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Contribution of interdigitation to the occlusal development of the dentition in *Macaca fascicularis*

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SUMMARY The contribution of interdigitation to the development of the dentition of juvenile *Macaca fascicularis* was studied on a series of dental casts and at the histological level by the use of vital staining. Fourteen laboratory-born monkeys were allocated to a control group (n = 7) or an experimental group (n = 7). They were followed from 31 to 152 weeks of age. In the animals of the experimental group, interdigitation was eliminated by gradually grinding the cusps of the molars and canines in both dental arches as soon as possible after emergence.

Silicone impressions of the dental arches of each monkey were taken at regular intervals. Two experimental and two control animals received vital staining at regular intervals and were processed for histological evaluation at the end of the experimental period.

Changes over time in the dimensions of the dentition were analysed. Locally, the maxillary dental arch in the experimental group broadened significantly faster than in the control group. No significant differences between the experimental and the control group were found for any of the mandibular parameters.

The experimental intervention also led to less prevalence of anterior open bite in the experimental group than in the control group.

It is concluded that interdigitation plays a role in the development of the maxillary dental arch and does not seem to affect mandibular dental arch development.

Introduction

Interdigitation probably plays a role in the coordination of the development of the mandibular and maxillary dental arches (Schwarz, 1951; Van der Linden, 1983). The cone-shaped cusps of the maxillary posterior teeth and the crater-like occlusal anatomy of their antagonists are held responsible for a guided emergence toward each other by the so-called cone-funnel mechanism (Schwarz, 1951).

Possibly, this mechanism also exerts its influence beyond the dentition, as was hypothesized by Brace (1977). He supposed that intercuspal relationships act as a guidance system for the developing face. This is in agreement with Petrovic and co-workers (Petrovic *et al.*, 1975; Stutzmann and Petrovic, 1976; Petrovic and Stutzmann, 1977) who concluded from a series of experiments in rats that occlusion is an important factor in the coordination of jaw growth, in contradiction to Kantomaa and Rönning (1985) who did not find any evidence for such a regulation system.

Van der Linden in 1986 developed a more elaborate hypothesis stating that once occlusal contact is established, further transverse development of the maxillary dental arch and its surrounding maxillary structures is regulated by the mandibular dentition by means of interdigitation. Owing to the rigidity of the mandibular basal anatomy and the already mineralized symphysis, the mandibular dental arch would function as a mould or a rail to which the maxillary dental arch would adapt. By this so-called rail-mechanism, normal inter-arch relations are maintained under varying skeletal relationships by the 'dento-alveolar compensatory mechanism' (Solow, 1980). Consequently, elimination of interdigitation would result in a disturbance in the development of the maxillary arch, but it would not affect mandibular dental arch development.

An opposite view was expressed by Zingeser (1973), who stated that facial capsules are the determinants for facial configuration and hence for the gross orientation of the maxillary dento-alveolar region. The more accurate orientation is, in his opinion, mediated by neuro-muscular mechanisms. In his concept, the mandible and its dentition will accommodate to a so-called upper occluso-facial component which implies guidance of the mandibular growth and dento-alveolar development by the maxilla. This would mean that elimination of interdigitation results in a disturbance of the development of the mandibular dental arch and a normal maxillary development.

All experimental studies on this subject (Petrovic *et al.*, 1975; Stutzmann and Petrovic, 1976; Petrovic and Stutzmann, 1977; Kantomaa and Rönning, 1985) deal with interference of the dento-facial development by surgical intervention or orthopaedic devices in animal models with a normal interdigitation. The present study was designed the other way round, with the purpose of investigating the contribution of interdigitation to maxillary and mandibular dental arch development in growing *Macaca fascicularis* monkeys by only eliminating interdigitation. The effects of this intervention were studied by measurements on a series of dental casts and by histological evaluation.

Materials and methods

Experimental set-up

Eleven male and three female laboratory-born crab-eating monkeys (*M. fascicularis*) were randomly assigned to a control group (n = 7) and an experimental group (n = 7), after balancing for dental development, dental arch dimensions, and age. The sexes were combined in the analysis of the data, as sexual differences in *M. fascicularis* are found only after 3 years of age (Swindler and Sirianni, 1973), which is beyond the scope of this study. One male monkey of the control group died accidentally after 1 year.

