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Relationship between masticatory cycle morphology and unilateral crossbite in the primary dentition

Ecijo Sever*, Ljubo Marion* and Maja Ovsenik**
Departments of *Fixed Prosthodontics and **Orthodontics, Medical Faculty, University of Ljubljana, Slovenia

Correspondence to: Maja Ovsenik, Department of Orthodontics, Medical Faculty, University of Ljubljana, Hrvatski trg 6, 1000 Ljubljana, Slovenia. E-mail: maja.ovsenik@dom.si

SUMMARY Occlusion is an important factor that affects chewing. Unilateral posterior crossbites (UPXBs) have been reported to be one of the most prevalent malocclusions in the primary dentition and patients with UPXBs show abnormal condylar motion on the crossbite side in the mediolateral direction during mastication. The aims of this study were to investigate the characteristics of common chewing cycles in the primary dentition in children with UPXBs, when chewing gum on the UPXB side and on the non-UPXB side, and to compare the average chewing pattern with a group of children with a normal buccal relationship.

Twenty children in the primary dentition with a UPXB (6 boys, mean age 5.3 ± 1.2 years, and 14 girls, 4.8 ± 1.3 years of age; 9 with a left and 11 with a right UPXB) and 10 children with a normal occlusion were randomly selected. Chewing movements were recorded with the Sirognathograph computer analysing system (COSIG II). All children were asked to chew gum on both sides. The chewing patterns were averaged and analysed in two projection planes and compared using a Student´s *t*-test with respect to the relationship between chewing pattern and occlusion. Significance was set at $P \leq 0.05$.

Children with a UPXB showed a difference between the chewing pattern on the UPXB and non-UPXB sides. Greater lateral deviation in the chewing cycle was observed on the working side when chewing on the non-UPXB side. The closing angle was found to be more pronounced towards the non-working side when chewing on the UPXB side and the time spent in maximal intercuspation showed reduced values when chewing on the same side. Children with a UPXB opened their mouths wider and showed greater chewing cycles in the sagittal and horizontal projection planes while chewing on the UPXB side and also in the frontal projection while chewing on both the UPXB and the non-UPXB sides in comparison with the control group, $P \leq 0.05$. Children with a UPXB produced chewing cycles with a shorter rest position and more frequently in a reverse direction when chewing on the UPXB side in comparison with children with a normal occlusion and with the non-UPXB side.

Based on the results of this study, early treatment is recommended to normalize the masticatory chewing cycle pattern to ensure normal growth and development of the orofacial system.

Introduction

Unilateral posterior crossbites (UPXBs) have been reported to be one of the most prevalent malocclusions of the primary dentition in Caucasian children (Larsson *et al.*, 1992; Øgaard *et al.*, 1994; Bishara *et al.*, 2006) that may lead to craniofacial asymmetry if left untreated (Melsen *et al.*, 1979; Pirttiniemi *et al.*, 1990; Kurol and Berglund, 1992; Sonnesen *et al.*, 2001; Thilander and Lennartsson, 2002; Ovsenik *et al.*, 2004, 2007). A UPXB may originate from a skeletal or dental malrelationship, or both, and may lead to mandibular displacement. It has also been suggested that the later crossbites are treated, the greater the risk of damage to the temporomandibular joint (TMJ; Pirttiniemi *et al.*, 1990; Sonnesen *et al.*, 2001; Kurol, 2006). Moreover, children with a UPXB show abnormal condylar motion during mastication on the crossbite side in the mediolateral direction. Many studies have shown a high susceptibility to TMJ disc displacement and temporomandibular disorders in such patients. It is suggested that there is greater and more frequent occlusal loading in such patients than in those with a normal occlusion (Miyawaki *et al.*, 2004).

