

Reverse-sequencing chewing patterns evaluation in anterior versus posterior unilateral crossbite patients

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SUMMARY It is well established that patients with a unilateral posterior crossbite exhibit reverse-sequencing chewing patterns when chewing on the affected side. The aim of the study was to compare the prevalence of reverse-sequencing chewing cycles in patients with anterior versus posterior unilateral crossbite during chewing soft and hard boluses. Eighty-six children (39 boys, 47 girls) were included in the study: 26 (10.4 ± 2.7 years) with unilateral anterior crossbite, 43 (10.2 ± 4.2 years) with unilateral posterior crossbite, and 17 (10.6 ± 2 years) with normal occlusion were selected for the study. Mandibular movements were measured with a kinesiograph (K7, Myotronics Inc. Tukwila). The kinematic signals were analyzed using custom-made software. The results showed a low prevalence of reverse-sequencing chewing cycles in patients with anterior crossbite, without any significant difference between sides and with the control group, with both soft ($P = 0.33$) and hard ($P = 0.29$) bolus. The patients with posterior unilateral crossbite showed a significant higher prevalence of reverse-sequencing chewing cycles during chewing on the crossbite side with respect to the non-crossbite side ($P < 0.001$) and to the control group ($P < 0.001$). Comparing the patients with anterior versus posterior unilateral crossbite, a significant difference ($P < 0.001$) in the prevalence of reverse chewing cycles was demonstrated during chewing on the posterior crossbite side only with both soft and hard bolus. In conclusion, patients with anterior versus posterior unilateral crossbite show different functional characteristics depending on which dental region is involved.

Introduction

Crossbite is a common malocclusion developing at an early stage of growth. It may involve the anterior and/or the posterior regions of the dental arches.

The posterior unilateral crossbite has been defined as: ‘a malocclusion in which one or more deciduous or permanent posterior upper teeth occlude in an abnormal buccal–palatal relationship with their corresponding lower teeth’ (Daskalogiannakis and Miotti, 2001). It has been classified by Björk considering different regions of the occlusion and has been defined as ‘a malocclusion in the canine, premolar, and molar regions, characterized by the buccal cusps of the maxillary teeth occluding lingually to the buccal cusps of the corresponding mandibular teeth’ (Björk *et al.*, 1964). The prevalence of unilateral posterior crossbite ranges from 8 to 16% (Thilander *et al.*, 1984; Harrison and Ashby, 2008; Perillo *et al.*, 2010).

It is well established that patients with a unilateral posterior crossbite exhibit reverse-sequencing chewing patterns when chewing on the affected side only. Reverse-sequencing chewing patterns are dyskinetic cycles characterized by a reverse direction of closure and a severely unbalanced muscular activation (Lewin, 1985; Ben-Bassat *et al.*, 1993;

Throckmorton *et al.*, 2001; Sonnesen and Bakke, 2007; Piancino *et al.*, 2006, 2009; Sever *et al.*, 2010). This serious functional asymmetry may be prevented by orthodontic therapy at an early stage in development (Pirttiniemi *et al.*, 1990, 1991; Lam *et al.*, 1999; Nerder *et al.*, 1999; Thilander and Lennartsson, 2002; Piancino *et al.*, 2006, 2008, 2010).

Anterior unilateral crossbite might be, incorrectly, considered a similar malocclusion, involving a different area of the occlusion: the incisal region. It has been defined as: ‘a malocclusion in which one or more deciduous or permanent lower incisors are vestibular to the corresponding upper teeth (one or more upper incisors are palatal to the corresponding lower teeth) in habitual occlusion’ (Daskalogiannakis and Miotti, 2001).

There are not studies dedicated to the masticatory function evaluating reverse chewing cycles on crossbite and non-crossbite sides, with both soft and hard boluses of patients with this malocclusion.

The interest in this study stems from the fact that each region of the occlusion plays a very different functional role; for this reason, the dental arches have been divided into two main regions, anterior and posterior, for the dynamic control of the mandible (Slavicek, 2002).

