The effect of palatal plate therapy on the growth and development of the maxilla in children with Down syndrome

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Abstract

Background: In children with Down syndrome (DS) the retarded growth potential cause a number of different clinical signs. Morphological deviations and an underdeveloped midface together with hypotonia contribute to increased prevalence of occlusal anomalies. Since the early 1980’s orofacial neuro-motor habilitation with palatal plates therapy have been used in Sweden.

Aim: to investigate if use of palatal plates for three and a half years could normalise the growth of the maxilla for children with Down syndrome.

Material and methods: In a multi-centre, multidisciplinary project started 1995, 42 children with Down syndrome have been followed longitudinally. The children started oral habilitation including palatal plate therapy at the age of 6 months. At the age of four years of age a clinical examination was performed and dental impressions were taken from the 42 children and two age matched control groups; one group with Down syndrome children and one group children with normal development. In this study palatal height, length and width were measured on the dental casts with digital calliper on totally seventy-five casts from three groups of children; one group with DS who had used palatal plates, one untreated DS group and one group with normally developed children.

Results: The measurements showed no significant differences in growth and development of the maxilla in DS children who had used palatal plates for three and a half year compared to DS-children who had never used palatal plates. The short observation time, three and a half year, may be one cause why no orthopaedic effects could be
seen after use of palatal plates.

**Conclusions:** In children with DS, palatal plate therapy between 6 and 48 months of age show no orthopaedic effects on the growth of the maxilla. Probably is the observation time of three and a half year to short. Anyhow clinical evaluation on the same project children show that palatal plate use, in connection with speech – and language intervention, had a positive effect on occlusion, oral motor function, facial expression and speech.

**Keywords:** Down syndrome, palatal plates, maxillary dimensions, orthopaedic effect, oral morphology, oral-motor function.
Introduction

Down syndrome (DS) is the most prevalent chromosomal aberration in Sweden and the most prevalent single cause of mental deficiency. DS is an autosomal numerical chromosomal anomaly that results from trisomy of chromosome 21 (Epstein 1986). In Sweden about 120 children with DS are born yearly. The DS-children have an unbalanced genetic disposition which affects many aspects of the development of the child, both systemic and mentally (Gustavsson 1981). The mental development is complex, varied and changing in relationship with the individual, their contexts and experiences.

Beside mental retardation, morphological characteristics, cardiovascular and haematopoietic anomalies are reported in the literature (Desai et al. 1997). Also musculoskeletal anomalies, nervous system anomalies and general muscle hypotonia are associated with DS (Annerén et al. 1986).

Many of the clinical signs are due to the generally retarded growth potential caused by the trisomy.

Morphological deviations in children with DS also affect the dentition and the oral cavity. The midface is underdeveloped in relation to the mandible (Fisher–Brandies 1988a). The cranio-facial dysplasia is congenital and becomes more accentuated with age. The open mouth, mouth breathing, the protruded position of the tongue and the hypotonic oral muscles contribute to the increased prevalence of mandibular overjet, anterior open bite, posterior crossbite and drooling. (Kiesling 1966, Kiesling 1976, Jensen et al. 1973, Meredith 1987, Oreland et al. 1987).

Tongue protrusion and mouth-breathing may also be a symptom of an
airway restriction due to enlarged tonsils and/or adenoids. Adeno-
tonsillectomy however often fails to improve tongue protrusion and may
cause hypernasality (Kavanagh et al. 1986). On the other hand, a study on
normally developed children who were tonsillectomized because of sleep
apnea, showed a higher proportion of malocclusions before the operation
and a normalised occlusion in 77% (open bite) after the tonsillectomy
(Hultcrantz et al. 1991).

The human tongue is a flexible organ consisting of muscles. Yarom et al.
1987 found evidence of degeneration of nerve endings and changing in the
endplates of neuromuscular junctions in tongue tissue in patients with DS.
This could be part of the explanation of hypotonia of the tongue. True
macroglossia is rare ( Limbrock 1988, 1990) but due to hypotonia the
tongue seems to be enlarged, also known as relative macroglossia. (Hoyer
1990).

