Palatal surgery without denudation of bone favours dentoalveolar development in dogs


Abstract. The present study compared the dentoalveolar development in beagle dogs after palatal repair according to the partially split flap technique and the von Langenbeck method. It was concluded that palatal surgery according to the partially split flap technique resulted in significantly wider transverse distances of the maxillary dental arch than after the von Langenbeck procedure and that its final outcome closely resembled that of the control group.

The facial morphology of patients with cleft lip and palate differs from the non-cleft population. This is caused by three main factors: intrinsic developmental deficiencies, functional distortions, and iatrogenic factors. The last factors are considered to be the major reason for midface hypoplasia in patients treated for clefts. The quantity and distribution of scar tissue which develops as a result of the surgical soft-tissue management are probably responsible for this phenomenon.

Several experimental animal studies have been carried out to get more insight into the effects of repair of lip, alveolus, and/or palate on facial growth. HERPERT-7 was the first to perform experiments on beagle dogs. He concluded from a split-mouth study on five dogs that raising mucoperiosteal flaps and leaving denuded bone exposed to the oral environment resulted in maxillary growth impairment. HERPERT-7 created unilateral soft-tissue and hard-tissue defects in the lip, alveolus, and palate of rabbits and beagle dogs. Growth aberrations were found after surgical repair of the lip and palate, or after lip closure alone.

WIDEVELD et al.15,16 simulated palatal surgery according to the method of von Langenbeck in beagle dogs of different ages in a non-bony cleft model. Their surgical approach resulted in a narrowing of the posterior dental arch which became apparent only after transition of the teeth. This was in contrast to the arch development in control animals, where the posterior teeth tended to be displaced laterally during growth. Histologic evaluation showed that the composition of the palatal scar tissue in the experimental groups remained different from the normal mucoperiosteum, irrespective of the age at which surgery was performed. The scar tissue covering the lateral wound areas adjacent to the posterior teeth lacked large blood vessels and elastic fibres, and showed a mainly transversal orientation of collagenous fibres. The scar tissue was also attached to the underlying bone by Sharpey's fibres, and the mucoperiosteum was continuous with the periodontal ligament. The combination of these factors in a growing animal might result in a medially directed tensile force on the teeth, resulting in narrowing of the dental arch during or after transition. The authors suggested that prevention of scar tissue attachment to the underlying bone after surgery might lead to more favourable dentoalveolar development.

Using the experimental model of WIDEVELD, IN DE BRAEKT et al. attempted to prevent scar tissue attachment by separating scar tissue and palatal bone by implantation of biocompatible and biodegradable membranes. Premature degradation of the mem-
branes influenced the results negatively, but, by improvement of the material characteristics of the membranes, the development of Sharpey's fibres might be prevented. It remains still to be proven that membrane implantation precludes growth inhibition.

Apart from the use of biodegradable membranes, scar tissue attachment by Sharpey's fibres may also be prevented by modification of the surgical technique of palatal repair. Leenstra et al.13 developed a partially split flap technique to prevent denuded bony areas after surgery (Fig. 1). This technique is a combination of the mucosal palatal flap technique used by Perko14 and the von Langenbeck technique. A study on beagle dogs found that, in contrast to the von Langenbeck procedure, the partially split flap technique largely prevented the development of Sharpey's fibres. The scar tissue in the lateral parts of the palate of the latter group was demarcated only vaguely, and the palatal bone consisted of normal lamellar bone.

The aim of this study was to compare the dentoalveolar development in beagle dogs after palatal repair according to the partially split flap technique and that of von Langenbeck.

Material and methods

Animals

The experiments were performed on 22 beagle dogs. In experimental group 1 (n=10; age 12 weeks), palatal surgery used the partially split flap technique. In experimental group 2 (n=6; age 12 weeks), palatal repair according to von Langenbeck was simulated, as previously described by Windels et al.15. Six dogs (age 12 weeks) served as controls.