All selected animals had a neutro-occlusion of the posterior teeth and a nearly end-to-end occlusion in the anterior region. None of the animals had a malocclusion or a skeletal deviation.

At the start of the study, the mean age of the animals was 31 weeks. At that age, crypt formation of the mandibular permanent canines had just started and the second deciduous molars had recently emerged (Ostyn *et al.*, 1995a). The study lasted until 153 weeks of age. Figure 1 shows the sequence of the emergence of the teeth during the experimental period. These data are partly based on Ostyn *et al.* (1995a) and partly on Bowen and Koch (1970).

The animals were housed in the Central Animal Laboratory of the University of Nijmegen, The Netherlands, and they received a standard diet of wet compressed pellets and drinking water *ad libitum*.

Anaesthesia

Prior to all experimental interventions or the taking of impressions of the dentition, the animals were premedicated with 10 mg/kg ketamine (Nimatek®, A.U.V., Cuijk, The Netherlands). Subsequently, general anaesthesia was induced by 0.1 ml Thalamonal® (Janssen Pharmaceutica, Beerse, Belgium) and 0.25 mg atropine (Atropine Sulphate, A.C.F. Pharma B.V., Maarssen, The Netherlands) intra-muscularly.

Experimental intervention

In the animals of the experimental group, interdigitation was eliminated in several subsequent sessions by gradually grinding the cusps of the deciduous molars, first permanent molars and the deciduous canine tips in both dental arches as soon as possible after emergence until a flat surface was obtained. The grinding did not affect the approximal contact points. The canine cusps were ground as much as possible without jeopardizing the vitality of the pulp.

Dental casts and measurements

Silicone impressions (Xantropren®, Bayer, Leverkusen, Germany) of the jaws were taken every 3 weeks during the first part of the study. Once the maxillary first molars had reached the occlusal plane, impressions were taken every 6 weeks. Impressions were poured the same day as they were taken.

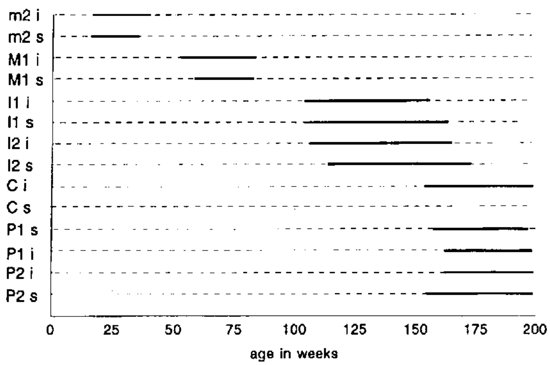

Figure 1 Graphic presentation of ages (ranges) of emergence of teeth between 25 and 200 weeks of age.

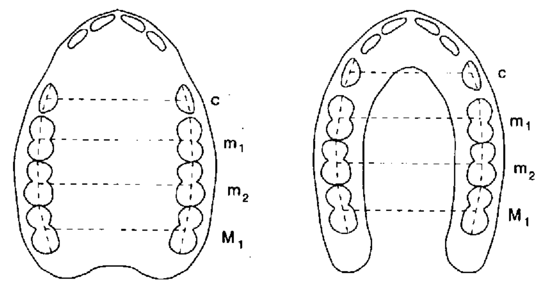

Figure 2 Schematic drawing of the upper and lower jaw and their dental arches after emergence of the first permanent molars, showing the measuring points.

Measurements on the dental casts were performed using an Optocom measuring table, equipped with a microscope, resulting in ×10 magnification (Van der Linden *et al.*, 1972). Each dental cast was orientated in a Cartesian coordinate system with the *y*-axis as a line through the central incisor point (CIP = mid-point between the mesial anatomical contact points of the central incisors) and the middle of the two distal-most measuring points at the right and left side of the dental arch, and the *x*-axis as a perpendicular to the *y*-axis through the central incisor point. The position of each tooth was digitized as the midpoint between the anatomical contact points. Where a diastema existed, these points were defined as the most mesial and most distal points of a tooth (Figure 1). All measurements were performed by the same observer (I.H.). For the determination of the total error of the method, the dental casts of one younger and one older monkey were measured twice. The measurement error was calculated as $\sqrt{(\Sigma\, diff^2/2N)}$.

