Original Article

Orthodontic Anchorage Implants Inserted in the Median Palatal Suture and Normal Transverse Maxillary Growth in Growing Dogs:

A Biometric and Radiographic Study

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Abstract: Small osseointegrated implants inserted in the palate provide a reliable anchorage control during orthodontic treatment. When these implants are inserted in the median palatal suture in growing individuals, the possible effects on normal transverse maxillary growth are still unknown. Therefore, the aim of this study was to evaluate the influence of orthodontic anchorage implants on transverse maxillary growth when inserted in the median palatal suture of growing dogs. Five growing dogs were used, one of them randomly selected as a control dog. The test dogs each received two implants in the median palatal suture. Impressions and occlusal radiographs of the upper jaws were taken at baseline (T0), after 84 days (T1), and at the end of the study after 168 days (T2). Measurements to compare increases in maxillary width between test dogs and control dog were performed on study casts and occlusal radiographs at T0, T1, and T2. Restricted transverse growth was observed in the test dogs in the canine region. Transverse growth in the region of second and fourth premolars was similar for the test dogs and the control dog. These results may be of some clinical relevance when orthodontic anchorage implants are to be inserted in growing individuals. An alternative insertion site, for example the parasagittal region, should be considered in these cases, to avoid possible negative effects on normal transverse maxillary development. (*Angle Orthod* 2005;75:826–831.)

Key Words: Implants; Orthodontics; Growth; Median palatal suture

INTRODUCTION

Anchorage control is a fundamental problem in the treatment of dental dysgnathia. Additional anchorage aids such as headgear and intermaxillary elastics can be used, but have the disadvantages of visibility, compliance dependence, and the risk of undesirable side effects. Not all patients are cooperative enough to rely on these types of anchorage aids.[1]

To minimize the effect of the patient's compliance on treatment outcome, implants could be used to provide extra anchorage. Different devices, all belonging to the infinite anchorage group, have been developed. These are all osseointegrated, subperiosteal or transosteal orthodontic implants. Osseointegrated implants constitute excellent anchorage for even the most complicated types of tooth movement because they do not show any clinically significant reactive movement to orthodontic forces. Case reports,[2,3] prospective clinical studies[4] as well as experiments on animals[5,6] have shown that osseointegrated implants remain positionally stable, even under orthodontic loading conditions. They can thus be used as orthodontic anchorage elements in the maxillofacial complex.

The following insertion sites for pure orthodontic anchorage implants have been described:

- The interradicular septum;[2,3]
- The supra-apical and infrazygomatical area;[3,7]
- The retro molar area in the mandible;[8]
- The median or para median anterior palate.[9–12]

During normal growth, the upper jaw is continuously expanding in a transverse direction.[13] Transverse

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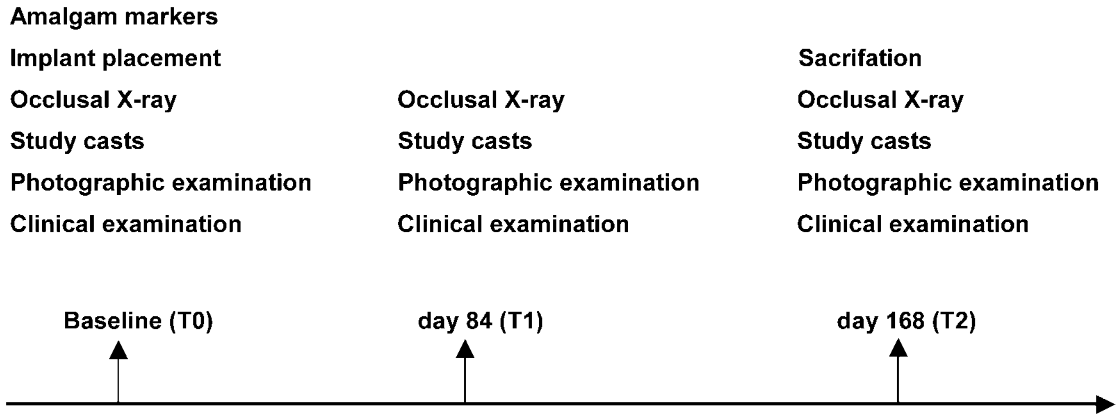

FIGURE 1. Research design.

growth of the maxilla is the result of the combination of two processes. Appositional remodeling of the alveolar processes leads to the expansion of the dental arches. Growth in the median suture leads to expansion of the palate. The growth in the median suture is more important than appositional remodeling in the development of maxillary width.[14] Björk and Skieller found an average growth in maxillary width of three mm between ages 10 to 18 years, as measured on radiographs between posterior implants in nine boys.[15] As long as growth processes in the palatal suture are not completed, there is still some potential for growth.