In 80-90% of children with DS younger than 3 years of age, a diastase is
seen on the tongue, i.e. the midline of the tongue is elevated with fissures on
each side along the midline (Limbrock 1988, 1990). An insufficiency of the
transversal fibres of m. genioglossus and/or an inadequacy of septum
linguae have been suggested as the cause (Limbrock 1990). The lingual
diastasis may disappear due to the midline development of the tongue.

In 1870, Wolff formulated a basic rule govering the physiology of growth.
In essence, this rule, which has been labelled Wolff’s law, states that the
spongiosa of bone can be reoriented by a process of rearrangement of its
trabecular system in response of different mechanical stress. Thus, bone is
reorganized in response to differing pressures against it. In the infant the
comparatively large muscle mass of the tongue is apposed to the fragile hard palate and to a relatively underdeveloped mandible and alveolar processes. The infant tongue may therefore be viewed as the internal “molder” of the oral cavity (Fletcher 1973).

Closure of the palatal shelves during normal prenatal palate formation is the result of a complex interaction between tissue growth processes and functional factors such as mandibular- and tongue movements (Kjaer 1993). The skeleton undergoes perpetual remodelling, an activity governed by growth factors and cytokines. Also activity, stretching and pressure, from the muscles contributes to the formation and the modelling of the bone (Eriksen 1986, de Vernejoul 1996).

The palate in DS children is often described as high-vaulted and narrow (Westerman et al. 1975) or simply as narrow (Jensen et al 1973). Soft tissue prominences along the palatal lateral surfaces of the maxilla, known as “tectal walls”, persist after preschool age. One suggested explanation is that the hypotonic tongue does not contribute to remodelling of the palatal vault (Cohen 1971, Hansson et al. 1976).

In children with DS eruption of primary teeth is approximately 6 month delayed (Fisher- Brandies 1988), the eruption sequence can be irregular, and the prevalence of tooth agenesis is increased in the primary as well as in the permanent dentition (Jensen 1973, Russel 1995).

Speech and facial expression

Neuromuscular orofacial function is dependant on sensoric information for adjusting the contraction of muscles. The receptors for touch and pressure are well represented in the oral cavity (Weifenbach et al. 1973, Edin et
Speech production can be viewed as a complex neural work of cooperation between primary, secondary and tertiary areas in motor and sensory cortex, cerebellum and subcortical areas (Luria 1973). The feed-forward and the feed back mechanisms in the process of articulation are assumed to play a dynamic role. The proprioception of children with DS is assumed insufficient and the tactile feed back system of articulation may be deficient in children with DS, thus producing a devious mental map of vocal tract and a lack of online feedback information on a movement already begun (Seyfort et al. 1979, Abbs et al. 1991) resulting in reduced control of articulation.

In a study from Finland the relationship between arch dimensions and the occurrence of misarticulation in non-syndromic children with cleft/lip palate was investigated. Misarticulation were associated with narrower and shorter maxillary arches and shallower palates, not with mandibular arch dimensions although (Laitien et al. 1998).

Language acquisition is a part of general enculturation process acquired trough interaction between the linguistic and the general psycho-motor development of the child. It cannot be excluded that the occlusion anomalies and the poor speech skills often found in children with DS are worsened by their deficiencies in oral motor and sensory function. The speech skills and language capacity is often underestimated in the DS children because of articulation problems. They can even be regarded as more mentally retarded than they really are because of these difficulties.

Smile of the infant is a physiologic and automatic reflex used in
communication (Rinn 1984). Facial expression, as a smile, demands motor function and the capacity for conscious sensation, closely associated with the total development of the child. The muscles that control facial expression have their evolutionary origin in the breathing apparatus. Children with DS have an aberrant, often stiff and rigid facial appearance. Lack of vivid expression may be due to slower motor development, hypotonic muscles and difficulties with motor coordination (Limbrock et al. 1990).