The anterior region involves canines and incisor teeth and is dedicated to the sensory control of the mandibular posture; the posterior region involves molars and premolars teeth and is dedicated to grinding and to the support of the occlusion during different functions, especially mastication.

In the upper and lower arch, the functional subdivision is the same, except for the first lower premolar, which is functionally included in the anterior region in the lower arch, and in the posterior region in the upper arch. In agreement with Slavicek (2002), the anterior region of the dental arches is to be considered an 'organ of control and guidance': most of the tactile contacts take place on the functional lingual surface of the upper incisors while the upper canines are laterotrusive sliding areas, protecting the posterior teeth.

The functional role and aim of the posterior region of the dental arches is very different from the anterior one; the posterior regions are dedicated to the grinding of the bolus and are able to support the forces of mastication, swallowing and occlusion.

These functional considerations are supported by the physiology of the periodontal mechanoreceptors that show a different sensitivity of the periodontal afferents innervating anterior and posterior teeth (Johnsen *et al.*, 2007; Figure 1A and 1B).

The subdivision in different functional regions of the occlusion is the gnathologic definition of the organic occlusion.

Reverse chewing cycles are highly represented in posterior crossbite malocclusions during chewing on the crossbite side.

In this study, we investigated the prevalence of reverse chewing cycles in patients with anterior and posterior crossbite to establish if the different functional roles of the anterior and posterior regions of the occlusion result in a different masticatory function.

The aim of the study was to compare the prevalence of reverse-sequencing chewing cycles in patients with anterior versus posterior unilateral crossbite, during chewing soft and hard boluses on the crossbite side and on the non-crossbite side, to evaluate the effect on masticatory function of a malocclusion involving different regions of the occlusion. The clinical outcome of this study is the estimation of the masticatory function asymmetry.

Subjects and methods

Eighty-six children (39 boys, 47 girls) were included in the study and subdivided as follows: 26 children (10 boys, 16 girls; mean age \pm SD, 10.9 ± 3.3 and 10.4 ± 2.7 years, respectively) with unilateral anterior crossbite, 43 children (22 boys, 21 girls; mean age \pm SD, 10.2 ± 4.2 and 10.1 ± 2.8 years, respectively) with unilateral posterior crossbite, and 17 children (7 boys, 10 girls; mean age \pm SD, 12.2 ± 2.9 and 10.6 ± 2.0 years, respectively) with normal occlusion were selected among

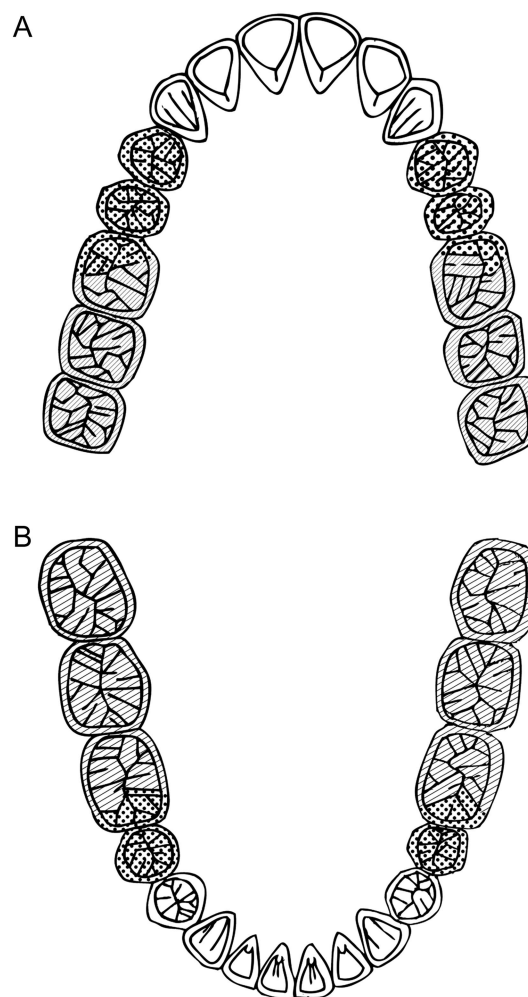


Figure 1 Anterior and posterior functional region of the dental arches. (A) Upper arch; (B) lower arch. The only difference between the upper and lower arch is the first premolar that, in the lower arch, is functionally included in the frontal group.

patients referred to the Orthodontic Department of the University of Turin, Italy, in the period from September 2008 to September 2010. Before entering the study, informed consent was obtained from all the patients' parents.