To study transverse development of the dental arches in both jaws, increments of the following distances between the posterior teeth were calculated parallel to the *x*-axis and recorded in µm/week: the distance between the deciduous canines (c–c), the distances between the deciduous first and second molars (m_1–m_1 and m_2–m_2), and the distance between the permanent first molars (M_1–M_1) (Figure 2). To analyse the differences in the transverse development of the jaws, the increments of corresponding transverse maxillary and mandibular dental arch dimensions were compared.

The antero-posterior dental arch changes were studied by calculating the increments of the distances between the central incisor point and the lines connecting contralateral teeth parallel to the *x*-axis in µm/week: CIP – line c–c, CIP – line m_1–m_1, and CIP – line m_2–m_2.

The differences in antero-posterior changes between the jaws were analysed by comparing the antero-posterior increments of corresponding parameters in the mandibular and the maxillary dental arch.

The vertical development in the anterior region was scored using a 5-point scale: 1 = severe open bite, distance between mandibular and maxillary incisors ≥ 2 mm; 2 = mild open bite, distance between mandibular and maxillary incisors > 0 and < 2 mm; 3 = end-to-end bite, mandibular and maxillary incisors in vertical contact; 4 = mild overbite, vertical overlap between mandibular and maxillary incisors > 0 and < 2 mm; 5 = severe overbite, vertical overlap between mandibular and maxillary incisors ≥ 2 mm.

Scoring was performed at casts taken at 31, 103 and 153 weeks of age by one observer (J.M.O.). As the results were rather surprising, it was decided to perform an additional cross-sectional survey in an existing colony of *M. fascicularis* monkeys. This colony comprised 27 animals from 6 months to nearly 4 years of age. The anterior vertical relation in each individual was determined intra-orally using the same 5-point scale as described above by one observer (J.M.O.).

Histological procedures

In two animals of the control group and two animals of the experimental group, four fluorescent vital stains: 90 mg/kg xylenol orange (Fluka Chemie A.G., Buchs, Switzerland), 7 mg/kg calcein (Fluka Chemie A.G.), 30 mg/kg alizarine (Fluka Chemie A.G.) and 30 mg/kg tetracycline (Gist Brocades, Delft, The Netherlands) were used. Sequences of these dyes were administered intravenously every 9 weeks under general anaesthesia, resulting in a polychrome sequential labelling.

The animals were sacrificed 2 weeks after the last labelling was performed at 152 weeks of age. They were anaesthetized, as described previously, and subsequently 0.5 mg/kg heparin (Thromboliquine®, Organon Teknika, Boxtel, The Netherlands) was administered intravenously, followed by a lethal dose of Thalamonal after some minutes. The thorax of the animals was opened and the vascular system was perfused via the arch of the aorta with physiologic saline followed by 4 per cent neutral formaldehyde as a fixative.

After perfusion, the maxilla and the mandible were dissected out and immersed in 4 per cent neutral formaldehyde. They were then cut into small blocks. One side of each maxilla and mandible was used to obtain sagittal sections, and the contralateral side to obtain transverse sections. In both animals of each group the sides were alternated. From each side of the jaws, alternate blocks were decalcified in 20 per cent formic acid and 5 per cent sodium citrate, dehydrated and embedded in Paraplast® (Monoject Medical Inc., Athy, Ireland). From these blocks, sections of 7 μm were prepared and stained with haematoxylin and eosin. The other blocks were not decalcified, but embedded in poly-methyl-methacrylate (PMMA), and sections were cut at 15 μm and examined using fluorescence microscopy. Thus, decalcified as well as undecalcified sections were obtained from all parts of the maxilla or mandible.