Therefore, the question arises whether or not the insertion of orthodontic anchorage implants in the median palatal suture may influence normal transverse growth. Because of ethical considerations, such investigations can only be carried out in animals.

Therefore, the aim of this study was to evaluate the potential influences of orthodontic anchorage implants, inserted in the median palatal suture on normal transverse maxillary growth, using the growing dog as the experimental model.

MATERIALS AND METHODS

The anchorage device evaluated in this study was the palatal orthodontic implant anchor of the Orthosystem® (Straumann AG, Waldenburg, Switzerland). The implant was inserted into the median area of the anterior palate.

Experimental animals

Five male adolescent beagle dogs (6.5 months old) from the same mother were used. One of them was randomly selected as the control dog. The dogs were housed in the animal center of the Free University of Brussels. Throughout the experimental period, general health of the dogs was checked by a veterinarian, who was also responsible for general anesthesia at the surgical procedure and the evaluation time points. The treatment of the experimental animals was approved by the Ethic Committee for Research on Animals of the Free University of Brussels.

Experimental design

The duration of the experiment was 168 days. The research design is outlined in Figure 1.

Surgical procedure

The insertion of the implants was performed under general anesthesia. The dogs were first sedated with an intramuscular injection of 0.5 ml Domitor (Orion Corporation, Espoo, Finland) and five mg/kg ketamine (Sanovi, Hannover, Germany). Subsequently, they were brought under general anesthesia with an intravenous injection of 5–7 mg/kg Nembutal (Sanovi).

The four test dogs each received two orthodontic anchorage implants (Orthosystem®, Straumann AG) in the median palatal suture. One implant was inserted just behind the canines between two rugae and another one at the level of the second premolars, between the two rugae (Figure 2). All implants were placed by one surgeon according to the procedure described by Wehrbein et al.[11] The endosseous part of all implants used in this study had a length of four mm and a diameter of 3.3 mm.

Clinical registration

All five dogs were followed daily by a veterinarian and weighed every six weeks. The health state of the dentition and the mucogingiva as well as the implants (mobility and sound upon percussion) was evaluated every six weeks, and color slides were taken.

Biometric evaluation

At baseline, day 84, and day 168, impressions of the upper jaws were obtained with individually made

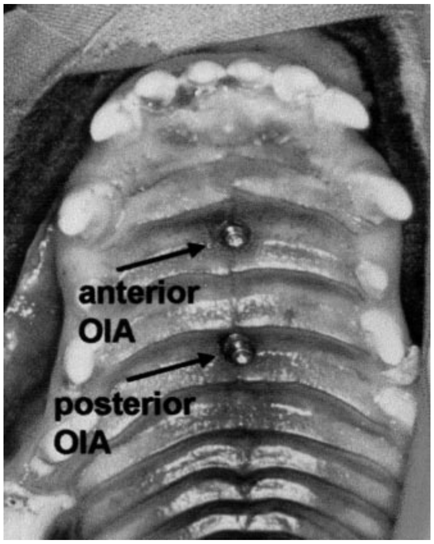

FIGURE 2. Implants inserted in the median palatal suture at the level of the canines, anterior orthodontic implant anchor (OIA) and at the level of the second premolars, posterior orthodontic implant anchor (OIA).

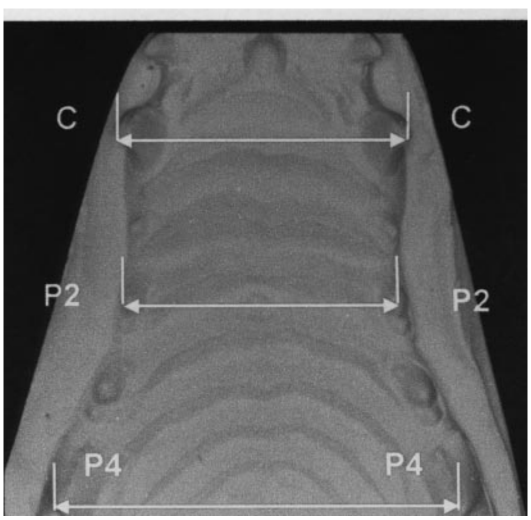

FIGURE 3. Measurements performed on the study casts.

trays. Evaluation of transverse growth was performed using measurements on the study casts (Figure 3). The cusp tips were marked with a sharp pencil and the distances between the corresponding teeth were measured. The following distances were assessed, to the closest 0.1 mm, using a digital caliper:

- Distance between cusp tips of upper canines (C-C);
- Distance between mesial cusp tips of upper second premolars (P2-P2);
- Distance between mesial cusp tips of upper fourth premolars (P4-P4).

