Evaluation of middle ear function in primary dentition children with posterior cross bite

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Abstract

Posterior cross bite in the primary dentition causes not only functional disorders in jaw movements but also maxillofacial asymmetry. Previous reports have demonstrated a functional relationship between the stomatognathic system and middle ear. The purpose of this study was to investigate the association between cross bite and middle ear function. Thirteen children with posterior cross bite (mean age 5.3 years) and 10 children with normal occlusion (mean age 5.5 years) in the primary dentition were examined. The size of the primary tooth crowns and primary dental arches was measured in dental models. The middle ear compliance was measured on a tympanogram using Impedance Audiometer SI-50I (Morita Co.). Differences among the measured values of Static Compliance, Pressure, and Ear Clearance in the left and right ears were computed as absolute values and the pattern of tympanograms observed. The following results were obtained: (1) There was no significant difference in the mesiodistal width of the primary tooth crown. In the cross bite group, the arch width of maxilla was smaller than that of the normal Japanese standard of 5-year-olds. (2) Regarding the pressure, there was significant difference between children with posterior cross bite and normal occlusion. (3) Regarding tympanogram, in the normal group, 90% showed symmetrical Type A (normal range for tympanogram) on both sides, and in the cross bite group, 53.8% showed symmetrical Type A and 7.7% showed Type As (restricted tympanogram) on both sides. Type C (retracted tympanogram) indicating eustachian tube abnormality was not seen in the normal group, however, in the cross bite group, it was seen in 7.7% of the right and 23.1% of the left side ears. (4) There was no correlation between incisor midline shift and the pressure. It was concluded that children with posterior cross bite were at a significantly increased risk for middle ear dysfunction.

Key words

Eustachian tube,
Middle ear,
Posterior crossbite,
Primary dentition,
Tympanometry

Introduction

Posterior cross bite 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. It is a relatively common malocclusion in children, with a prevalence of between 8.7% and 23.3%. The most frequent cause of unilateral posterior cross bite is a reduction in maxillary dental arch width compared with mandibular arch width. In children, unilateral posterior cross bite is usually accompanied by a lateral functional shift of the mandible from initial contact to maximum intercuspsation.

Posterior cross bite may develop during eruption of the primary dentition and can involve the permanent dentition at a later stage of development. If unilateral posterior cross bite is left untreated, skeletal remodeling of the temporomandibular joints may occur over time so that the condyles become...
more symmetrically positioned in their fossae, and facial asymmetry and lower midline deviation toward the cross bite side may persist\(^7\). There is a close embryologic and anatomical relationship between the temporomandibular joint, the muscles of mastication, the middle ear and also the tensor veli palatini muscle which opens and closes the eustachian tube. The muscles of mastication, as well as the tensor veli palatini muscle are all derived from the mesoderm of the first branchial arch, and thus share common innervation by fifth cranial nerve\(^8,9\).

Otitis media, defined as inflammation of the mucoperiosteal lining of the middle ear, is the most commonly diagnosed disease in children\(^10\). The eustachian tube (ET) connects the tympanic cavity to the nasal part of the pharynx, and its orifice lies on its respective lateral nasal pharyngeal wall. The ET comes from the tensor veli palatini muscles, at their origins and it facilitates gas exchange between the nasopharynx and the middle ear space allowing for aeration and pressure equilibration. The ET maintains a closed position at rest, which protects the middle ear from rapid fluctuations in nasopharyngeal pressure associated with breathing, swallowing, coughing, sneezing and nose blowing. Eustachian tube dysfunction (ETD) is defined as a persistent failure of the ET to effectively facilitate gas exchange, regulate the pressure in the middle ear and mastoid spaces, or prevent retrograde flow of bacteria\(^11\). It is currently thought that variations in angulation, width, and length of the ET are responsible for defects in its function\(^10\).