General tissue survey and qualitative evaluation of bone deposition and resorption were carried out on decalcified sections; semi-quantitative evaluation of the amount of tooth migration, as reflected by the growth and remodelling of alveolar bone, was performed on undecalcified sections. Distances between the dye marker lines were estimated using an ocular micrometer and a conversion factor to obtain real distances. The mean of the distances in μm between the dye marker lines was calculated for different sides of the teeth in the vertical and mesio-distal direction.

Incisors and canines were not included in this part of the study, as transition of these teeth complicated the situation in such a way that no relevant observations could be made.

Statistical procedures

Statistical analysis was only performed for the measurements on the dental casts. For dental arch width measurements, the experimental period was divided into two periods: the first period from 31 to 76 weeks of age, before the first permanent molar could be used in the measurements; and the second period from 87 to 153 weeks of age in which the first permanent molars were included. Data collected in the intervening period could not be used due to a large variation in timing of emergence of the first permanent molar. For the dental arch depth measurements, the period from 31 to 102 weeks of age was analysed. Thereafter, transition of the incisors took place and calculation of dental arch depth was no longer possible.

To compensate for size differences among the animals, an analysis of co-variance was performed. For calibration of the transverse measurements, the mean of the distances between the centres of the maxillary and mandibular first deciduous molars of each monkey at 31 weeks of age was used. For calibration of the depth measurements, the mean of the distances at 31 weeks of age between the central incisor point and the maxillary and mandibular first deciduous inter-molar line was used.

The paired *t*-test was used to analyse differences between the two periods within each group. Student's *t*-test was used to analyse differences between the control and the experimental group.

Table 1 Mean increments in µm/week ± SD over the first, second, and total period of the transverse distances between corresponding teeth. Differences between periods: ($) = $0.05 \leq P < 0.1$, $ = $P < 0.05$. Differences between groups: * = $P < 0.05$.

	Control				Experimental			
Age (weeks)	Deciduous canines	First dec. molars	Sec. dec. molars	First perm. molars	Deciduous canines	First dec. molars	Sec. dec. molars	First perm. molars
Maxillary arch width								
31–76	45 ± 19	46 ± 15$	23 ± 17		50 ± 6($)	46 ± 11	24 ± 18	
87–153	37 ± 11	25 ± 12$	30 ± 10	13 ± 6	38 ± 12($)	36 ± 14	42 ± 18	19 ± 16
31–153	39 ± 10	33 ± 10	29 ± 7*		42 ± 8	41 ± 5	40 ± 7*	
Mandibular arch width								
31–76	27 ± 20	32 ± 14	30 ± 22		42 ± 21	37 ± 16	38 ± 12	
87–153	41 ± 10	27 ± 9	25 ± 11	22 ± 11	44 ± 14	30 ± 17	30 ± 18	26 ± 17
31–153	35 ± 10	27 ± 10	25 ± 11		41 ± 13	34 ± 13	34 ± 10	

Results

Error of the method

The total error of the measurements on the dental casts was calculated separately for the transverse and the antero-posterior dimensions. For antero-posterior distances, the error of the method was approximately 40 µm, for the transverse distances about 100 µm. These values were considered to be acceptable.

Transverse dental arch changes (Table 1)

The mean growth rates did not differ significantly between the two periods, except for the maxillary first deciduous molar width in the control group, which increased more slowly in the second period than in the first.

The mean rate of the increase of any distance for any period was higher in the experimental than in the control group. However, the only significant difference between the control group and the experimental group was the increase in the maxillary second deciduous molar width over the total period, which was higher in the experimental than in the control animals. In the mandible no significant differences were found, between the periods, or between the groups.

Histological sections of the control animals showed that bone was resorbed at the cervico-palatal area of the maxillary first permanent molars (Figure 3) and bone apposition took place at the apico-palatinal area indicating palatal tilting of the teeth. Bone deposition in the experimental animals was found at the cervico-palatal (Figure 4) as well as at the apico-palatal area of the maxillary first permanent molar, suggesting buccal drift.

In both the experimental and the control animals, bone apposition was found at the lingual side and bone resorption at the buccal side of the mandibular teeth.