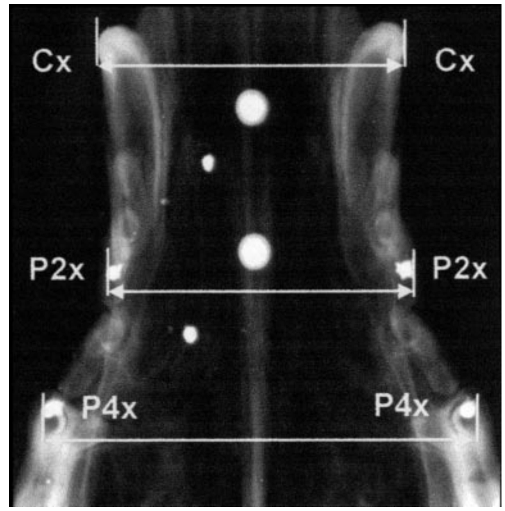

FIGURE 4. Measurements performed on the occlusal radiographs.

Radiographic assessments

At baseline, day 84, and day 168, standardized occlusal radiographs of the upper jaws were obtained with a dental X-ray machine (Philips secondent oralix, 65 kV, 7.5 mA; Gendex division, Milano, Italy), using Kodak screens and Agfa films (green sensitive, medical; Agfa Gevaert NV, Mortsel, Belgium). The film was placed in the mouth in contact with the upper canines and upper fourth premolars. A special device was developed to take standardized radiographs. The distance between focus and film was kept constant.

To study the development and growth of the jaws in transverse direction on the occlusal radiographs, amalgam markers (fillings) were placed in the occlusal surfaces of upper second and upper fourth premolars in all five dogs.

Reference points used for measurements on the occlusal radiographs are shown in Figure 4. The following distances were assessed to the closest 0.1 mm, using a digital caliper:

- Distance between buccal projections of upper canines (Cx-Cx);
- Distance between buccal outlines of amalgam fillings in second premolars (P2x-P2x);
- Distance between buccal outlines of amalgam fillings in fourth premolars (P4x-P4x).

Reproducibility of measurements

To eliminate interexaminer bias, all measurements were carried out by the same investigator (Dr Asscherickx). The intraexaminer reproducibility of the measurements on the study casts and the occlusal radiographs was tested by repeated measurements at a two-week interval on all study casts ($N = 3 \times 5$) and all radiographs ($N = 3 \times 5$).

Individual correction factor

Individual correction factors were used for the transverse distances for all animals. The individual standardization factor was defined as the quotient of the mean value of all five dogs and the individual initial value. These individual correction factors were applied for all measurements at T1 and T2. Thus initial differences in size, which were present at the start of the study were eliminated.

Statistical analysis

To evaluate the correlation between the first and second measurements on study casts and occlusal radiographs, Pearson correlation test was applied. For the measurements, only mean values and associated standard deviations were calculated because of the restricted number of experimental animals.

RESULTS

Clinical registration

All five dogs remained in good health throughout the experimental period. Except for one test dog, all dogs gained some weight during the first 18 weeks of the experimental period, indicating that they were still growing. During the last six weeks of the experiment, all dogs lost some weight.

All anterior implants revealed primary stability directly after insertion. One of the four posteriorly placed implants had a slight mobility directly after insertion, whereas the other three posteriorly placed implants revealed no mobility. On day 42, three of the four posterior implants and one of the four anterior implants were lost.

Reproducibility

Repeated analysis resulted in a highly significant correlation for the measurements on the study casts as well as on the occlusal radiographs. The Pearson correlation coefficient (r) for the different distances measured were 0.99 (C-C), 0.99 (P2-P2), 0.99 (P4-P4), 0.99 (Cx-Cx), 0.98 (P2x-P2X), and 0.99 (P4x-P4x).

Biometric analysis

Because one test dog lost both anterior and posterior implant, this dog was excluded from the test group. Only the three test dogs, which still had the anterior implant in place at the end of the study, were included.