However, some evidence exists implicating craniomandibular and neuromuscular factors in the etiology of ETD. Cleft palate, high palatal vault, and long, narrow facial growth patterns have each been shown to be associated with middle ear disease\(^12\). Bylander \textit{et al.}\(^13\) found that the muscle function opening of the eustachian tube works less efficiently in children with positive otitis media with effusion (OME) history than in those without. Braun\(^14\) observed a correlation between hearing loss and maxillary constriction. Ruben\(^15\) stated that tubal malfunction was more frequently seen in children who had extremely high palatal arches, as well as malformations of the palate and nasopharynx, that may predispose them to otitis media. Some authors\(^16–22\) reported that the orthopedic effect of rapid maxillary expansion helps to improve hearing levels in patients with maxillary deficiency.

The purpose of this study was to investigate the association between posterior cross bite in primary dentition (Hellman dental age IIC) and middle ear function by using tympanometry.

**Materials and Methods**

Thirteen children (five boys, eight girls; mean age 5.3 years), with a posterior unilateral cross bite involving a primary canine and first and second primary molars, were selected from patients referred to the Department of Pediatric Dentistry, Nihon University Hospital, School of Dentistry at Matsudo, Japan. Ten normal subjects with acceptably good occlusion were selected (three boys, seven girls; mean age 5.5 years) as control group. Before starting the study, informed consent was obtained from all subjects. This study was approved by the Ethical Committee of Nihon University School of Dentistry at Matsudo (EC 06-023).

**Analysis of dental model**

Dental models were prepared for all patients. The sizes of the primary tooth crowns and primary dental arches were measured and compared to Japanese standard values\(^23\).

1) Measurement of mesiodistal crown diameters

The mesiodistal crown diameters were measured using a caliper with 1/20 calibration according to Fujita’s method\(^24\). Each measurement was repeated...
three times and the mean was used in the statistical analysis.

2) Measurement of the arch width and arch length
The arch width and length of dental models were measured using a caliper with 1/20 calibration. Each measurement was repeated three times and the mean was used in the statistical analysis.

The points of measurement according to The Japanese Society of Pediatric Dentistry\(^{23}\) were used as shown in Fig. 1.

3) Measurement of incisor midline deviation
The incisor midline deviation was measured as shown in Fig. 2. Correlation between the incisor midline deviation and the middle ear pressure (it is described in the next section) was estimated.

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**Fig. 2** Measurement of incisor midline deviation in maximum intercuspsation

**dental midline**: the line through the point between mesial contacts of central primary incisors and interdental papilla

**e**: distance between upper dental midline and lower dental midline = incisor midline deviation

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**Fig. 3** Normal range for tympanometry, type A (shaded area)
The normal tympanogram shows a well defined maximum compliance at an air-pressure differential of 0 daPa. This curve is most often seen in patients with normal hearing.

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**Fig. 4** Restricted tympanogram, type A (a curve of black line, shaded area shows type A)
This pressure compliance function is characterized by normal middle ear pressure and limited compliance relative to normal mobility. Type A is most often seen in advanced cases of otosclerosis, lateral fixation of the ossicular chain and tympanic membrane fibrosis.

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**Fig. 5** Retracted tympanogram, type C (a curve with black line, shaded area shows type A)
A well defined compliance maximum occurring at negative pressures greater than \(-100\) daPa is seen in the retracted tympanogram (type C). This curve may or may not be related to the presence of middle ear fluid. Persistence of an intact but retracted membrane suggests poor eustachian tube function.

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 Evaluation of middle ear function

The changes in middle ear compliance were measured on a tympanogram using an Impedance Audiometer SI-50I (Morita Ltd., Tokyo, Japan), which records static compliance in the tympanic membrane (STC), peak pressure (PRS) and volume (EAC) in the middle ear cavity. The patient was seated, and ear probe was placed on the patient’s ear while the patient had bitten in intercuspal position. Differences among the measured values of STC, PRS, and EAC in the left and right ears were computed as absolute values. These tympanograms were classified according to the tympanogram pattern and also the side of cross bite as right or left. The frequency of bilateral symmetry of the right and left ears in the two groups was estimated. No subjects had a history of otorhinolaryngologic disease.