Since 1989 children with DS in Sweden are included in a special medical care programme (Pueschel et al. 1995). Each child is under the overall care of a pediatrician in collaboration with a “habilitation team”. Infection status, endocrine factors, hearing and vision are regularly checked. Examination by a pediatric dentist should be performed no later than 6 month of age. Structured speech and communication training with speech therapist and physiotherapy are included.

Oral motor therapy

Castillo-Morales, an Argentinean pediatric neurologist have developed a method for neuro-motor habilitation of disabled children including training with palatal plates (Castillo-Morales 1991). Since the middle of the 1970s the method has also been used mostly in children with DS and cerebral palsy. The orofacial regulation therapy was developed to help the child achieve a position of the tongue and movement patterns as close to normal conditions as possible (Castillo-Morales 1978). The palatal plate is an individually made, removable acrylic device. The plates can be used early-from the age of 5 month. Before the teeth have erupted the plate stays in
position through negative pressure against the mucosa, in the same way as a full denture. When teeth have erupted, the plate is retained with clasps, in the same way as a removable orthodontic device. The plates must be changed regularly so the growth of the maxilla and further eruption of teeth is not influenced. In the early age the plates have to be changed several times a year.

The plate is designed to activate the muscles inside and around the mouth. This is achieved through plastic knobs, rough areas and moveable balls on stainless steel wires. The plate should be used in combination with active oral-motor stimulation. Several studies on the effect of plate therapy on oral motor function have been published, but in most of them no untreated control group have been involved (Fisher-Brandies 1988, Limbrock et al. 1990, Glatz-Noll 1991, Daikoku et al. 2000). Improved tongue position in approximately 50-70% of the treated patients is reported in the studies. Improved mouth closure and oral motor function are also described. In 20 DS-children with a mean age of 55 month a positive effect on initial speech development, as well as improved lip activity and swallowing pattern was found after one year of palatal plate therapy (Hohoff er et al. 1997). Carlstedt et al. (1996) reported indication of palatal plate therapy as a valuable complement to a training program for improving orofacial muscle function. In a randomised controlled trail a positive effect on oral motor function habitual tongue position, facial expression, mouth closure and articulation was found in nine DS-children after 4-years use of palatal plates. The children had a mean age of 10.7 month at the start of training (Carlstedt et al. 2001).
“Speech-, mouth- and oral function in children with Down syndrome” is a project started in 1995. It is a multi-centre, multi-disciplinary study started by a group of pediatric dentists and speech therapists (Bäckman et al. 2003). A project group of children with DS started palatal plate therapy from 6 months of age. At the evaluation at the age of 18 ± 3 month of age there was no differences in oral development or oral morphology between the 42 children with DS in the project and a group of age-matched control-children with DS after use of palatal plates between 6 and 18 months of age (Bäckman et al 2003). A second control group of age-matched children with normal development had more teeth erupted than both the DS children who used palatal plates (p=0.0001) and the control children with DS (p<0.001). All children with normal development except one had normal tongue morphology. Tongue diastase was seen in 12 (30%) of the DS children who had used palatal plates and in 8 (24%) of the control children with DS. Negative overjet or an edge-to edge relation was seen in 12 DS children who had used palatal plates and in 11 DS-children in the control group. All children with normal development had positive values for overjet. No differences were found between the three groups concerning overbite. When the project children were four years old a new evaluation regarding oral morphology and oral motor function was made. At four years of age the normal developed group had 2,8% not erupted teeth, the DS control children 32,2% not erupted teeth and the DS palatal plate children had 16,3% not erupted teeth. Classification of facial expression in the three groups showed differences between the children with normal development and both the groups of
children with DS. In all but one child with normal development facial expression was classified as “Active co-ordinated”, but this was not the case in any of the children with DS. Of the DS-children in the project 22 (66.7%) children had “Active, almost co-ordinated“ or “Active, partly co-ordinated facial expression” compared with 10 (34.5%) of the DS-children in the control-group.
Aim

Many earlier studies of palatal plate therapy indicate positive effects on the craniofacial growth and improved orofacial function. The aim of the study was to evaluate if children with DS and hypotonia, who had used palatal plates from 6 month to 4 years of age, have normalised dimensions of the maxilla compared to children with DS who had never used palatal plates.