Table 1 demonstrates the means and standard deviations of the adjusted distances, as measured on the study casts. In the control dog, all distances measured, increased during the six-months experimental period, indicating that there still was growth potential of the maxilla in transverse direction. Growth was most pronounced in the region of the canines (increase of 3.9 mm). In the region of the second premolars, almost no increase in transverse distance was found (increase of one mm). In the region of the fourth premolars, a slight increase in transverse distance was found (increase of three mm).

TABLE 1. Mean and Standard Deviations (SD) of Adjusted Dental Arch Distances as Measured on the Study Casts (mm)

		Test dogs		Control dog
Distance	Time	Mean	SD	Value
C-C	T0	36.6	0	36.6
	T1	37.6	0.4	39.5
	T2	38.0	0.3	40.5
	T2-T0	1.4	0.3	3.9
P2-P2	T0	35.0	0	35.0
	T1	36.0	0.4	35.7
	T2	36.2	0.2	36.0
	T2-T0	1.2	0.2	1.0
P4-P4	T0	51.2	0	51.2
	T1	53.1	0.4	53.7
	T2	53.8	0.2	54.2
	T2-T0	2.6	0.2	3.0

The average increase in transverse distances in the test dogs was comparable with those for the control dog in the region of the second and fourth premolars. Transverse distance in the region of the second premolars increased by 1.2 mm on average in the test dogs, compared with one mm in the control dog. In the region of the fourth premolars, transverse distance increased by 2.6 mm on average for the test dogs, compared with three mm in the control dog. However, in the region of the canines, a certain difference was found. Transverse width between canines increased by 3.9 mm in the control dog, compared with only 1.4 mm on average in the test dogs.

Radiographic assessments

For the same reason, explained in the results of the biometric analysis, only three test dogs were taken into account. Table 2 demonstrates the means and standard deviations of the adjusted distances as measured on the occlusal radiographs. In the control dog, all distances measured, increased during the six-months experimental period, indicating that there still was growth potential of the maxilla in transverse direction. Growth was most pronounced in the region of the canines (increase of 2.4 mm) and the fourth premolars (2.8 mm). In the region of the second premolars, almost no increase in transverse distance was found (increase of one mm).

The average increase in transverse distances in the

TABLE 2. Mean and Standard Deviations (SD) of Adjusted Dental Arch Distances as Measured on the Occlusal X-rays (mm)

Distance	Time	Test dogs Mean	Test dogs SD	Control dog Value
Cx-Cx	T0	39.7	0	39.7
	T1	40.4	0.4	41.9
	T2	40.8	0.4	42.1
	T2-T0	1.1	0.4	2.4
P2x-P2x	T0	39.3	0	39.3
	T1	39.8	0.4	40.3
	T2	40.1	0.3	40.3
	T2-T0	0.8	0.3	1
P4x-P4x	T0	53.0	0	53.0
	T1	54.3	0.2	55.5
	T2	54.9	0.6	55.8
	T2-T0	1.9	0.6	2.8

test dogs was comparable with those for the control dog in the region of the second and fourth premolars. Transverse distance in the region of the second premolars increased by 0.8 mm on average in the test dogs, compared with one mm in the control dog. In the region of the fourth premolars, transverse distance increased by 1.9 mm on average for the test dogs, compared with 2.8 mm in the control dog. However, in the region of the canines, a certain difference was found. Transverse width between canines increased by 2.4 mm in the control dog, compared with only 1.1 mm on average in the test dogs.

DISCUSSION

The design of this study was an adaptation of the study conducted by Ödman et al.[16]

Ödman used six pigs (five test pigs, one control pig) to investigate the effect of osseointegrated implants on vertical dentoalveolar development. The examination period took 165 days (five months) and evaluation was done using study casts and radiographs. To this extent, the study of Ödman and this study are comparable.

The only difference between both studies is the age of the animals upon insertion (the pigs were 12 weeks old, the dogs were six months old) and the insertion site (in the alveolar process in the pigs, in the median palatal suture in the dogs.)

In the study of Ödman et al,[16] a total of 20 fixtures were inserted. Six of the fixtures were lost during the experiment. The failure rate is comparable with that of our study. A similar explanation of preloading can be given because the dogs (the pigs in Ödman's study) were allowed to eat directly after surgery and the animals had adverse biting habits on the cage framework (pigs) and their baskets (dogs).

