with a computer for data storage and subsequent analysis.

The raw data were analysed using a customized program, the 'Chewing Cycles Analyser', developed at the University of Torino. This is based on the approximation of the chewing cycle using Bezier curves (Bezier, 1993; Piancino *et al.*, 2006). It divides the chewing cycles into clockwise and anti-clockwise movements depending on the vectorial direction of closure. Two portions of the curve are selected for both the opening and the closing phase. For the opening phase, two points, P1 and P2, are placed 0.5 and 2.5 mm, respectively, from the beginning of the cycle and, for the closing phase, points P3 and P4 are placed 4 and 2 mm, respectively, from the end of the cycle. The numerical integral of the closed curve delimited by P1, P2, P3, and P4 is then computed. The result of the integral is a number with a sign: its absolute value indicates the curve area and its sign the curve direction: if it is positive, the cycle is counter-clockwise and, if it is negative, the cycle is clockwise.

Statistical evaluation of the results was performed using Fisher's exact test and a two-sample Wilcoxon signed-rank test (Mann–Whitney) to evaluate differences between right and left crossbite chewing sequences. The proportion of reverse cycles was calculated for each subject before and after treatment and the difference in the matched pairs tested using a Wilcoxon signed-rank test.

Results

The results showed no statistically significant difference in the prevalence of reverse chewing sequences between the children with a right or left unilateral posterior crossbite, either with a soft or a hard bolus before therapy (Tables 1 and 2); pre- and post-treatment analyses were performed on the pooled sample.

A statistically significant difference was observed when the percentages of reverse-sequencing chewing patterns, on the crossbite and non-crossbite sides, before therapy, were compared. The percentage of reverse-sequencing chewing cycles was 41 per cent (0–96 per cent) for a soft and 66 per cent (0–98 per cent) for a hard bolus when chewing on the crossbite side and 5 per cent (0–31 per cent) for both a soft and a hard bolus when chewing on the non-crossbite side ($P < 0.001$; Table 3; Figure 5).

A statistically significant difference was found when comparing the percentage of reverse-sequencing chewing patterns before and after therapy on the crossbite side (Table 3). Before therapy, the percentage of reverse-sequencing chewing cycles was 41 per cent (0–96 per cent) when chewing a soft and 66 per cent (0–98 per cent) when chewing a hard bolus. After therapy, it was 7 (0–59; $P < 0.001$) and 5 (0–3; $P < 0.001$) per cent, respectively (Table 3; Figure 5).

No statistically significant difference was observed when the percentages of reverse-sequencing chewing cycles were compared before and after therapy during chewing on the non-crossbite side. Before therapy, the percentage of reverse-sequencing chewing cycles was 5 per cent for both a soft (0–57 per cent) and hard (0–37 per cent) bolus. After therapy, it was still 5 per cent for both a soft (0–38 per cent) and a hard (0–48 per cent; Table 3; Figure 5) bolus.

Table 1 Comparison between children with a right and left unilateral posterior crossbite malocclusion.

	Right crossbite (n = 14)	Left crossbite (n = 8)	
Male (%)	5 (35.7)	4 (50.0)	$P = 0.66$
Age (mean ± SD)	8.8 ± 1.5	8.2 ± 0.9	$P = 0.19$
Treatment time (mean ± SD)	11.7 ± 11	7.6 ± 3.6	$P = 0.89$
Number (%) of children with more than one tooth in crossbite	8 (57.1)	6 (75.0)	$P = 0.64$

Table 2 Comparison between the prevalence of a reverse-sequencing chewing pattern in children with a right and left unilateral posterior crossbite malocclusion.

	Right crossbite (n = 14)	Left crossbite (n = 8)	
Soft bolus (%)			
Before treatment crossbite side	42	32	$P = 0.68$
After treatment crossbite side	5	9	$P = 0.21$
Before treatment normal side	9	2	$P = 0.16$
After treatment normal side	5	4	$P = 0.45$
Hard bolus (%)			
Before treatment crossbite side	67	49	$P = 0.26$
After treatment crossbite side	2	8	$P = 0.16$
Before treatment normal side	5	5	$P = 0.17$
After treatment normal side	7	4	$P = 0.24$

Discussion

In this study, the chewing patterns of children with unilateral posterior crossbites were monitored before and after therapy. There have been no previous reports in the literature demonstrating a significant reduction in reverse sequencing after orthodontic therapy.