The inclusion criteria for the patient group were as follows: (i) unilateral anterior crossbite for the anterior crossbite group, (ii) unilateral posterior crossbite for the posterior crossbite group, and (iii) mixed dentition. The exclusion criteria were the presence of (i) any previous orthodontic therapy, (ii) any signs or symptoms of dental or myofascial pain, (iii) any signs or symptoms of cranio-mandibular disorders, and (iv) any prosthesis.

The control group was strictly selected for normal occlusion and mixed dentition and was matched with the patient group for age and gender.

The recordings of the chewing cycles were carried out for all the patients and the subjects of the control group. The

patients were comfortably seated on a chair. They were asked to fix their eyes on a target on the wall, 90 cm directly in front of their seating position, avoiding movements of the head. The recordings were performed in a silent and comfortable environment. Each recording began in maximal intercuspation position. The patients were asked to find this starting position by lightly tapping their opposing teeth together and clenching. They were asked to hold this position with the test bolus on the tongue, prior to starting the recording. The patients were instructed to chew a soft bolus (chewing gum) and then a hard bolus (wine gum), deliberately on the right and left sides. The duration of each test was 10 s and each set was repeated three times. The side of mastication was visually checked by an operator. The soft bolus was a piece of chewing gum and the hard bolus was a wine gum, with the same size (20 mm in length, 1.2 mm in height, and 0.5 mm in width) but different weights (2 g for the soft bolus and 3 g for the hard bolus). The wine gum was chosen to provide a rubber-like resistance without sticking the teeth.

Mandibular movements were measured with a kinesiograph (K7, Myotronics Inc. Tukwila, Washington, USA) which measures jaw movements within an accuracy of 0.1 mm.

Multiple sensors (Hall effect) in a light-weight array (113 g) tracked 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 kinematic signals were analyzed using custom-made software (Department of Orthodontics and Gnathology, Dental School, Turin University, Italy). The first cycle, during which the bolus was transferred from the tongue to the dental arches, was excluded from the analysis. The chewing cycles were divided into non-reverse and reverse, based on the vectorial direction of closure.

Statistical evaluation of the results was performed using a Student's *t*-test. Significance was set at $P < 0.01$. The proportion of reverse cycles was calculated for each subject.

Results

The results showed that

- In the unilateral anterior crossbite group, the prevalence of reverse chewing cycles on the crossbite side (9% with soft bolus, 8% with hard bolus) was not significantly different from that on the normal side (7% with soft bolus, 13% with hard bolus) with both the soft ($P = 0.33$) and hard ($P = 0.29$) bolus.
 - In the unilateral posterior crossbite group, the prevalence of reverse chewing cycles during chewing on the crossbite side (55% with soft bolus, 72% with hard bolus) was significantly higher than that on the normal side (13% with soft bolus, 13% with hard bolus) with both the soft and hard bolus ($P < 0.001$).
 - In the control group, there was not a significant difference in the prevalence of reverse-sequencing cycles comparing right (3% with soft bolus, 9% with hard bolus) and left (9% with soft bolus, 7% with hard bolus) sides of mastication, with both soft ($P = 0.02$) and hard ($P = 0.47$) bolus.
 - Comparing patients with unilateral anterior versus posterior crossbite, the prevalence of reverse chewing cycles during chewing on the crossbite side was significantly higher for the patients with posterior crossbite, with both the soft and hard bolus ($P < 0.001$).
- No statistically significant difference was observed in the prevalence of reverse-sequencing chewing cycles during chewing on the non-crossbite side, both with soft ($P = 0.09$) and hard bolus ($P = 0.18$; Figure 2A and 2B).
- Comparing patients with unilateral anterior crossbite with control group, the prevalence of reverse-sequencing chewing cycles did not show any statistically significant difference (anterior crossbite group, crossbite side, versus control group: soft bolus ($P = 0.84$), hard bolus ($P = 0.81$); anterior crossbite group, normal side, versus control group: soft bolus ($P = 0.08$), hard bolus ($P = 0.50$)).
- Comparing patients with unilateral posterior crossbite with control group, the results showed a significant difference comparing the prevalence of reverse-sequencing chewing cycles during chewing on the crossbite side, versus control group, for both soft and hard bolus ($P < 0.001$); the comparison during chewing on the non-crossbite side, versus control group, did not show any difference for both soft ($P = 0.03$) and hard bolus ($P = 0.42$).