Children with a UPXB exhibit an abnormal chewing pattern when chewing on the affected side, which is characterized by an increased frequency of reverse-sequencing chewing (Lewin, 1985; Brin *et al.*, 1996; Piancino *et al.*, 2007). Usually, the mandible deviates laterally, towards the bolus side, and then, during closure, medially, through the transcuspal and intercuspal phases of mastication. In reverse sequencing, the mandible first deviates medially, then laterally, thus ensuring overlap of opposing dental occlusal surfaces. This reverse chewing pattern is dependent on the central motor system (Mongini *et al.*, 1986; Jankelson, 1990; Piancino *et al.*, 2007).

Masticatory jaw movements are mainly affected by food characteristics and occlusion. The occlusal factors include: classification, overbite, and overjet in the intercanine and transcanine region, inclination of the occlusal plane and steepness of occlusal guidance, occlusal facets of the posterior teeth, and the relationship between the maxillary and mandibular posterior teeth in the lateral mandibular position (Nishio *et al.*, 1988; Kang *et al.*, 1991).

The duration of different phases of the chewing cycle can be affected by occlusal wear, gender, age, bolus size, and changes in occlusal guidance (Salsench *et al.*, 2005). This malocclusion occurs at an early stage of dental development and has a significant influence on the developing motor control of mastication in the central nervous system (Jankelson, 1990; Throckmorton *et al.*, 2001; Piancino *et al.*, 2007).

There are many investigations confirming the reverse sequence chewing pattern in UPXB patients using different kinematic devices (Ben-Bassat *et al.*, 1993; Brin *et al.*, 1996; Throckmorton *et al.*, 2001; Warren *et al.*, 2001; Neto *et al.*, 2007; Piancino *et al.*, 2007), mostly performed in the mixed dentition period to evaluate the success of interceptive treatment (Neto *et al.*, 2007; Piancino *et al.*, 2007).

The standard chewing pattern in male and female subjects in the permanent dentition has been previously determined using the computer analysing system, COSIG II (Sever *et al.*, 1997; Sever 2003; Sever and Marion, 2005).

As a unilateral functional crossbite develops early during growth and development of the dentition, the muscles, jaws, and face could be affected. Most studies on UPXB chewing cycle morphology have concentrated mainly on the affected side; however, the non-UPXB side could also be involved because of the compensatory movements while chewing on the UPXB side.

As there have been no reports in the literature evaluating chewing cycle morphology in UPXB children on the affected and non-affected site using the COSIG II system (Marion *et al.*, 1990; Ahlin *et al.*, 1992), the aims of this study were to investigate the characteristics of chewing cycles in the primary dentition in children with a UPXB, when chewing gum on the UPXB and on the non-UPXB side, and to compare the chewing pattern with a group of children in the primary dentition without a UPXB.

Subjects and methods

Twenty children, 9 with a left and 11 with a right UPXB (Figure 1), were selected from the Pedodontic Clinic in Kranj, Slovenia (6 boys, mean age 5.3 ± 1.2 years, and 14 girls, mean age 4.8 ± 1.3 years). A UPXB was diagnosed when two or more posterior teeth were in crossbite. From the nearby nursery in Kranj, 10 children (5 boys, mean age 5.3 ± 1.3, and 5 girls, mean age 5.1 ± 0.9) with a normal occlusion in the primary dentition were randomly selected

Figure 1 Unilateral posterior crossbite on the right side in a 5-year-old child in the primary dentition.

and included in the study as the control group. The selection criteria for the control group were, in addition to age and gender, the same socio-economic status and same geographical area as the UPXB children. The children showed no signs or symptoms of dental or myofacial disorders. Informed consent for the study was obtained from all the parents and confirmed by the Ethics Committee at the Medical Faculty, University of Ljubljana. Chewing pattern morphology was observed using the method described by Lewin (1985).

Each child was asked to sit in an upright position on a wooden chair with no ferromagnetic material to prevent interference with the magnetic field. To achieve craniofacial stability, a padded headband connected to the chair was used. The headset of the Sirognathograph (Siemens AG, Bensheim, Germany) was then aligned with the bipupillary line and the Frankfort horizontal plane in such a way that the magnet remained equidistant from the left and right sensors (Figure 2). The magnet was attached to the labial surface of the mandibular first primary incisors with carboxylate cement (Durelon; 3M Espe AG, Seefeld, Germany) so as not to interfere with central occlusion or function (Figure 3).