Tympanometry

Tympanometry is a technique that assesses the mobility or compliance of the tympanic membrane during variations of air pressure in a hermetically sealed canal. For diagnostic purposes, it can provide valuable information for identification of tympanic membrane mobility, middle-ear pressure, tympanic membrane perforations, patency of the pressure equalization tubes and eustachian tube function. It is plotted on the graph in terms of relative compliance of the tympanic membrane and middle ear space.

Table 1 Mesiodistal crown diameters of primary teeth

<table>
<thead>
<tr>
<th>Types of teeth</th>
<th>Cross bite</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (n = 5)</td>
<td>Female (n = 8)</td>
</tr>
<tr>
<td>A</td>
<td>6.85 ± 0.27</td>
<td>6.73 ± 0.26</td>
</tr>
<tr>
<td>B</td>
<td>5.86 ± 0.22</td>
<td>5.57 ± 0.29</td>
</tr>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>7.15 ± 0.24</td>
<td>6.67 ± 0.27</td>
</tr>
<tr>
<td>D</td>
<td>7.71 ± 0.52</td>
<td>7.23 ± 0.32</td>
</tr>
<tr>
<td>E</td>
<td>9.44 ± 0.48</td>
<td>9.00 ± 0.37</td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4.58 ± 0.60</td>
<td>4.36 ± 0.41</td>
</tr>
<tr>
<td>B</td>
<td>4.78 ± 0.22</td>
<td>4.88 ± 0.25</td>
</tr>
<tr>
<td>C</td>
<td>6.08 ± 0.21</td>
<td>5.78 ± 0.32</td>
</tr>
<tr>
<td>D</td>
<td>8.76 ± 0.52</td>
<td>7.50 ± 1.41</td>
</tr>
<tr>
<td>E</td>
<td>10.68 ± 0.38</td>
<td>10.21 ± 0.48</td>
</tr>
</tbody>
</table>

Table 2 Analysis of dental arch dimensions

<table>
<thead>
<tr>
<th>Points of measurement</th>
<th>Cross bite</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (n = 5)</td>
<td>Female (n = 8)</td>
</tr>
<tr>
<td>ARCH WIDTH (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-C</td>
<td>30.07 ± 2.65</td>
<td>28.35 ± 2.19</td>
</tr>
<tr>
<td>D-D</td>
<td>38.47 ± 1.63*</td>
<td>36.61 ± 2.61</td>
</tr>
<tr>
<td>E-E</td>
<td>45.77 ± 1.79</td>
<td>41.55 ± 2.72</td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-C</td>
<td>25.53 ± 1.91</td>
<td>24.69 ± 2.32</td>
</tr>
<tr>
<td>D-D</td>
<td>32.77 ± 1.34</td>
<td>31.16 ± 2.03</td>
</tr>
<tr>
<td>E-E</td>
<td>40.90 ± 0.79</td>
<td>39.00 ± 2.29</td>
</tr>
<tr>
<td>ARCH LENGTH (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
<td>A-E0</td>
<td>29.00 ± 1.44</td>
</tr>
<tr>
<td>Mandible</td>
<td>A-E0</td>
<td>26.57 ± 1.55</td>
</tr>
</tbody>
</table>

*: P<0.05
The procedure for obtaining a tympanogram consists of introducing a specified positive pressure into the external auditory canal (usually equivalent to $\frac{1}{2} \times 200$ mm H$_2$O) and subsequently decreasing the pressure to approximately $\frac{1}{2} \times 200$ mm H$_2$O. As the pressure is varied, a certain range of movement will be observed graphically if the tympanic membrane is normal. There are three basic types as Type A, Type As and Type C of tympanogram relevant to this study. They are shown in Figs. 3–5.