Discussion

In this study, we compared the prevalence of reverse-sequencing chewing cycles, during chewing on crossbite and non-crossbite side, with soft and hard boluses, in a group of patients with anterior versus posterior unilateral crossbite and in a control group. There are no studies evaluating the percentage of reverse-sequencing chewing cycles on crossbite and non-crossbite side, with soft and hard boluses. The clinical importance of this study is the estimation of the functional asymmetry in the considered malocclusions.

The results showed a low prevalence of reverse-sequencing chewing cycles in patients with anterior crossbite, without any significant difference between sides with both soft and hard bolus. The same result was obtained from the control group. The results of the group of patients with posterior unilateral crossbite, in agreement with the literature (Piancino *et al.*, 2006, 2009, Sever *et al.*, 2010, Throckmorton *et al.*, 2001), showed a higher prevalence of reverse-sequencing chewing cycles during chewing on the crossbite side with respect to the non-crossbite side. Comparing the patients with anterior and posterior unilateral crossbite, a significant difference in the prevalence of reverse chewing cycles was demonstrated during chewing on the crossbite side with both soft and hard boluses.

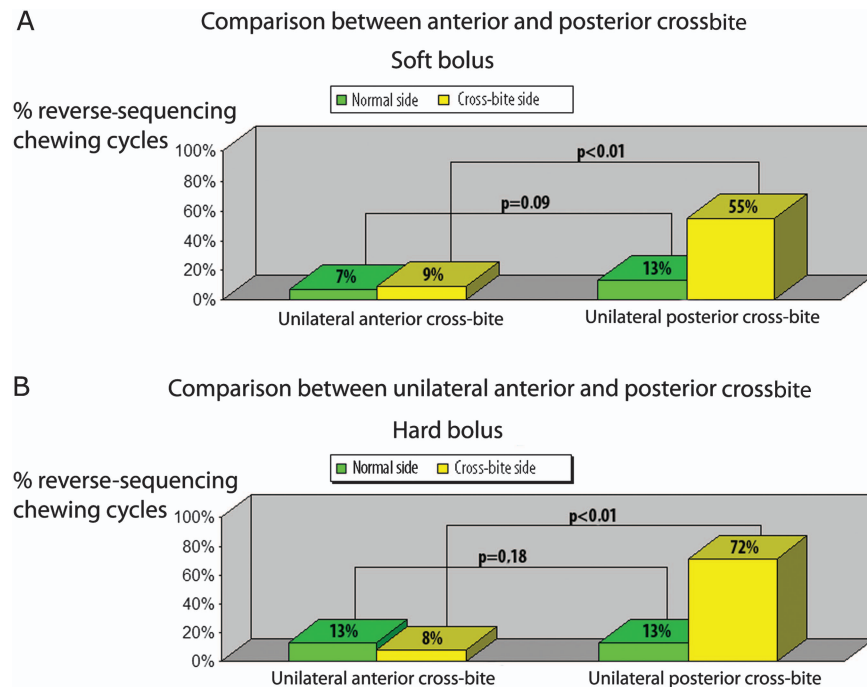


Figure 2 Comparison of the proportion of reverse-sequencing chewing cycles in children with unilateral anterior versus posterior crossbite: during chewing a soft bolus (A) and a hard bolus (B) on the normal side and on the crossbite side.