During the examination, all the children were instructed to chew a soft bolus made of chewing gum (Orbit Ca; Wrigley, Unterhaching, Germany), non-deliberately first on the left side for 20 seconds and then on the right side for the same period of time. Jaw movements were recorded using the Sirognathograph and the pattern of the chewing sequence was measured for spatial and temporal variables. Eight magnetometer sensors, located in the headset, tracked the motion of a bipolar magnet (through the Hall effect; Soboleva *et al.*, 2005), attached to the midpoint of the lower incisors, and the signals were then tracked in the sagittal, frontal, and horizontal planes (Figure 4). The Sirognathograph was recalibrated before each set of jaw movements by its internal rezeroing mechanism. The position of the magnet in three-dimensional space was recorded to the nearest 0.1 mm along three orthogonal axes in real time. All recordings were made by one experienced examiner (ES), according to

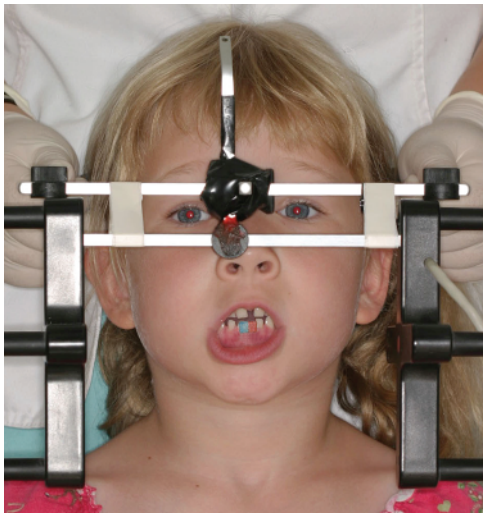

Figure 2 The Sirognathograph is aligned parallel to the bipupilar line and the Frankfort horizontal plane in such a way that the magnet remains equidistant from the left- and the right-sided sensors. Eight magnetometer sensors, located in the headset array, track the motion of a bipolar magnet (through the Hall effect), attached to the midpoint of the lower incisors, and the signals are then tracked in the sagittal, frontal, and horizontal planes.

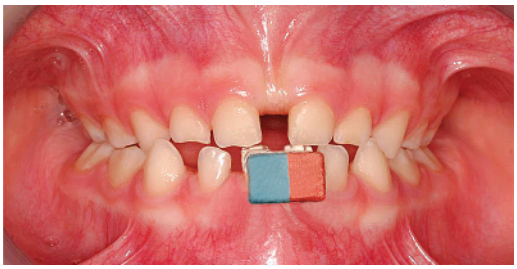

Figure 3 Fixation of the permanent magnet with carboxylate cement on the labial surface of the first mandibular incisors. The midline of the permanent magnet was orientated with the facial symmetry line, with the North Pole on the right side (blue) and the South Pole (red) on the left side, resulting in no interference in central occlusion and function.

the method described previously by Lewin (1985). The measuring device was connected to a computer through an analogue-digital converter for recorded data storage and for subsequent analysis.

The recordings obtained were then analysed using a customized software program, COSIG II developed by Professor Lewin (Marion *et al.*, 1990; Ahlin *et al.*, 1992). The measurements were based on pre-established selection and numerical data treatment of the chewing cycles from the deliberate left- or right-sided chewing sequences, at a speed that was found to be natural and comfortable (Figure 5). The jaw movements were sampled from pre-established chewing cycles. These chosen chewing cycles were the second, fifth, and ninth of the chewing sequence. The average numerical values were calculated from all three one-sided chewing cycles and then used for further statistical analysis. Each subject was given a code number and the group assignment was not revealed until all the data had been compiled. The Sirognathographic examination was performed in both groups of children.