Transverse inter-arch differences (Table 2)

The mean differences in the rate of widening of upper and lower dental arches were analysed in both groups. Comparison of the two age periods revealed significant changes in the control group. The inter-canine width and the first deciduous inter-molar width in the control group increased faster in the maxilla than in the mandible in the first period. In the second period, this difference was reduced significantly.

Comparing the findings of the control and the experimental group for the whole period, no significant differences were found. However, if the analysis of co-variance was involved, to compensate for initial size differences, the difference between the growth rates of the maxillary and the mandibular inter-canine width was significantly larger in the control than in the

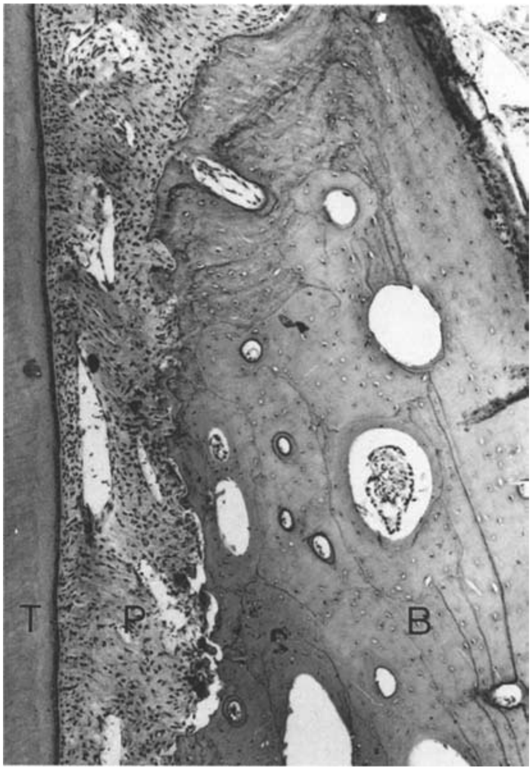

Figure 3 Low-power photomicrograph of a transverse paraffin section of the cervico-palatal region of the maxillary first permanent molar of a control animal showing osteoclastic resorption in the cervico-palatal region. H and E staining, ×25. T = tooth, P = periodontal ligament, B = alveolar bone.

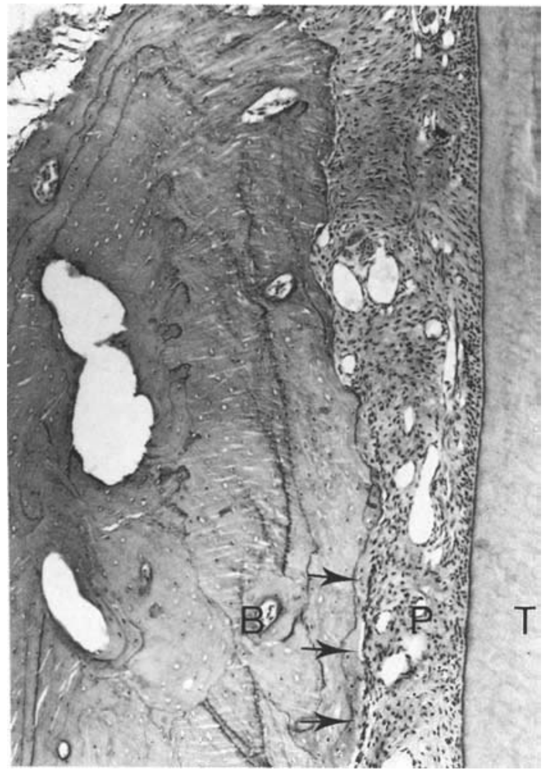

Figure 4 Low-power photomicrograph of a transverse paraffin section of the apico-palatal region of the maxillary first permanent molar of an experimental animal showing resting osteoblasts (arrows). H and E staining, ×25. T = tooth, P = periodontal ligament, B = alveolar bone.

experimental group, indicating that the maxillary expansion in the experimental group was faster than in the control group.