Before therapy, it was found that the percentage of reverse sequencing during chewing on the crossbite side was significantly higher than that on the unaffected side. This was expected and has been confirmed in previous studies (Lewin, 1985; Ben-Bassat *et al.*, 1993; Brin *et al.*, 1996; Pinto *et al.*, 2001; Throckmorton *et al.*, 2001; Saitoh *et al.*, 2002).

Some authors have evaluated the prevalence of reverse-sequencing chewing cycles after dental correction of a unilateral posterior crossbite. Ben-Bassat *et al.* (1993) showed that successful treatment of a unilateral crossbite, with palatal expansion, did not eliminate the reverse-sequencing chewing cycles. Throckmorton *et al.* (2001), evaluated masticatory cycles in children treated with rapid palatal expansion but did

Table 3 Proportion of reverse-sequencing chewing cycles in subjects with a unilateral posterior crossbite malocclusion before/after treatment on the crossbite and non-crossbite sides.

	Crossbite side (%)	Non-crossbite side (%)	
Soft bolus			
Before treatment	41 (0–96)	5 (0–57)	*P* = 0.0003
After treatment	7 (2–59)	5 (0–38)	*P* = 0.1011
	P = 0.0003	*P* = 0.6606	
Hard bolus			
Before treatment	66 (0–98)	5 (0–37)	*P* = 0.0003
After treatment	5 (0–31)	5 (0–48)	*P* = 0.9899
	P = 0.0001	*P* = 0.6142	

not obtain a reduction in the reverse-sequencing chewing pattern. They speculated that the reverse sequencing persists after dental correction of a unilateral posterior crossbite because this malocclusion develops during eruption of the primary dentition and has an influence on the developing central pattern generator, establishing the reverse-sequencing type of chewing pattern which is then resistant to change.

The results of the present study show that the percentage of reverse-sequencing chewing cycles, during chewing on the crossbite side, significantly reduced after therapy, suggesting that not only the anatomical dental relationship but also the function, were restored (Figure 5 and 6).

No significant differences were found for the non-crossbite side following treatment.

Masticatory movements are characterized by rhythmicity and a diversity of patterns of jaw posture. Yoshino *et al.* (1999) suggested that the primary motor cortex may be involved in the initiation and control of jaw movements and that the ventral pre-motor cortex may be involved in preparation for motoneurones and play a role as a higher order motor area related to the initiation and control of jaw movements (Onozuka *et al.*, 2002; Takada and Miyamoto, 2004).

The cortex signals the collection of neurones in the brain stem which elaborate different patterns of mastication in response to variations in inputs from the masticatory cortex and from the periphery (Katoh *et al.*, 1982; Enomoto *et al.*, 1987). Sensory receptors, such as muscle spindles, periodontal, and even intradental pressure receptors, exert strong influences on the chewing pattern being generated by the central pattern generator, eventually modifying both the frequency of motor neurone bursts and their intensity (Lund *et al.*, 1999).

Inputs from mechanoreceptors are critical, not only for various trigeminal reflexes such as the jaw-opening reflex or the periodontal-masseter reflex but also for masticatory control (Ishii *et al.*, 2002; Johnsen and Trulsson, 2003).

The oral environment, after orthodontic tooth movement, is different, and changes occur in the sensory inputs. In particular, stimuli from the molar mechanoreceptors may be important: the appliance used in this study prevents the upper and lower teeth from potentially opposing occlusal contacts by using stainless steel 'resilient' bite planes (Figures 3 and 4) and controls the static and dynamic posture of the mandible. It is therefore hypothesized that the peripheral receptors and proprioceptors play an important role in the reorganization of a new cortical chewing motor network.