Reverse chewing cycles are highly dyskinetic patterns characterized by a reverse direction of closure and by alterations of both the kinetic pattern and the neuromuscular activation. Chewing cycles are related to a dental malocclusion and they are clearly associated with the unilateral posterior crossbite (Throckmorton *et al.*, 2001; Piancino *et al.*, 2006). Specifically, this means that during chewing on the crossbite side, a high percentage of chewing cycles is reversed. Usually the mandible deviates laterally, towards the bolus side, and then, during closure, medially, through the trans-cuspal and intercusp phases of mastication. In reverse sequencing, the mandible first deviates medially and then laterally, thus ensuring the overlap of opposing dental occlusal surfaces: one reason for the reverse sequencing is to facilitate the opposition of the tooth surfaces during the close/open transition to grind the bolus. The central motor control programs the reverse pattern on the crossbite side to establish the most efficient chewing cycles when the molar relationship is 'reverse'. On the non-crossbite side, the number of reverse chewing cycles is negligible: the central motor control programs a normal pattern which is the most convenient to crush the bolus in conditions of normal occlusion. The result is a severe asymmetry of the kinetic pattern and electromyographic activity between sides.

One of the main problems of posterior unilateral crossbite is the serious functional asymmetry that is established from a very early stage in development. During growth, asymmetrical masticatory function has a biological impact on the growing structures and may lead to irreversible asymmetric anatomical

structures (bones, temporomandibular joint, muscles, and teeth) on completion of growth. There is a good indication to prevent such asymmetries by functional orthodontic therapy at an early stage in development (Figure 3).

Considering the anterior regions of the dental arches, we know that they are dedicated to biting and controlling the mandibular position in the space, but not to the bolus crushing. When an anterior crossbite occurs and the posterior teeth show a normal relationship in the frontal plane, the reverse chewing cycles are not useful, from a functional point of view. The low percentage of reverse sequencing chewing cycles on both sides of patients with anterior crossbite was an original and expected result based on the functional knowledge of the organic occlusion previously described (Figure 4). This study confirms the different functional roles of the posterior and anterior region of the occlusion.

In conclusion, it is confirmed that patients with anterior versus posterior unilateral crossbite show different functional characteristics depending on which dental region is involved. Even if the influence on reverse chewing cycles of the unilateral anterior crossbite is not as important as that of the posterior crossbite, we know that the anterior guidance is altered involving the growth of the mandible. The last is an important reason for early treating children with anterior, as well as children with posterior unilateral crossbite especially when there is an anterior or lateral sliding of the mandible due to a premature contact between the upper and lower teeth. The detection of a premature