### Statistical analysis

Data from the measurement of study models and evaluation of middle ear function were compared between normal group and cross bite group using parametric student $t$ test. A variable was considered to be statistically significant if the $P$ value was below a level of .05.

### Results

Analysis of mesiodistal crown diameters of primary teeth and dental arch dimensions are shown in Tables 1, 2. Those in the normal group were compared to those of the Japanese standard for 5-year-olds$^{23}$ and they were in the midrange. In the cross bite group, the arch width of the maxilla (distances between C-C, D-D, E-E in Fig. 1) was smaller than that of the normal group. Especially, the distance between primary first molars in the cross bite group in male was statistically smaller. However, the distances between primary canines and second primary molars in the mandible were longer than those of normal group (Table 2). There were no significant differences in mesiodistal crown diameters of the primary teeth in cross bite group compared to those of the normal group (Table 1).

Table 3 shows the differences between the measured values of STC, PRS, and EAC in the two groups. There were no significant differences for STC and EAC. However, there was a statistically significant difference in the measured value of PRS (PRS = 38.6 in the cross bite group and 6.2 in the healthy group, $P<0.05$). An example of the tympanogram of patients with posterior cross bite from cross bite group is shown in Fig. 6.

Table 4 shows the frequency of appeared type of tympanogram pattern and bilateral symmetry of right and left ears in the two groups. While 90% children showed bilateral symmetry of normal middle ear compliance with type A tympanograms in the normal group, 53.8% children showed bilateral symmetry in the cross bite group. In the right side ear, there were 76.9%, 90% of type A, 15.4%, 10.0% of type As and 7.7%, 0% of type C and in the left side ear, 61.5%, 100% of type A, 15.4%, 0% of type
Table 5 shows the comparison between the types of tympanogram in children with a right or left posterior cross bite. With right side cross bite, there were 83.3% of type A and 16.7% of type C in the right ear and 66.7% of type A and 33.3% of type C in the left ear. With left side cross bite, there were 71.4% of type A and 28.6% of type As in the right ear and 57.1% of type A, 28.6% of type As and 14.3% of type C in the left ear.

Figure 7 shows no correlation between the side shift of mandibular incisor midline to the maxillary central incisor midline with centric occlusion and PRS in cases of the cross bite group.

Discussion

Analysis of dental models

Posterior cross bite is defined as the transversal discrepancy of teeth relationships, because of the narrowing of the upper dental arch compared with the lower dental arch. In this study, there were no significant differences in mediodistal crown diameters of the primary teeth in the cross bite and the normal group. However, children with posterior cross bite had a narrow dental arch in maxilla compared to that of normal children. It might be accompanied by a lateral functional shift of the mandible from initial contact to maximum intercuspation because of the maxillary deficiency. It was suggested that the functional displacement of the mandible for a long period suppresses mandibular growth toward the cross bite side. Kilic et al. indicated that condylar asymmetry was observed in unilateral posterior cross bite patients and the condyles on the cross bite side were relatively shorter than those of non cross bite side. Asymmetric postural muscle activity was also reported in children with functional posterior cross bite. Subsequent adaptation of the neuromusculature to the acquired mandibular position can cause asymmetric mandibular growth, facial disharmony, and severe skeletal cross bite in the permanent distortion. Moreover, unilateral posterior cross bite has been shown statistically to be associated with temporomandibular disorders. In my cases, there may give some neuromuscular influence on TMJ because of their occlusion, posterior cross bite...
so that the middle ear dysfunction may be caused. In my cases, there may be some neuromuscular influence for TMJ so that the middle ear dysfunction may be caused.

Symmetry of middle ear function
Matsumoto\textsuperscript{29} studied the relationship between TMD and the function of hearing organs by tympanometry in three groups, healthy subjects, subjects with clicking and TMD patients. He concluded that there was a significant difference in the measured values of PRS between healthy and clicking subjects (Healthy = 5.1 daPa: S.D. 4.4, Clicking = 14.6 daPa: S.D. 13.3) groups. The present study found that children with posterior cross bite had not only malocclusion but also a mal-function of the middle ear. There was a significant difference in the measured value of the pressure (PRS = 38.6 in the cross bite group and 6.2 in the healthy group, $P<0.05$) in which unilateral ear pressure was increased to negative in cross bite group.