Antero-posterior dental arch changes (Tables 3 and 4)

Elimination of interdigitation did not result in any significant change in the rate of increase in depth of both dental arches. Calculation of the differences between maxillary and mandibular antero-posterior increments revealed that the increase in dental arch depth was larger in the maxilla than in the mandible. Compared to the control group, this difference in the experimental group was significantly larger in the canine region and nearly significantly larger in the region of the second deciduous molar.

Histological evaluation showed, in the control as well as in the experimental animals, a distinct mesial drift at the end of the experimental period. Despite regular labelling, only the last two dye markers could be evaluated for all sites, since most previous labels were lost due to remodelling of the alveolar bone or to bone resorption in the vicinity of the deciduous molars caused by erupting premolars. However, gradual differences were found in the undecalcified sections. Mesial drift of any control tooth was larger than that of the corresponding experimental one (Figures 5 and 6), and the difference between the control and the experimental animals in mesial tooth movement tended to be larger for the maxillary than for the mandibular teeth (Figure 7).

Anterior vertical changes (Figures 8 and 9)

At the start of the experiment, all animals showed an anterior end-to-end bite. At the age

Table 2 Mean differences in increments of the maxillary and mandibular transverse distances in μm/week ± SD over the first, second, and total period. Positive values indicate an excess of maxillary transverse growth over the mandibular one; negative values the reverse. Differences between periods: \$ = $P < 0.05$.

	Differences in transverse increments							
	Control				Experimental			
Age (weeks)	Deciduous canines	First dec. molars	Sec. dec. molars	First perm. molars	Deciduous canines	First dec. molars	Sec. dec. molars	First perm. molars
31–76	20 ± 22\$	15 ± 12\$	−9 ± 18		6 ± 23	10 ± 20	−14 ± 27	
87–153	−5 ± 11\$	−2 ± 8\$	7 ± 9	−8 ± 14	−6 ± 10	4 ± 10	13 ± 17	−6 ± 21
31–153	5 ± 8	6 ± 7	3 ± 9		−0 ± 9	7 ± 7	5 ± 9	

Table 3 Mean increments in μm/week ± SD over the period from 31 to 102 weeks of age of the antero-posterior distances between the central incisor point and the respective teeth. There were no significant differences between groups.

	Control			Experimental		
	Dec. canines	First dec. molars	Sec. dec. molars	Dec. canines	First dec. molars	Sec. dec. molars
Maxillary arch depth	26 ± 16	27 ± 18	24 ± 20	35 ± 8	35 ± 7	35 ± 7
Mandibular arch depth	10 ± 9	16 ± 11	15 ± 13	8 ± 5	16 ± 5	16 ± 4

Table 4 Mean differences in increments of the maxillary and mandibular antero-posterior distances in μm/week ± SD over the period from 31 to 102 weeks of age. Positive values indicate an excess of maxillary antero-posterior growth over the mandibular one; negative values the reverse. Differences between groups: (*) = $0.05 \leq P < 0.1$, * = $0.01 \leq P < 0.05$.

	Differences in antero-posterior increments					
	Control			Experimental		
Age (weeks)	Dec. canines	First dec. molars	Sec. dec. molars	Dec. canines	First dec. molars	Sec. dec. molars
31–102	14 ± 8*	11 ± 11	9 ± 11(*)	26 ± 8*	19 ± 6	20 ± 7(*)

of 103 weeks in the control group, three out of seven animals had developed a mild or severe open bite. At 153 weeks, these three animals showed a severe open bite, two others a mild open bite and only one animal showed an end-to-end relation (Figure 8). The development in the anterior region was different in the experimental group. At the end of the experimental period, only one out of seven animals showed a severe open bite, five still showed an end-to-end relation and one animal even showed a slight overbite (Figure 8).