Surgical procedures

Prior to the surgical procedures, the animals were premedicated with 0.5 ml Thalamonal® (fentanyl, 0.05 mg/ml plus droperidol 2.5 mg/ml; Janssen Pharmaceutica, Beerse, Belgium) and 0.5 ml atropine (atropine sulphate 0.5 mg/ml). Subsequently, they were anaesthetized with an intravenous injection of 30 mg/kg Narcovet® (sodium pentobarbital 60 mg/ml; Apharmo, Arnhem, The Netherlands). After intubation, anaesthesia was maintained with Ethrane® (enflurane 15 mg/ml; Abbott, Amstelveen, The Netherlands). The oral mucosa and the dentition were cleaned with chlorhexidine digluconate 1% in water. In addition, approximately 6 ml Xylocaine® (lidocaine hydrochloride 0.4 mg/ml plus adrenaline 0.0125 mg/ml; Astra Chemicals, Rijswijk, The Netherlands) was injected into the palatal mucoperiosteum to avoid excessive bleeding during surgery.

In all experimental animals, a standardized soft-tissue defect was created in the medial region of the palate by incising, elevating, and removing an elliptically shaped mucoperiosteal flap. This flap extended distally from the canines to the region of the hard palate, distally of the primary third molars. The maximum width of the flap was one-third of the transverse distance between the primary first molars.

In the dogs in which surgery was performed by the partially split flap technique (Fig. 1), the mucoperiosteum was elevated from the medial side of the bone to localize the greater palatine foramen and the major palatine neurovascular bundle in order to prevent its damage during surgery. On both sides of the palate adjacent to the posterior teeth, the mucoperiosteum was incised for half of its thickness. These incisions reached from canine to primary third molar. Horizontal cleavage of the mucoperiosteum was then performed in a medial direction, until the split area was at least half the size of the soft-tissue defect in the midline. A vertical incision was then made in the deep layer of the mucoperiosteum reaching to the bone. Subsequently, the medial part of the mucoperiosteum was mobilized in full thickness. The partially split flaps were repositioned medially, and the soft-tissue defect was closed and sutured in one layer with 4-0 Vicryl. The areas of the palate adjacent to the dentition thus remained covered with the deep layer of the mucoperiosteum. No additional protec-
tion of the wounds or measures to adapt the flaps to the underlayer were used.

In the dogs in which palatal repair according to von Langenbeck was simulated (Fig. 2), relaxation incisions reaching to the bone were made on both sides of the palate adjacent to the posterior teeth, and the remaining palatal mucoperiosteum was elevated from the underlying bone with a small rasp.

Table 1. Interobserver errors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transversal distances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C, P1</td>
<td>0.07-0.13 mm</td>
<td>0.11 mm</td>
</tr>
<tr>
<td>P2</td>
<td>0.35-0.50 mm</td>
<td>0.45 mm</td>
</tr>
<tr>
<td>P3, P4, M1</td>
<td>0.09-0.22 mm</td>
<td>0.15 mm</td>
</tr>
<tr>
<td>Arch depth</td>
<td>0.12-0.22 mm</td>
<td>0.17 mm</td>
</tr>
<tr>
<td>Tipping</td>
<td>0.08-0.31 mm</td>
<td>0.14 mm</td>
</tr>
<tr>
<td>Rotation</td>
<td>1.3-2.1°</td>
<td>1.8°</td>
</tr>
<tr>
<td>Arch form</td>
<td>0.8-1.0°</td>
<td>0.9°</td>
</tr>
</tbody>
</table>

Fig. 3. Schematic drawing of maxillary primary dentition with measuring points.

Fig. 4. Schematic drawing of maxillary permanent dentition with measuring points.

The major palatine neurovascular bundle was not damaged during the operation. The soft-tissue defect in the midline was closed and sutured in one layer with 4-0 Vicryl, leaving two areas of denuded bone adjacent to the dentition.

All experimental animals were medicated preoperatively with 1 ml of Albinpen® 15% (ampicillin anhydrate 150 mg/ml; Mycoform, de Bilt, The Netherlands) and maintenance doses of 1 ml Albinpen® LA (ampicillin anhydrate 100 mg/ml; Mycoform, de Bilt, The Netherlands) on days 2 and 4 postoperatively. All animals received a normal diet after surgery.

Dental casts

Alginate impressions (CA 37®; Cavex, Haarlem, The Netherlands) of the maxilla of all animals were taken at 12 weeks of age at the start of the study or prior to surgery, and at 15, 17, 19, 22, and 25 weeks of age. For this purpose, the animals were premedicated each time with 0.5 ml Thalamonal® (fentanyl 0.05 mg/ml plus droperidol 2.5 mg/ml) and 0.5 ml atropine (atropine sulphate 0.5 mg/ml). Subsequently, they were anaesthetized with an intravenous injection of 15 mg/kg Nesdonal® (thiopental sodium 50 mg/ml). The alginate impressions were poured out within 2 h.