The jaw movement response while chewing gum was recorded during deliberate chewing on the left and right side. The pattern of the chewing sequence was measured in spatial and temporal variables in all children.

Masticatory cycle analysis

The computer program, COSIG II, for analysis of mandibular motion, was used to select the masticatory cycles (Figures 2 and 4), to analyse and average the masticatory cycles in the subjects and to compare them between the groups (Figure 4). Specific changes and relationships in mandibular motion were determined to assess masticatory cycle phases. Changes in the velocity of the vertical motion curve were used by the COSIG II program to automatically determine the end of the opening and beginning of the closing phase of the chewing cycle. Determination of the occlusal phase was made within the space of 0.3 mm on the vertical axis from the mandibular position of maximal intercuspation (ICP). The surface of the trajectory area of the interincisal mandibular point in the given projection of the masticatory cycle was calculated automatically by the computer program. Spatial variables, such as the maximum length and inclination of the masticatory cycle axis, the maximal lateral deviation from the vertical axis on the frontal projection plane, and the angles of approach to maximal ICP in the opening and closing phases (0.7 mm from ICP on the vertical axis) were measured with an incorporated electronic ruler in the phase graph on the frontal and sagittal projection plane of the selected masticatory cycle. The duration of the masticatory cycle and the occlusal phase was measured with a selected point projection between phase- and time-dependent graphs by the computer program. For the purpose of analysis, the variables (Table 1) were split into two groups: temporal variables (duration: the entire masticatory cycle and the occlusal phase) and spatial variables (maximal excursion 'mouth opening' viewed in the sagittal and frontal masticatory cycle projection plane), inclination angles of approach to the ICP during the opening and closing phases in the frontal and sagittal masticatory cycle projection planes, and the maximal lateral displacement of the interincisal mandibular point from the midline vertical axis in the frontal projection plane (surfaces of the chewing cycles in the frontal, sagittal, and horizontal projection planes). The data obtained were first averaged for each individual and then analysed for all measured spatial and time variables of the masticatory cycles. The 12 variables (Table 1) describing the chewing cycle were grouped according to the respective subject's occlusion type, and statistical tests were undertaken to detect significant differences between the groups and correlations of the variables within the same group.

Groups 1 and 2 comprised UPXB children and group 3 control group (children with no crossbite). Movements of the