Hypothesis

the functional oral-motor stimulation induced by palatal plates will contribute to a normalised growth of the maxilla in children with Down syndrome. In the future this can contribute to normalised occlusion, improved oral motor function and improved speech capacity.
Material and methods

42 DS children in the Speech-, mouth and oral function-project had used palatal plates since 6 month of age. The plates were designed to stabilise the basic tonicity of the oral muscles and to adequate for the age, meet the articulation demands. Their design is based on the progression of sound development in children of the same ages with normal development (Fig 1 a-e)

Fig 1. Design of plates used from 6-48 month of age

a. 6-10 month  

b. 10-14 month  

c. 14-18 month  

d. 18-30 month  

e. 30-48 month

The first plate was designed to retract the tongue and activate the upper lip. To the second plate a tool for activating the tip of the tongue was added. The third plate had the bowl for retracting the tongue and knobs for the upper lip as well as for activating the lateralisation of the dorsal part of the tongue.

The aim for the forth plate was to stimulate the mobility of the anterior part of the tongue by the moveable ball on a stainless steel-wire behind the maxillary incisors. The facial bow is placed as high as possible in the buccal
fold to improve lip-closure by stimulating m. orbicularis oris. If further training to retract the tongue body was necessary, this could be achieved by adding the bowl-shaped elevation in the back of the plate.

The fifth plate had plastic bulbs attached to a facial bow, which is extended laterally in the buccal fold to stimulate lip closure. To stimulate the mobility of the lateral and dorsal parts of the tongue, the plate had a transversal steel-wire with three bends at the borderline between the palate and the velum. A pearl is moved along the wire and placed in a new bend every time the plate is used, so that the tongue is stimulated both medially and laterally.

Five children (DS-ppl) left the project since the evaluation at 18 ± 3 months when the second evaluation was performed at the age of 48± 6 months. The remaining 37 children in the DS-ppl group had used the palatal plates for three and a half year (table 1).

Table 1. Number of children evaluated in the project at the age of four years

<table>
<thead>
<tr>
<th>Examined groups</th>
<th>Age in months</th>
<th>Clinical evaluation</th>
<th>Evaluation of maxillary casts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-group with normal development (N)</td>
<td>49.3 (42-55)</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 girls</td>
<td>12 girls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 boys</td>
<td>16 boys</td>
</tr>
<tr>
<td>Control-group with Down syndrome (DS-c)</td>
<td>49.8 (42-56)</td>
<td>31</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 girls</td>
<td>8 girls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 boys</td>
<td>12 boys</td>
</tr>
<tr>
<td>Project-group with Down syndrome (DS-ppl)</td>
<td>50.6 (44-57)</td>
<td>37</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 girls</td>
<td>11 girls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 boys</td>
<td>16 boys</td>
</tr>
</tbody>
</table>
The 31 age-matched control-children (DS-c) were selected by their habilitation teams in Stockholm, Umeå, Karlstad, Skövde and Gothenburg. Only children with trisomy 21 who had never been treated with palatal plates were included. The 36 age-matched children with normal development (N) were selected from Child Health Centres and the Public Dental Health Service in Stockholm and Umeå. A clinical examination and dental impressions for dental cast were taken. Not all of the clinically evaluated children did cooperate to dental impressions. The number of children and the number of casts that were possible to evaluate is presented in table 1. In all seventy-five casts were available for examination.

The children in both the DS groups were included in the special medical care program for children with DS (Puschel et al. 1995) including speech and communication training with speech therapists. For the DS control group (DS-c) and DS-ppl group the speech and language therapists provided language intervention and oral motor and sensory stimulation in close co-operation with the parents according to methods described by Johansson I (1994).

On the seventy-five cast that were available for evaluation the measurements were made directly on the study casts by using a digimatic calliper "Digital Caliper ISO 9001:2000" (Fig 2) (Al-Dashti et al. 2005). The following measurements were recorded (fig 3) (Al-Wahadni A et al. 2005).