Myrhang\textsuperscript{30} proposed an association between the temporomandibular joint and the middle ear based on embryology. Portions of the middle ear ossicles, middle ear musculature, and muscles of mastication all originate from the first branchial arch and are innervated by the fifth cranial nerve. Therefore, in children with cross bite, spasm of the muscles of mastication caused by a displaced condyle could cause neuromuscular dysfunction of all the muscles innervated by the fifth cranial nerve including the tensor palatini. Abnormal function of this muscle can result in ETD and decreased middle ear ventilation.

It is interesting to note that the tensor tympani muscle, the tensor veli palatini muscle, the medial pterygoid muscle, and the rest of the muscles innervated by fifth cranial nerve all develop from the mesoderm of the first branchial arch\textsuperscript{31}. Thus, if one of these muscles is hypertonic, the rest are probably hypertonic as well.

Myers \textit{et al.}\textsuperscript{32} reported that posterior cross bite in children influenced the position of the mandibular condyle. Ten children from 4 to 9 years of age with functional posterior cross bite were treated by maxillary expansion. Standardized transcranial temporomandibular joint x-ray photographs were taken pretreatment and posttreatment. Prior to treatment, there were significant differences in the horizontal and vertical joint space measurements between the cross bite and non cross bite sides. However, after correction of cross bite, there were no significant differences between the two sides.

It was presumed that the unbalance of the middle ear pressure in right and left ears was caused by the turbulence of nerve and muscle and also the change of lymphatic and blood flow resulting from the deviation of the condyle which causes spasm of the muscles of mastication.

Several researchers have also examined the relationship between dental occlusion and OME. OME is probably one of the most prevalent illnesses in the developing child. Since the eustachian tube is analogous to a sinus ostium, infections of the nose and nasopharynx are directly transmissible to the middle ear in the same manner as such infections spread to the paranasal sinuses. In addition to infections, other conditions (allergic, metabolic) can similarly involve the middle ear. Foreign material (water, inhaled particles, regurgitated esophageal contents, etc.) can enter the middle ear via the eustachian tube. Last, but not the least, barometric pressure variations in the contained air of the middle ear and mastoid cell system can also be an etiologic factor\textsuperscript{35}.

In children from 1 to 12 months old, the incidence of OME increased to 57 to 67%. Between ages 1 and 6 years, the incidence of OME fell to 40%, with the disease falling gradually from 62% at age 2 years down to 17% at age 5 years. By the time the child was 7 to 8 years old, the incidence of OME was down to 4.2%\textsuperscript{33}.

Niemela \textit{et al.}\textsuperscript{34} examined the relationship between ear infections and the dentition. The dental variables were open bite, posterior cross bite, overjet, and dental crowding of the maxilla and mandible. In univariable analysis, open bite was associated with MED. McDonnell \textit{et al.}\textsuperscript{35} proposed that children with deep bite are 2.8 times more likely to develop ETD than children without deep bite.

Marasa and Ham\textsuperscript{36} treated five patients suffering from OME between ages of 4 and 7 years in which all presented with an over bite of 90 to 100%, and four out of the five exhibited narrow dental arches and were classified as retrognathic. All patients had multiple courses of antibiotic therapy and several had ventilation tubes placed in their tympanic membrane to allow for drainage. The authors treated them with craniomandibular methods by placing composite material on the occlusal surfaces of the lower deciduous molars, which reduced the vertical over bite and also using a maxillary expansion appliance to widen the arch. The patients had a
significant decrease in the occurrence of their OME bouts after alteration of the vertical dimension and narrow dental arch. In the present study, it was also found that children with cross bite had maxillary deficiency, which was suggestive of eustachian tube dysfunction.