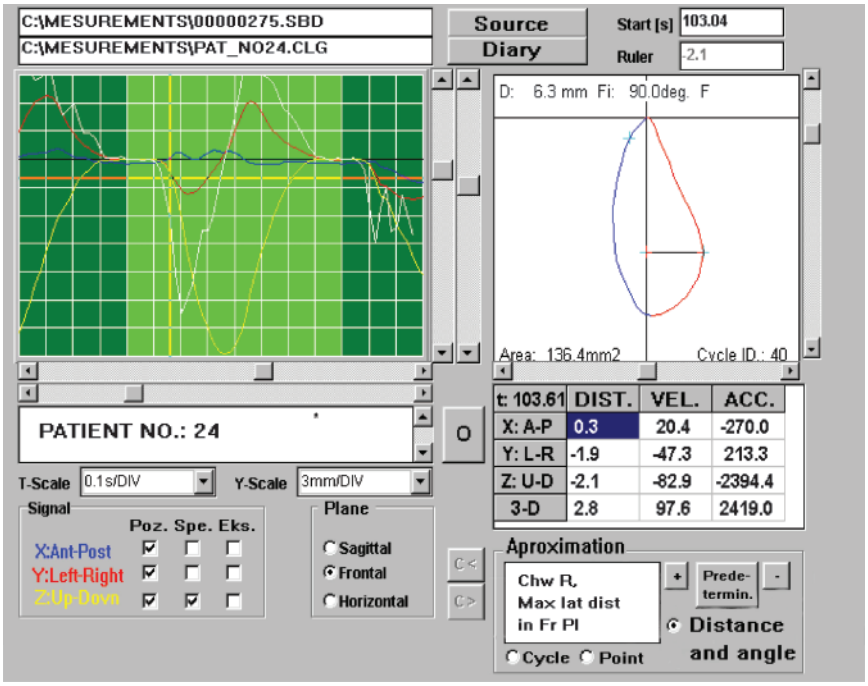

Figure 4 The computer program, COSIG II, for analysis of mandibular motion was first used to select the masticatory cycles and then to analyse and average the masticatory cycles in the subjects and compare them between the groups. Analysis of the masticatory cycles was made using the temporal and spatial variables.

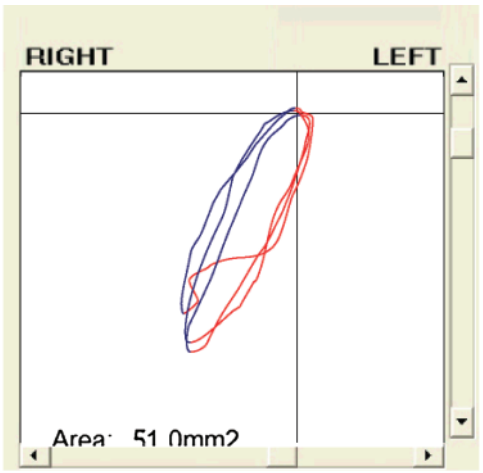

Figure 5 The sequence of the second, fifth, and ninth chewing cycle in unilateral posterior crossbite children while chewing on the affected right side in the frontal projection plane. The opening phases of chewing cycle are coloured blue and the closing phases red. Medially orientated closing angles show the nature of reverse sequence chewing cycles on the frontal projection plane.

Table 1 List of the spatial and temporal chewing cycle variables used in this study. ICP, intercuspation.

Abbreviations of the variables	Explanations
MAX LAT DIST F	Maximal lateral distance in the frontal plane
MAX F DIST	Maximal distance of chewing cycle in the frontal plane
MAX S DIST	Maximal distance of chewing cycle in the sagittal plane
OP S ANG	Opening angulation in the sagittal plane
OP F ANG	Opening angulation in the frontal plane
CL F ANG	Closing angulation in the frontal plane
CL S ANG	Closing angulation in the sagittal plane
F SURF	Frontal surface
S SURF	Sagittal surface
CYC TIME	Duration of the dynamic part of chewing cycle
ICP	Time in maximal ICP
H SURF	Horizontal surface

Eight of the 12 variables measured showed statistically significant differences in comparison between unilateral posterior crossbite (UPXB) side, the non-UPXB side, and the control group of children in primary dentition period.

lower jaw during chewing were performed in all groups. In group 1, the chewing cycles of individuals with a UPXB who chewed the soft bolus of chewing gum on the affected side were investigated, while in group 2, the chewing cycles of the UPXB individuals chewing a soft bolus on the side of the normal buccal overlap were examined. Group 3 comprised children with a normal occlusion in the primary dentition (individuals with a normal buccal overlap on both sides).

Statistical analysis

The data were analysed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA). The

means and standard deviations were calculated for all the measured Sirognathographic values. Data were compared between the groups using parametric statistics (Student's *t*-test). Significance was set at $P \leq 0.05$.

Results

The results showed only three statistically significant differences between the chewing cycles in children with a UPXB on the affected and non-affected side. A difference was found in the time spent in ICP, the closing angle in frontal projection (CL F ANG), and the maximum lateral deviation towards the working side in frontal projection (MAX LAT DIST F; Table 2). The deviation in the chewing cycle was found to be greater on the non-affected side ($P = 0.044$). Children with a UPXB spent less time in ICP when chewing on the affected side.