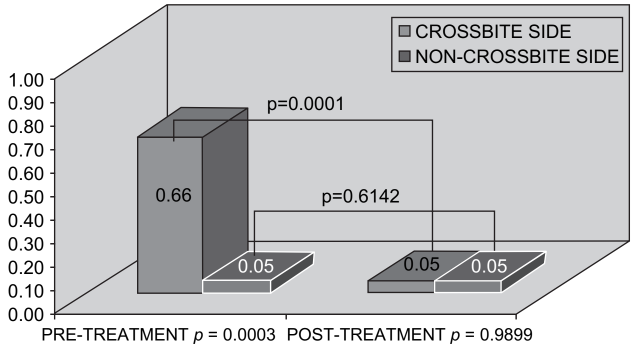

Figure 5 Comparison of the proportion of reverse-sequencing chewing cycles pre- and post-treatment in children with a unilateral posterior crossbite: during chewing of a hard bolus on the crossbite side and on the non-crossbite side.

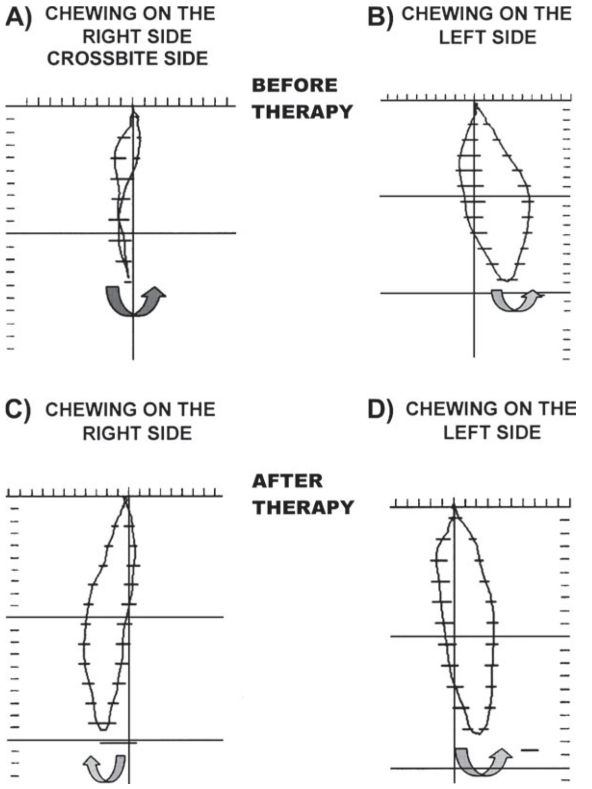

Figure 6 Chewing pattern of one patient with a right-sided crossbite. Deliberate chewing (A) crossbite side and (B) non-crossbite side before therapy. (C) Post therapy: previous crossbite side and (D) non-crossbite side. x- and y-axis are in millimetres. The mean and standard deviation are represented by the horizontal lines.

Conclusions

This study investigated the prevalence of the reverse-sequencing chewing cycles in children with a unilateral posterior crossbite before and after therapy. The results showed the following.

1. Before therapy, the percentage of reverse-sequencing chewing cycles, on the crossbite side, was significantly higher than that on the unaffected side ($P < 0.001$) with both a soft and hard bolus.
2. After therapy, the percentage of reverse-sequencing chewing cycles on the crossbite side was significantly decreased with both a soft ($P < 0.001$) and a hard ($P < 0.001$) bolus.
3. No significant differences were found in the percentage of reverse-sequencing chewing cycles on the non-crossbite side, before or after treatment, either with a soft or hard bolus.

It is of clinical relevance, for successful orthodontic therapy, to consider not only the repositioning of teeth within the dental arches but also the effects of therapy on function. The latter can readily be determined using electrognathography.

Further investigations are required to establish a deeper understanding of these phenomena, as our knowledge of the motor control neurophysiology improves.

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Acknowledgement

The authors are grateful to Dario Farina of the Center for Sensory-Motor Interaction, Aalborg University, for technical assistance.

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