Maximum palatal height was measured with the calliper furnished with a horizontal extension (perpendicular) placed on the cusps of second primary molars (a). Inter-canine length (b) was measured between the cusp tips of
the canines. Arch length was measured as the distance connecting the distal surface of the second primary molars to the labial surface of the most anterior tooth in the arch (c). Anterior arch length was measured between the mesial contact point of the primary central incisors and the point between the canine and the first primary molar (d). Posterior arch length was measured between the canine and the distal surface of the second primary molar (e). Inter-second primary molar distance, palatal width, was measured both at tip of the mesio-lingual cusp (g) and the distance between the gingival margin of these teeth (f).
Fig 3. Distances analysed on study models:

a. maximal palatal depth in the midline at a point between 55 and 65 ml cusp, b. arch width at the canine position- inter canine length,
c. anterior arch length- left and right, d. posterior arch length- left and right,
e. palatal arch width at second deciduous molar/ gingival ridge, g. palatal arch width at second deciduous molar- ml cusps

**Statistical analysis.** In order to determine the reliability of the method, duplicate measurement were made in the casts of a separate group comprising 10 randomly selected subjects. The error of method ($S^1$) was calculated using the formula:

$$S^1 = \sqrt{\frac{\sum d^2}{2N}}.$$  

Where $d$ is the difference between two measurements and $N$ is the number of double determinations. The error was found to vary between 0.6 mm (e left) and 2.7 mm (d left). To compare differences in arch distances between the groups an unpaired Student’s t-test was used.
Results

Occlusal relations registered at the clinical evaluation at 4 years for the three groups are shown in table 2. Posterior cross-bite was significant less common in the palatal plate treated DS group. The children who had used palatal plates had significant less open bite compared to normal developed children. Judgement of occlusion was possible in all the normal developed children and in most of the children with DS (Table 2). A prenormal sagittal relation was significantly (p<0.001) more often diagnosed in both of the DS groups compared with the children with normal development. A posterior lateral cross-bite was more prevalent in the control children with DS then in the project children with DS (p=0.02) and in the children with normal development (p<0.007). The project group (DS-ppl) had a lower prevalence of frontal open bite compared to the children with normal development (p=0.011). In both the DS groups there was a higher prevalence of negative value for overjet and cusp-to-cusp relation (p<0.001) compared to the children with normal development.
Table 2. Occlusal relations at 4 years of age - clinical evaluation. P-values of group comparisons

<table>
<thead>
<tr>
<th>Sagittal relation</th>
<th>Normal development</th>
<th>DS-control</th>
<th>DS-ppl</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a (n=36)</td>
<td>b (n=31)</td>
<td>c (n=36)</td>
<td></td>
</tr>
<tr>
<td>Angle Class I</td>
<td>29</td>
<td>25</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Angle class II</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Angle class III</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>a/b, a/c p&lt;0.001</td>
</tr>
<tr>
<td>Judgement not possible</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Transversal relation</th>
<th>Normal</th>
<th>DS-control</th>
<th>DS-ppl</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>b (n=31)</td>
<td>c (n=36)</td>
<td></td>
</tr>
<tr>
<td>Normal right side</td>
<td>33</td>
<td>19</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Normal left side</td>
<td>30</td>
<td>22</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Posterior crossbite</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>b/c p= 0.02, b/a p= 0.007</td>
</tr>
<tr>
<td>Cusp-to-cusp</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Judgement not possible</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Frontal vertical relation</th>
<th>Overbite</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Cusp-to-cusp</td>
<td>5</td>
<td>8</td>
<td>15</td>
<td>c/a 0=0.001</td>
</tr>
<tr>
<td>Open bite</td>
<td>12</td>
<td>12</td>
<td>6</td>
<td>c/a p=0.001</td>
</tr>
<tr>
<td>Deep bite</td>
<td>19</td>
<td>9</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Judgement not possible</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frontal horizontal relation</th>
<th>Overjet</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cusp-to-cusp</td>
<td>0</td>
<td>7</td>
<td>9</td>
<td>a/b, a/c p&lt;0.001</td>
</tr>
<tr>
<td>Negative</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>a/b, a/c p&lt;0.001</td>
</tr>
<tr>
<td>Positive</td>
<td>36</td>
<td>18</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Judgement not possible</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
There was no statistically significant differences in number of erupted teeth between DS-ppl group and the normal developed group. In the DS-ppl group the mean number of erupted teeth was 19.7, in the group with normal development 19.9 and in the control group of children with DS 19.4. There was a statistically significant difference in number of erupted teeth between the DS control group and the normal developed group of children (p=0.011).