Comparison between children with a UPXB and those with a normal occlusion also showed a significant difference in the closing angulations of the frontal projection plane between the chewing cycles on the affected side compared with the control children (Table 3). The time for the dynamic part of the chewing cycle was not found to be statistically significantly different, but a difference was found for ICP. Children with a UPXB spent less time in maximal ICP when chewing on the affected side. Greater opening of the chewing cycles in the sagittal projection on the affected side was found with a larger area in the sagittal (S SURF) and horizontal projection planes (Table 3).

The statistically significant difference in closing angulations and the negative difference between opening and closing in the chewing cycles on the UPXB side showed a greater frequency of reverse sequence chewing cycles in comparison with the control group (Tables 2–4).

The results for the spatial variables showed statistically significant differences between the chewing cycles generated on the non-UPXB and the control group. These occurred during maximal opening excursion viewed in the sagittal and frontal projection planes and in generation of surfaces in all the three projection planes (Table 5).

The differences between the opening and closing angulations showed a tendency for reverse sequence chewing if the result was negative; a greater frequency of reverse chewing cycles was found in children with a UPXB during chewing on the affected side than in the control children. There were no statistically significant differences in reverse chewing cycles during chewing on the non-affected side in children with a UPXB and the control group (Table 4).

The above findings confirm that the chewing cycles in children with a UPXB result in longer excursions of mouth opening during mastication particularly on the non-UPXB side. The chewing cycle loops also showed greater surface values when generated by children with a UPXB, particularly on the opposite side to the crossbite (Tables 3 and 5).

Table 2 Comparison of statistically significant chewing cycle variables in children with a unilateral posterior crossbite (UPXB) when chewing on the UPXB and non-UPXB side.

	UPXB side	Non-UPXB side	*P*
Time in maximal intercuspation (s)	0.10 ± 0.05	0.15 ± 0.05	*
Closing angulation in frontal plane (˚)	97.51 ± 29.97	67.1 ± 32.78	*
Maximal lateral distance in the frontal plane (mm)	3.73 ± 2.47	5.77 ± 3.6	*

*$P \leq 0.05$.

Table 3 Comparison of statistically significant chewing cycle variables in children with a unilateral posterior crossbite (UPXB) when chewing on the affected side and children with a normal primary dentition.

	UPXB side	Normal dentition	*P*
Maximum distance of chewing cycle in the sagittal plane (mm)	14.64 ± 4.53	11.78 ± 3.43	*
Closing angulation in the frontal plane (˚)	97.51 ± 29.97	69.41 ± 25.20	*
Sagittal surface (mm^2)	7.92 ± 7.28	2.61 ± 1.49	*
Time in maximal intercuspation (s)	0.1 ± 0.05	0.16 ± 0.04	***
Horizontal surface (mm^2)	7.8 ± 8.15	3.6 ± 4.26	*

*$P < 0.05$, ***$P < 0.001$.

Discussion

Studying movements at the mandibular incisors reflects the full range of mandibular motions without interfering with physiological functions and the ability of individuals with a normal range to have precise proprioception (Kang *et al.*, 1991). Different authors have investigated the accuracy of measuring mandibular movements at the lateral incisors with electrognathography and concluded that the linearity and quantitative accuracy ranged from 0 to 0.1 mm during ICP (Jankelson, 1980; Ahlin *et al.*, 1992), while the COSIG II program was found to have excellent accuracy, reliability, and validity (Ahlin *et al.*, 1992).

One of the limitations of the present study was that only one food consistency was used. Therefore, the results cannot be extrapolated to other food consistencies because masticatory patterns depend on the food fragmentation index, bolus hardness, food consistency, and food size. Gum was used because it maintains the same consistency during chewing thus permitting chewing cycles to be compared (Murai *et al.*, 2000). There was also no necessity to swallow the bolus and interrupt the chewing sequences.

Table 4 Comparison of statistically significant chewing cycle variables in children with a unilateral posterior crossbite (UPXB) when chewing on the affected side, of children with a UPXB, when chewing on the non-affected side (non-UPXB), and of children with a normal primary dentition (control). OP F ANG, opening angulation in the frontal plane; CL F ANG, closing angulation in the frontal plane.