The following measuring points were defined on the dental casts for the primary as well as for the permanent dentition (Figs. 3 and 4):

Midpoint (mid): midpoint between central incisors
Tip points: tips of right and left canines; primary first, second, and third molars; permanent first, second, third, and fourth premolars; permanent first molars

Crest points: mesial and distal crests at gingival margin of right and left primary first and second molars; permanent first, second, and third premolars

The coordinates of the measuring points were digitized with a Reflex Microscope® (Reflex Measurement, London, UK). Inevitably, due to the transition period, some measuring points were missing at some ages. All series of dental casts were measured by one observer. For determination of the measurement error, 35 dental casts were digitized by two independent observers. The coordinates of the measuring points in the primary and permanent dentition were used to calculate the following categories of variables.

Table 2. Results of multiple regression analysis for comparison of transversal and sagittal distances in permanent dentition of experimental groups and control group at age of 25 weeks. Differences are given at P<0.025 level

<table>
<thead>
<tr>
<th>Variable</th>
<th>C</th>
<th>1</th>
<th>2</th>
<th>Significant difference</th>
<th>Residual SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transversal distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC tip</td>
<td>35.3</td>
<td>36.5</td>
<td>33.9</td>
<td>1 &gt; 2</td>
<td>1.6</td>
</tr>
<tr>
<td>CC mesial crest</td>
<td>26.8</td>
<td>27.5</td>
<td>26.1</td>
<td>1 &gt; 2</td>
<td>0.8</td>
</tr>
<tr>
<td>P1P1 mesial crest</td>
<td>27.5</td>
<td>28.6</td>
<td>24.4</td>
<td>1, C &gt; 2</td>
<td>1.2</td>
</tr>
<tr>
<td>P1P1 tip</td>
<td>30.5</td>
<td>31.9</td>
<td>27.5</td>
<td>1, C &gt; 2</td>
<td>1.1</td>
</tr>
<tr>
<td>P1P1 distal crest</td>
<td>30.8</td>
<td>32.4</td>
<td>28.7</td>
<td>1, C &gt; 2</td>
<td>1.2</td>
</tr>
<tr>
<td>P2P2 mesial crest</td>
<td>28.6</td>
<td>29.0</td>
<td>25.6</td>
<td>1, C &gt; 2</td>
<td>1.1</td>
</tr>
<tr>
<td>P2P2 tip</td>
<td>33.0</td>
<td>32.8</td>
<td>28.1</td>
<td>1, C &gt; 2</td>
<td>1.7</td>
</tr>
<tr>
<td>P2P2 distal crest</td>
<td>33.1</td>
<td>34.2</td>
<td>29.8</td>
<td>1, C &gt; 2</td>
<td>1.4</td>
</tr>
<tr>
<td>P3P3 mesial crest</td>
<td>32.4</td>
<td>29.4</td>
<td>28.7</td>
<td>C &gt; 2</td>
<td>2.0</td>
</tr>
<tr>
<td>P3P3 tip</td>
<td>28.5</td>
<td>36.4</td>
<td>35.6</td>
<td>C &gt; 1, 2</td>
<td>1.0</td>
</tr>
<tr>
<td>P3P3 distal crest</td>
<td>42.3</td>
<td>43.1</td>
<td>40.3</td>
<td>1 &gt; 2</td>
<td>1.6</td>
</tr>
<tr>
<td>P4P4 tip</td>
<td>48.5</td>
<td>48.9</td>
<td>46.4</td>
<td>1, C &gt; 2</td>
<td>1.4</td>
</tr>
<tr>
<td>M1M1 tip</td>
<td>50.3</td>
<td>49.9</td>
<td>48.3</td>
<td>C &gt; 2</td>
<td>1.4</td>
</tr>
<tr>
<td>Arch depth (M1mid)</td>
<td>71.9</td>
<td>75.5</td>
<td>72.3</td>
<td>1 &gt; 2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

1 = experimental group 1 (partially split flap technique).
2 = experimental group 2 (von Langenbeck technique).
C = control group.
Palatal repair in beagle dogs

Fig. 5. A) Dental cast of control dog at age of 25 weeks. B) Dental cast of dog at age of 25 weeks of partially split flap group. C) Dental cast of dog at age of 25 weeks of von Langenbeck group. Omega shape of arch is more pronounced.

determination of the arch depth and the line through the mesial and distal crests of individual teeth. This was calculated for the same teeth as mentioned for tipping.