The on the casts measured mean distances, regarding maxillary dimensions at four years of age, are shown in table 3 and 4. Table 3 illustrates the values for the DS children who had used palatal plates and table 4 the DS control children. The analysis of the dental models in this study, showed large differences between the group with normal development and the two DS groups (tables 3, 4).

No significant differences were seen, on the maxillary study models, between the two groups of children with DS, either treated with palatal plates or not.

The transversal width of the dental arch both anterior values (inter-canine distance, b fig. 3) and posterior values (f and g) was in both the DS groups significantly smaller than in the normally developed control group.

The palatal vault was not higher in the DS groups compared to the normally developed control group. Height measured in the midline was lower in the children with DS compared to the normally developed children, the difference was not significant.

In both DS groups palatal height was 11 ± 1.5 m.m. and the mean medial arch length 27 ± 1.9 m.m. The sagittal arch length in the midline was significant smaller in both the DS groups compared to the children with normal development.

There was no difference between females or males regarding arch sizes or palatal height in any if the groups.
Table 3. Measured mean distances for maxillary dimensions in the group of DS children treated with palatal plates (n=27) and the normally developed control group (n=28)

<table>
<thead>
<tr>
<th></th>
<th>DS-ppl</th>
<th></th>
<th>N</th>
<th></th>
<th>DS-ppl/N p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>sd</td>
<td>X</td>
<td>sd</td>
<td></td>
</tr>
<tr>
<td>(a) palatal hight</td>
<td>11.4</td>
<td>1.5</td>
<td>12.6</td>
<td>1.6</td>
<td>0.0104 *</td>
</tr>
<tr>
<td>(b) inter-canine length</td>
<td>25.9</td>
<td>1.8</td>
<td>28.1</td>
<td>2.2</td>
<td>0.0003 ***</td>
</tr>
<tr>
<td>(c) arch-length</td>
<td>26.9</td>
<td>1.4</td>
<td>29.5</td>
<td>1.8</td>
<td>&lt;0.0001 ***</td>
</tr>
<tr>
<td>(d) anterior arch length dx</td>
<td>17.4</td>
<td>2.0</td>
<td>19.3</td>
<td>2.5</td>
<td>0.0039 **</td>
</tr>
<tr>
<td>sin</td>
<td>17.4</td>
<td>1.3</td>
<td>19.2</td>
<td>1.5</td>
<td>&lt;0.0001 ***</td>
</tr>
<tr>
<td>(e) posterior arch length dx</td>
<td>16.6</td>
<td>0.6</td>
<td>17.3</td>
<td>0.8</td>
<td>0.0062 **</td>
</tr>
<tr>
<td>sin</td>
<td>16.8</td>
<td>0.8</td>
<td>17.1</td>
<td>0.7</td>
<td>0.1368 ns</td>
</tr>
<tr>
<td>(f) palatal width – ging.marg.</td>
<td>24.1</td>
<td>2.7</td>
<td>26.4</td>
<td>1.6</td>
<td>0.0007 ***</td>
</tr>
<tr>
<td>(g) palatal width – dental</td>
<td>29.9</td>
<td>2.7</td>
<td>32.5</td>
<td>1.7</td>
<td>0.0001 ***</td>
</tr>
</tbody>
</table>
Table 4. Measured mean distances for maxillary dimensions in the group of DS children never treated with palatal plates (n=20) and the control group with normal development (n=28)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>DS-c</th>
<th>N</th>
<th>DS/N p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) palatal height</td>
<td>11.2</td>
<td>12.6</td>
<td>0.0031 **</td>
</tr>
<tr>
<td>(b) inter-canine length</td>
<td>25.6</td>
<td>28.1</td>
<td>0.0010 ***</td>
</tr>
<tr>
<td>(c) arch-length</td>
<td>27.3</td>
<td>29.5</td>
<td>0.0003 ***</td>
</tr>
<tr>
<td>(d) anterior arch length dx</td>
<td>17.7</td>
<td>19.3</td>
<td>0.0156 *</td>
</tr>
<tr>
<td>(e) posterior arch length dx sin</td>
<td>18.1</td>
<td>19.2</td>
<td>0.0119 *</td>
</tr>
<tr>
<td>(f) palatal width – ging. marg. dx</td>
<td>16.7</td>
<td>17.3</td>
<td>0.0266 *</td>
</tr>
<tr>
<td>(g) palatal width – dental dx sin</td>
<td>16.8</td>
<td>17.1</td>
<td>0.1821 ns</td>
</tr>
<tr>
<td></td>
<td>23.9</td>
<td>26.4</td>
<td>0.0007 ***</td>
</tr>
<tr>
<td></td>
<td>29.1</td>
<td>32.5</td>
<td>0.0001 ***</td>
</tr>
</tbody>
</table>
Discussion