Three of the four posterior implants were lost during

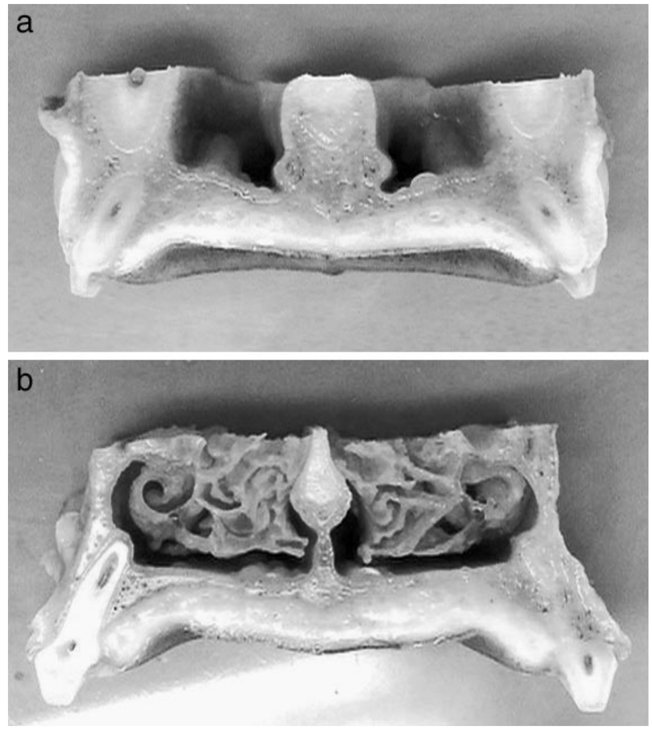

FIGURE 5. Macroscopic image of the section of the palate at the level of the (a) anterior orthodontic implant and (b) posterior orthodontic implant.

the first 42 days of the experimental period despite the fact that two of these lost implants showed primary stability directly after insertion. This was probably because of a lack of bone height (quantity) in this region. On the macroscopic section of the specimens, it was clearly seen that not enough bone was available in the posterior region to allow for adequate osseointegration (Figure 5).

Test dog 2 lost both anterior and posterior palatal implant within the first 42 days after insertion. Therefore, this dog was excluded from the test group. In this dog, both implants were placed one ruga more posteriorly than in the other dogs, which supports the hypothesis that bone height (quantity) reduces further in posterior direction. However, this dog exhibited the same restriction in normal expansion in the canine region. A possible explanation is that the suture was disturbed during the insertion of the implant and that, when the anterior implant was lost, a bone bridge was formed or that the cells in the suture did not have the time to recover from the trauma to allow further growth. Further histological evaluation is needed to support this hypothesis.

At the start of the examination period, all permanent teeth were erupted. However, the root development was not completed. Therefore, the developmental stage could be classified as adolescent at the beginning of the experimental period and might correspond to an age of between 12 and 14 years in humans.

The restriction in normal transverse expansion of the maxilla as seen in the test dogs seems to be of some clinical relevance only in the canine region. The clinical effect on the normal transverse expansion of the palate by implants in the suture in the regions of the premolars is negligible.

An explanation for the difference in increase in width between the canine region and premolar region might be the fact that, at the beginning of the study, the median palatal suture in the posterior region was more closed than in the anterior region, as can be seen on the occlusal radiographs (Figure 4). The effect of the palatal implants in the suture on the normal transverse expansion in the regions of the premolars was less pronounced than in the canine region. Probably, the increase in transverse width at the level of the fourth premolars is mainly caused by appositional remodeling of the alveolar processes.

Deficient transverse maxillary width could cause maxillary arch length discrepancies, as for example canine impaction.[17] Therefore, all interventions that might cause a restriction in normal transverse maxillary growth should be avoided. Because it is shown in this study that the insertion of implants in the median palatal suture in adolescent beagle dogs could cause some restriction in normal clinically relevant transverse development, it might be considered better to insert the orthodontic palatal implants parasagittally in growing individuals. Further studies are needed to evaluate possible influences on normal transverse maxillary growth, when the implants are inserted parasagittally. Unfortunately, the beagle dog cannot be used as experimental model to study this question because no sufficient bone height (quantity) is available parasagittal to insert implants in this region.

CONCLUSIONS

- The insertion of orthodontic anchorage implants in the median palatal suture in adolescent beagle dogs could cause a restriction of the normal transverse expansion of the maxilla in the canine region.
- Whether sutural growth in beagle dogs is comparable with sutural growth in humans is not proven. However, it is advised to take safety measurements to avoid possible negative effects on growth and development, and therefore, it is considered more safe to insert the orthodontic palatal implants in the paramedian (parasutural) area of the anterior palate, in growing individuals, to prevent interactions with potential residual intermaxillary suture growth changes (transverse plane).

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