**Arch form.** The arch form was expressed as the outer angle between the line through the tip of the most posterior tooth and the tip of the primary first molar or its successor, and the line through the tip of the primary first molar or its successor and midpoint. The angles were calculated for both sides of the dental arch.

**Statistical procedures**

Individual correction factors were used for the following categories of variables: transversal distances, and arch depths for all the animals. Thus were eliminated initial differences in size which were present despite randomization at the start of the study. Thereafter, multiple regression analyses were used to compare these variables with the Bonferroni correction, leading to $a=0.025$ per test. Tukey's multiple comparisons test was used to compare the variables tipping, rotation, and arch form of the different groups, because these variables did not need correction of the initial values.

**Results**

**Reproducibility**

No significant systematic differences were found between the two independent observers for the five categories of variables, i.e., transversal distances, arch depths, tipping, rotation, and arch form. For the range and the standard errors, see Table 1. The accuracy of the method was considered to be acceptable.

**Dental cast measurements**

The relevant results of the multiple regression analyses are presented in Table 2. At the age of 12 weeks, at the start of the study, no significant differences between the groups were detected for any of the categories of variables, except for tipping of the first primary molar on the left side, which had more tip in group 2 than in group 1. At the ages of 15, 17, 19, and 22 weeks, in general, no significant differences were found; therefore, these data are omitted in Table 2. At the age of 25 weeks, the transversal distances of group 2 were, in general, significantly smaller than in both group 1 and the control group. Group 1 had a significantly larger arch depth than the control group. In comparison of the variable arch form, Tukey's multiple comparisons resulted in a significantly smaller outer angle for group 2 than group 1, indicating a more omega-shaped arch form than for group 1. All groups were comparable for the variables tipping and rotation.

**Discussion**

Dentoalveolar development in growing beagle dogs was compared after palatal repair according to the partially split flap technique and according to von Langenbeck's procedure. The presence of a bony palatal cleft was not essential for the aim of the study, as primary closure of a human palatal cleft is generally achieved by mucoperiosteal manipulation alone, rather than by osseous surgery. The essential difference between the two surgical techniques used in the present study is that the von Langenbeck procedure results in areas of denuded bone adjacent to the posterior teeth, while denuded bone is avoided with the partially split flap technique.

Wound healing after surgery was without any problems in both experimental groups. This supports the results of an earlier study by Leenstra et al.\(^{13}\) which stated that in both techniques the risk of flap necrosis is almost nil, if correctly performed.

As in man, palatal closure in the dogs was performed when the primary dentition was still functioning. The dogs were followed until the age of 25 weeks when the transition of the dentition is completed. The dental arch width in beagle dogs hardly increases after the age of 25 weeks, as was shown by
WIDEVELD et al. Therefore, there was no need to study the dogs after the age of 25 weeks.

At the age of 25 weeks, transversal distances in the partially split flap technique group and the control group were, in general, significantly larger than in the von Langenbeck group (Fig. 5). The other variables of both groups were comparable. The results for the von Langenbeck group are comparable to those in other studies8,17, although there were some differences. For example, in the present study, the transversal width in the area of the first permanent molars after simulated von Langenbeck surgery was significantly smaller than in the control animals. This is in contrast to the results of IN DE BRAEKT et al.4,8, but it resembles the results of the von Langenbeck group operated at the age of 16 weeks, as described by WIDEVELD et al.17, DIJK et al.4 found no inhibition of maxillary growth after repair of palatal defects in 8-week-old beagle dogs, apparently in contrast to our results. In their study, however, the dogs were followed only until the age of 20 weeks, meaning that at the end of their study the transition of the teeth was not yet completed and growth was still continuing. As shown in the present study, the effect of palatal surgery becomes apparent only at the age of 25 weeks.

Earlier studies17,18 suggested that prevention of scar tissue attachment to the underlying bone might lead to more favourable dentoalveolar development. For this reason, the partially split flap technique was designed, which has been shown to cause less scar tissue with no attachment to the underlying bone19. This may explain the present finding that palatal surgery according to the partially split flap technique leads to normal transverse development of the maxillary dental arch.

The results of this study show that palatal surgery in which no denudation of palatal bone takes place favours dentoalveolar development in dogs.

References


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