Children	OP F ANG	SD	CL F ANG	SD	Difference of the means
UPXB	73.61	±37.67	97.51	±29.97	−23.9*
Non-UPXB	83.96	±38.01	67.1	±32.78	16.86
Control	94.04	±38.97	69.41	±25.2	24.63

*Negative results show a tendency to reverse-sequencing chewing cycles.

Table 5 Comparison of statistically significant chewing cycle variables in children with a unilateral posterior crossbite (UPXB) when chewing on the non-affected side and of children with a normal primary dentition.

	Non-affected side UPXB	Normal dentition	*P*
Maximum distance of chewing cycle in the frontal plane (mm)	15.58 ± 4.5	12.3 ± 3.52	*
Maximum distance of chewing cycle in the sagittal plane (mm)	14.93 ± 3.33	11.78 ± 3.43	*
Frontal surface (mm^2)	38.36 ± 26.77	18.66 ± 14.62	*
Sagittal surface (mm^2)	6.37 ± 6.17	2.61 ± 1.49	*
Horizontal surface (mm^2)	10.21 ± 8.41	3.6 ± 4.26	*

*$P \leq 0.05$.

In this study, the chewing patterns of children with UPXB were monitored and compared with those of a control group with a normal intermandibular Angle Class I relationship and normal buccal overlap.

While there are reports in the literature demonstrating the characteristics of the chewing patterns in children with a UPXB in the primary dentition (Kurol and Berglund, 1992; Ferrario *et al.*, 1999; Martin *et al.*, 2000; Throckmorton *et al.*, 2001; Thilander and Lennartsson, 2002; Piancino *et al.*, 2007; Kecik *et al.*, 2007; Neto *et al.*, 2007), the COSIG II system has only been previously used in the permanent dentition (Sever *et al.*, 1997; Sever, 2003; Sever and Marion, 2005).

From 12 sirognathographic variables (Table 1), 8 variables of the masticatory cycle between the UPXB children and control group were statistically significantly different, one temporal and seven spatial (Tables 2, 3, and 5). Comparison of mastication between all three groups showed that on the side with a normal buccal overlap, the UPXB children tended to open their mouths more widely in both projection planes (Tables 3 and 5). Furthermore, it was observed that chewing cycles in subjects, who chewed on the non-UPXB side, covered an area almost three times larger than that of the control children in the horizontal and sagittal projection planes, and more than twice that in the frontal projection plane. The greatest chewing cycle surface in the sagittal projection plane was found on the UPXB side, but no statistically significant difference was observed in the frontal projection plane in the control and non-UPXB group.

Statistically significantly higher values for the closing angle in the frontal projection plane (a more vertical closing angle) were found on the crossbite side in comparison with the non-crossbite side and with the control children. The negative difference in values between the opening and closing angles showed the nature of reverse sequence chewing cycle in the frontal projection plane.

In children with a UPXB in the mixed dentition, the mandible usually shifts laterally towards the crossbite side. This could be due to both poor interdigitation and occlusal interferences (Lam *et al.*, 1999; Miyawaki *et al.*, 2004). However, UPXB patients exhibit a significant lateral shift during mandibular movements (Martin *et al.*, 2000).

The present study also examined whether the type of lateral dental overlap affected the inclination angle of the masticatory cycle in the frontal projection plane. Although the data showed no statistically significant differences between the two groups, it was concluded that there was no lateral shift of the mandible towards the UPXB side during chewing in children in the primary dentition period. On the contrary, a smaller maximal lateral deviation towards the working side was found when chewing on the non-UPXB and on the crossbite side than in the control group. Throckmorton *et al.* (2001) also observed that UPXB patients had fewer lateral excursions than a control group with no malocclusions. Neto *et al.* (2007) also found increased lateral deviation after UPXB therapy on the non-UPXB side.