Braun\textsuperscript{14}) indicated that maxillary constriction is one of the causes of nasal stenosis, which may be associated with mouth breathing and can affect the ET and the middle ear, resulting in hearing loss. The ET connects the tympanic cavity to the nasal part of the pharynx, and its orifice lies on the respective lateral nasal pharyngeal wall. Physiologic obstruction of the ET comes from the tensor veli palatini muscles at their origin. It keeps the tube from opening in response to negative pressure in the middle ear. It is possible that the stretching that occurs in this muscle following midpalatal suture opening opens the pharyngeal orifice of the ET, thus allowing air to enter or leave the tympanic cavity. By allowing air to pass through the tube, the pressure on either side of the tympanic membrane is balanced, so the tympanic cavity and the ossicular chain can vibrate freely and function normally\textsuperscript{16,19}).

Classification of the tympanogram patterns

There are three basic types of tympanograms relevant to this study. In type A, usually consistent with normal middle ear pressure, maximum compliance occurs in the range of plus or minus 100 daPa. Type A is usually suggestive of hardening of ossicles. In type C, usually indicative of a negative middle ear pressure caused by poor eustachian tube function, maximum compliance occurs at a pressure more negative than minus 100 daPa. It was observed that there was asymmetry in the middle ear function of right and left ears in the cross bite group, only 53.8% had a symmetrical type A and 7.7% in right side ears and 23.1% in left side ears had type C although the patients did not have any symptoms. There were also 10% of type As in right ear in normal group and 15.4% of that in both right and left ears in cross bite group. Type As is often seen in advanced cases of otosclerosis and lateral fixation of the ossicular chain. However this pressure-compliance function is characterized by normal middle ear pressure and limited compliance relative to normal mobility\textsuperscript{25}).

According to a study by Matsumoto\textsuperscript{29}), all the healthy subjects showed a symmetrical type A on both sides and all the rest were asymmetrical. It was demonstrated that as the symptoms of temporomandibular joints were getting worse, the bilateral symmetry of right and left ear function was decreasing. Table 5 shows a comparison between the types of tympanogram with a right or left posterior cross bite. Type C can be seen in both sides of cross bite. In the right side cross bite, 16.7% showed a type C in the right ear, while 33.3% showed it in the left ear. In left side cross bite, there were 14.3% of type C only on the left side. The relationship between the side of cross bite and appearance of tympanogram pattern in right or left ears was not clear.

It is suggested that in children with posterior cross bite, the bilateral symmetry of tympanogram pattern was decreased significantly and in spite of having no symptoms in the ears, it appeared that the patterns indicated some disease in the middle ear. Negative pressure in the middle ear, by itself, may be another cause of tubal malfunction\textsuperscript{37}).

It was revealed that children with posterior cross bite had not only malocclusion but also a malfunction of the middle ear. Children with posterior cross bite must be treated in the early stage because malocclusion may affect their growth.

Conclusion

The following conclusions were drawn:

1. There were no significant differences in medio-distal crown diameters of the primary teeth in the cross bite and the normal group. Children with posterior cross bite had a narrow dental arch in maxilla compared to that of normal children.
2. There was a significant difference in the measured value of pressure in the left ear and that of the right ear in children with posterior cross bite.
3. Ninety percent of normal children had bilateral symmetry of normal middle ear compliance with type A tympanograms in the normal group, however in the cross bite group, 53.8% had bilateral symmetry with type A tympanograms. There was also type C (7.7% in right side ears, and 23.1% in left side ears) which indicated a negative middle ear pressure caused by poor eustachian tube function.
4. The relationship between the side of the cross bite and appearance of tympanogram pattern in the right or left ears was not clear.
5. There was no correlation between side shift of incisor midline and pressure.
It was concluded that children with posterior crossbite were at a significantly increased risk for middle ear dysfunction.

Acknowledgments

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31) Moore, K.L.: The branchial apparatus and the head