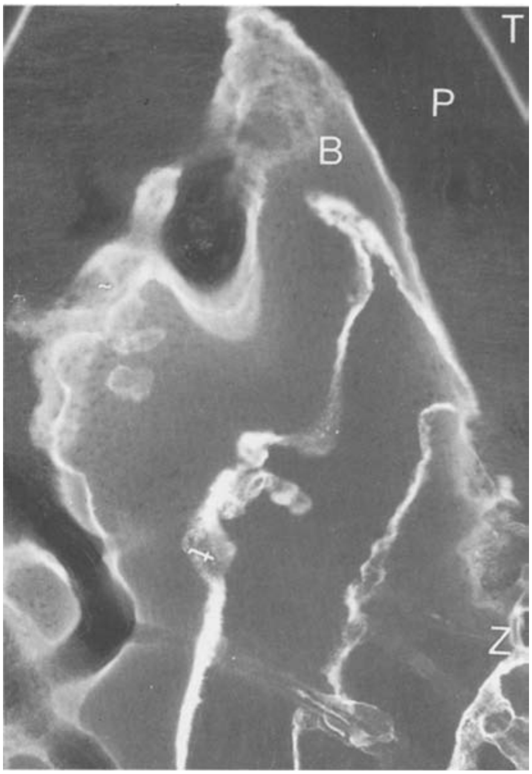

Figure 5 Low-power photomicrograph of a sagittal undecalcified section of the interradicular septum of the maxillary first permanent molar of a control animal. Unstained, ×20. T = tooth, P = periodontal ligament, B = alveolar bone.

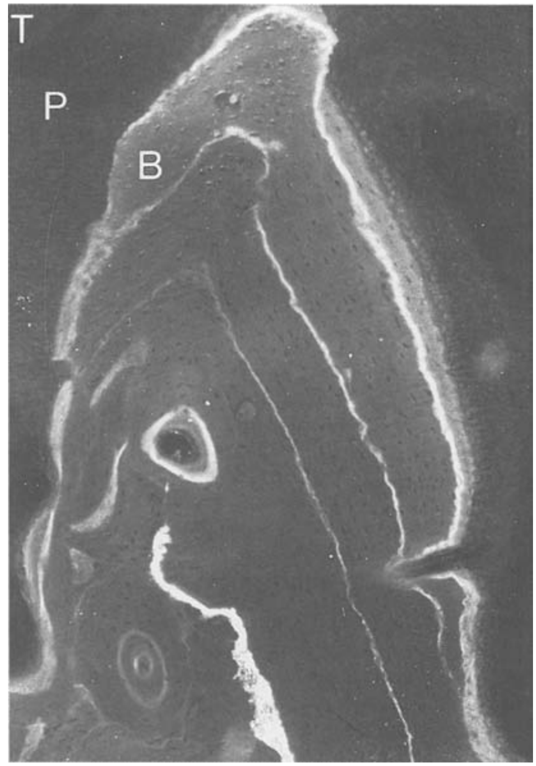

Figure 6 Low-power photomicrograph of a sagittal undecalcified section of the interradicular septum of the maxillary first permanent molar of an experimental animal. Unstained, ×20. T = tooth, P = periodontal ligament, B = alveolar bone.

The additional survey of an existing colony of normal *M. fascicularis* monkeys showed that in these animals a tendency to the development of an open bite also existed. The percentage of animals with an open bite increased at least until the age of over 3 years (Figure 9).

Posterior vertical changes

Posterior vertical tooth movements were best observed in undecalcified sections. It appeared that all those teeth moved in an occlusal direction, although at different rates. The vertical movements of the posterior control teeth seemed to be somewhat faster than the corresponding experimental ones in the period encompassing the histological evaluation. The total amount of vertical migration was about the same for all teeth histologically observed in a jaw except for the mandibular permanent first molar which, especially in the control animals, moved faster than the others (Figures 5, 6 and 10).

Discussion

The role of interdigitation in the coordination of the development of the dentition was studied in growing *M. fascicularis* monkeys. These animals are considered to be a good experimental model, as their occlusal morphology and development is comparable to that in man (Van der Linden, 1971; Moffett, 1973; Sirianni, 1985; Watts, 1985; Enlow, 1990) in spite of apparent limitations and differences (Moore and Lavelle, 1974; Smith and Minium, 1983).