As the life expectancy of individuals with DS has increased in recent years by improved medical care, especially in the field of cardiology, long-term results of different therapeutic approaches are of great interest.

In the clinic, use of palatal plates could in the future mean less orthodontic treatment and less problems for children with hypotonia. This would be a great benefit for the patient, parents and dentists because cooperation problems are common in children with Down syndrome. A normalised occlusion and an improved oral motor function could also improve speech capacity.

In the present study, the children in the control group with DS had fewer teeth erupted than both the children with normal development and the DS children treated with palatal plates. These results are in accordance with Fischer-Brandies (1988) and could possibly be attributed to the stimulation of the palatal plates on the oral mucosa, which might have initiated early tooth eruption in the DS-ppl group. Even though DS children are characterized by late tooth eruption, the present study shows that about 62% of the DS-control children and 84% of the DS-ppl children have all 20 primary teeth erupted at the age of 48 ± 6 months. Since the non-erupted teeth are incisors, it could not be excluded that they are absent because of hypodontia.

Oral motor and sensory training with or without combination with palatal plates does not seem to influence tongue morphology. Since tongue diastase is considered a sign of hypotonia, it has been assumed that oral motor training would decrease the prevalence (Limbrock et al. 1988, Limbrock et
al. 1990). This was not the case in the study presented 2006 from Bäckman et al. Although the prevalence of tongue diastase from the beginning was considerably lower than previously reported.

The aim of the plates is to increase the mobility of the tongue and to stimulate tongue retraction and lip closure. One beneficial effect on occlusion after the training with palatal plates could be the lower prevalence of posterior cross-bite in the DS-ppl children than in the DS control children in the control group (Bäckman et al. 2006). Another positive effect could the higher prevalence of cusp-to-cusp relation and the lower prevalence of frontal open bite in comparison with the children with normal development.

Since the prevalence of sucking habits are the same in the children with normal development and in the DS-children in the palatal plate group, the difference is most probably due to the training with palatal plates.

The consequences of the growth pattern in DS-ppl children (Fischer Brandies 1988) resulting in a prenormal sagittal relation and a negative overjet can not be hindered with palatal plate therapy to this group of DS children.

Active facial expression is important for non-verbal communication, in conveying messages and illustrating shades of meaning. There is a large difference in facial expression between all children with DS and the children with normal development. However, the DS-ppl children did score better than the DS-control children in the evaluation of oral-motor function (Bäckman et al. 2006). In evaluating facial expression, underlying parameters like tongue and jaw position and lip-closure are influenced by training with palatal plates, which should have contributed to the higher
scores in the DS-ppl children. The results are in accordance with Carlstedt et al. 2002.