Temporal variables demonstrated a shorter time spent in maximal ICP when chewing on the UPXB side. It was hypothesized that this occurred due to the unstable occlusion and more medial movements of the working condyle and/or the greater load on the TMJ in patients with a UPXB than in subjects with a neutral occlusion (Tanne *et al.*, 1993; Miyawaki *et al.*, 2004). On the other hand, the time spent in maximal ICP and most other spatial variables were found to be predictors of the UPXB chewing cycle group. This

showed the disturbances and corrections of pattern generator across afferent neural inputs during chewing on the affected side in UPXB children (Jankelson, 1990).

Piancino *et al.* (2007) evaluated the prevalence of reverse-sequencing chewing cycles in UPXB subjects in the mixed dentition during chewing on the crossbite side. They found that successful treatment of a unilateral crossbite, by palatal expansion, did not eliminate the reverse-sequencing chewing cycles in the mixed dentition.

A UPXB malocclusion develops early in the primary dentition and has an influence on the developing central pattern generator, establishing the reverse-sequencing type. This chewing pattern was found to be resistant to a change after therapy (Throckmorton *et al.*, 2001). According to the results of that study and previous reports in the literature, it is concluded that the reverse-sequencing pattern persists after treatment by palatal expansion.

The results of the present study showed a statistical difference in the angle of closing sequences of the chewing cycles in the frontal projection plane in children with a UPXB when chewing on the affected side compared with the control group. The angulation was measured between the ICP point and the projection point 0.7 mm distant along the *Z* axis on the opening and closing path of the chewing cycles. The same statistically significant differences were observed between the UPXB and non-UPXB side.

Analysis of the masticatory cycles in subjects with altered occlusal relationships showed statistically significant differences when chewing on the affected and non-UPXB side compared with the control group. Eight of the 12 variables (Table 1) were significant in both cases. In agreement with Ferrario *et al.* (1999), it was concluded that the altered oclusal relationship influenced the coordination of chewing on both sides. It is hypothetical that mandibular asymmetry, different joint vibrations, and imbalanced electromyographic findings (Kecik *et al.*, 2007) also affect chewing on the non-UPXB side. The data indicated that there was greater frequency of reverse-sequencing chewing cycles on the crossbite side with a lower lateral shift towards the working side.

Ben-Bassat *et al.* (1993), Throckmorton *et al.* (2001), and Piancino *et al.* (2007) proposed a possible interaction between successful treatment of a unilateral crossbite and the persistence of a reverse-sequencing chewing pattern. However, it is unclear whether the persistent chewing pattern is still in harmony with the new morphological occlusion or whether this influences later development of occlusal disturbances in chewing function (Ben-Bassat *et al.*, 1993). The working condyle on the affected side in patients with a UPXB moved more in a medial direction than in the control group during mastication. The more medial displacement of the working condyle during mastication might lead to a greater loading on the inner face of the mandibular fossa. The genesis of TMJ disc displacement in such patients might be related to such persistent condylar movements on the crossbite side during mastication (Miyawaki *et al.*, 2004).

According to the results of this study, it could be confirmed that the chewing cycle morphology differs not only on the UPXB side but also on the non-UPXB side due to compensatory movements while chewing on the UPXB side.

Further investigations will clarify whether early correction of a UPXB in the primary dentition with reverse-sequencing chewing cycles influences the central pattern generator and therefore establishes a normal path of chewing.

Conclusions

1. A reverse sequence chewing pattern was predominant in the UPXB children when chewing on the UPXB side.
2. The time spent in maximal ICP was reduced when chewing on the crossbite side in children with a UPXB. There was a pronounced lateral shift of the mandible towards the working side in children with a UPXB in the primary dentition when chewing on the non-UPXB side.
3. Children with a UPXB opened their mouths more and showed greater chewing cycles in the sagittal and horizontal projection planes while chewing on the UPXB side and also in frontal projection while chewing on the non-UPXB side in comparison with children with a normal occlusion in the primary dentition.

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