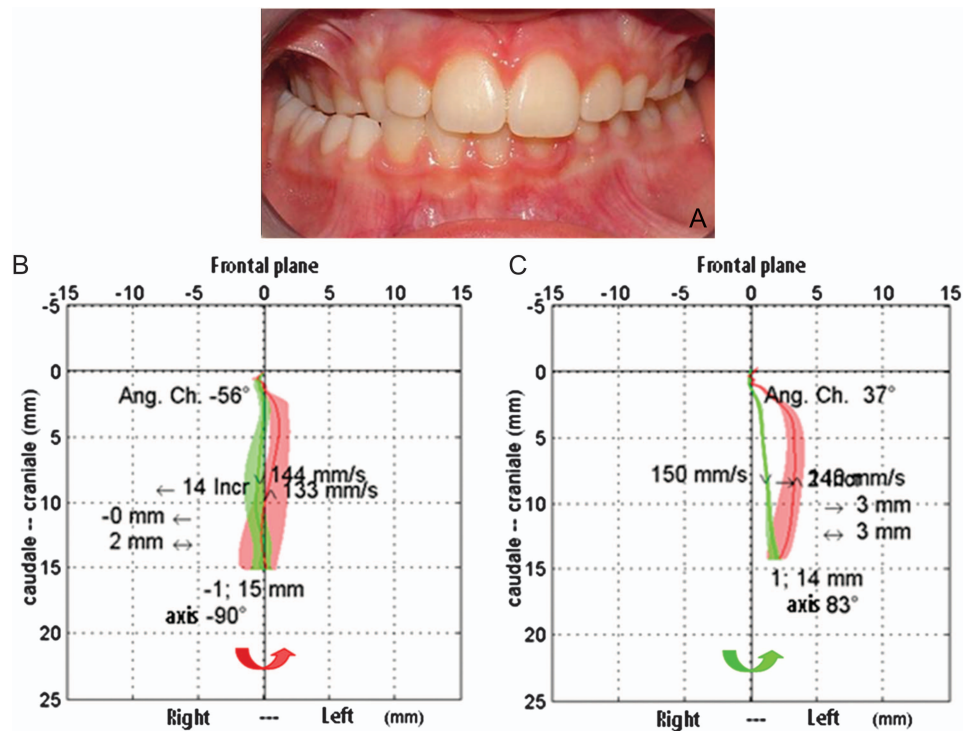


Figure 3 Right unilateral posterior crossbite occlusion (A), reverse-sequencing chewing cycles during chewing a hard bolus on the crossbite side (B), and chewing cycles with normal direction of closure during chewing on the non-crossbite side (C). In the frontal plane, the masticatory pattern is seriously asymmetric; such functional asymmetry should be prevented by early functional therapy.

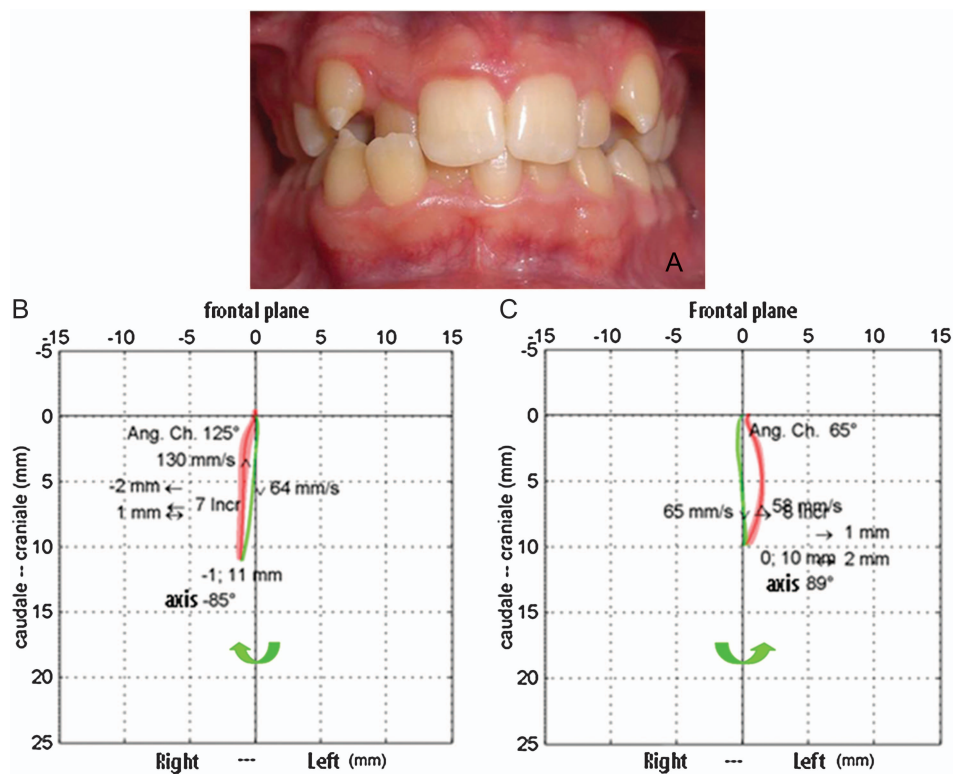


Figure 4 Right unilateral anterior crossbite occlusion (A), chewing cycles during chewing a hard bolus, with normal direction of closure on both the crossbite side (B), and the normal side (C).

contact is important to early treat the malocclusion avoiding, as soon as possible, local and general side effects on the motor control and on the bone growth of the mandible.

Further studies are necessary to understand more deeply the masticatory function of patients with crossbite.

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