After use of palatal plates for three and a half year in the DS-ppl group there were no increased or normalised values for maxillary dimensions. This is in agreement with Ehmer and Gundel (1993). They found no influence of palatal plate therapy on palatal growth.

Korbmacher et al. (2002) found in 20 children with DS that early start with palatal plates showed improved orofacial appearance more than 12 years after starting treatment. Children with a pronounced orofacial dysfunction showed a greater palatal plate induced improvement than children with initially moderate orofacial findings.

In an investigation on post palatal plate treatment Korbmacher et al. (2005) found that cephalometric values concerning the maxilla were generally closer to the means of healthy children. These children had started their palatal plate treatment 17 ± 24 months old and at the evaluation they were 13.4 years old (range 8 to 21 years). The children who had used palatal plates in the Korbmarcher study were compared with two control groups from the Fisher-Brandies study 1988. The control groups were sex- and age-matched group of children with DS who had never used palatal plates and one group of healthy children of the same age and sex as in the two DS groups. The comparisons indicated the presence of marked differences in the cranial base parameters and a favourable maxillary growth and a bialveolar protrusion. This indicates that a palatal plate therapy can influence craniofacial growth when evaluated later in life. Maybe the development of the maxilla will continue in a positive way due to the improved oral motor
In this study the result of the measurement of maxillary study models in both the DS groups showed shorter arch length in the front. This could be explained in some cases by missing incisors. Tree of the children in DS-ppl group did not have their canines erupted, one in the DS-c group. This could also contribute in some cases, to the shorter midline length of the maxillary dental arch.

According to Laitien (1998) narrow and short maxillary arches and shallower palate leads to misarticulation. This is the case for children with DS but the results from Bäckman et al. 2006 indicate that oral motor function can compensate for decreased arch size – although the DS-ppl children did not have normalised values in arch dimensions they performed more correct pronunciation.

The posterior dental arch measurements showed smaller values which could not be explained by aplasia of teeth. Maybe smaller tooth sizes (Jensen 1973) could be the explanation- which besides the decreased growth-potential may explain the generally smaller values in dental arch size.

The height of the palate was lower in the DS groups (DS-ppl and DS-c) compared to the normally developed children. In some literature it is suggested that the palatal height is greater then normal and some that the height is smaller. One explanation for describing the palate as higher could be that the tectal vaults make the palate look higher because the palate is narrower.

No measurements of the mandible were made in this evaluation but
occlusion status from the clinical examination was studied (table 1). A
prenormal sagittal relation was significant more often diagnosed in both the
DS groups – which can be a consequence of the smaller maxilla.

Even if the transversal values, palatal arch width measured at second
deciduous molars were not significant normalised the prevalence of cross-
bite was reduced in the DS-ppl group (table 1). This may be a result of the
normalised tonus of the tongue and a dento-alveolar effect on the maxilla
and the mandible.

When palatal plate therapy was introduced in Sweden in the 90ies it became
a popular therapy and because of positive indications on oral motor
function almost every child with DS were offered the method. That is why
all the control children with DS could not be followed longitudinally. So the
DS control group evaluated at four years of age was not the same group of
children as evaluated at 18 months of age. Anyhow it was of great value that
the DS children who had used palatal plate could be compared to an age-
matched untreated group of children with DS.

In conclusion, palatal plate therapy between 6 and 48 months of age in
connection with speech- and language intervention has a positive effect on
occlusion, oral motor function, facial expression and speech. No harmful
effects were observed. No orthopedic effect on the growth of the maxilla was
seen. The short observation time, three and a half year, may be one cause why
no orthopaedic effects were seen after use of palatal plates, at least not when
there is a generally retarded growth as in children with Down syndrome.
The children in the palatal plate group continued to use palatal plates two
more years after the evaluation at four yeast of age. Maybe the prolonged
use of palatal plates can contribute to a normalised growth of the maxilla in the future.

Although a valuable method it must be emphasized, that it puts additional demands on already burdened children and their caretakers.
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