Interdigitation was eliminated in the experimental animals by gradually grinding the cusps, while in the control animals the dentition was left undisturbed. The effect of this intervention on

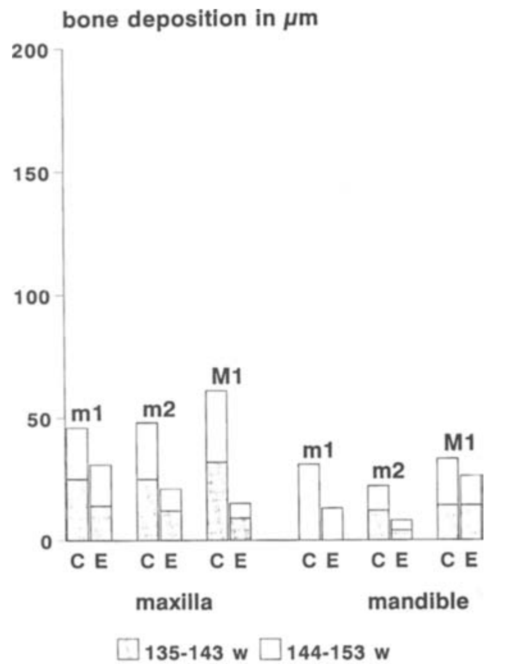

Figure 7 Mean distance in μm between the marker lines for the last two periods, indicating mesial drift of the teeth involved. C = control group, E = experimental group, m_1 and m_2 = first and second deciduous molar, M_1 = first permanent molar.

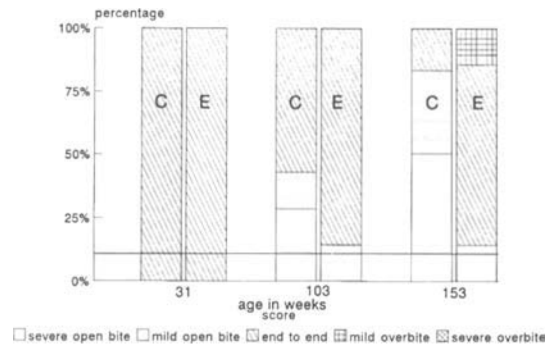

Figure 8 Histogram showing the development of the anterior occlusal relation. C = control group, E = experimental group.

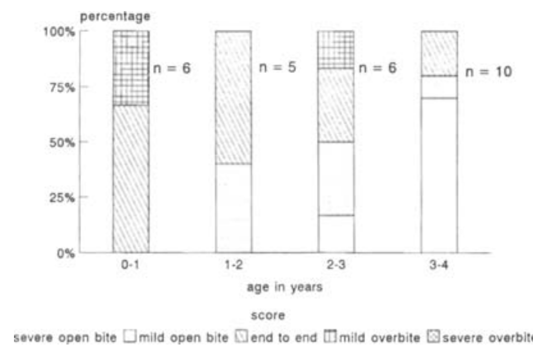

Figure 9 Histogram showing the development of the anterior occlusal relation in the additional normal colony of *M. fascicularis*.

the development of the dentition was studied by measurements on a series of dental casts and by histological evaluation.

The transverse development is more or less constant throughout the whole experimental period as only one significant difference was found between the two sub-periods for any transverse parameter in both groups.

The transverse development of the dentition was only slightly affected in the experimental group. The only significant difference was found for the increase in distance between the maxillary second deciduous molars which was faster in the experimental animals than in the controls if the whole experimental period was considered. Although the mean increase in all other transverse distances was also faster in the experimental than in the control group, none of these differences were significant.

The histological findings showed that the maxillary permanent molars in the control group underwent a palatal tilting, indicating a restraining effect by the mandibular dentition, which was in contrast to the findings in the experimental group. The absence of palatal tilting under experimental conditions indicated a tendency to an increased widening of the upper dental arch in the absence of interdigitation, as confirmed by the dental cast measurements. According to Björk and Skieller (1976), a relative palatal movement also occurs in humans and they assumed that in the human situation this is due to the fact that the posterior segments of the dento-alveolar arch undergo a mesial migration which is directed inwards over a mesially narrowing jaw base. In *M. fascicularis*, however, no such mesially narrowing jaw base exists in the posterior region (Figure 2) and, therefore, the results suggest that in these animals the relative palatal movement is merely due to interdigitation.

The larger buccal movement of the maxillary

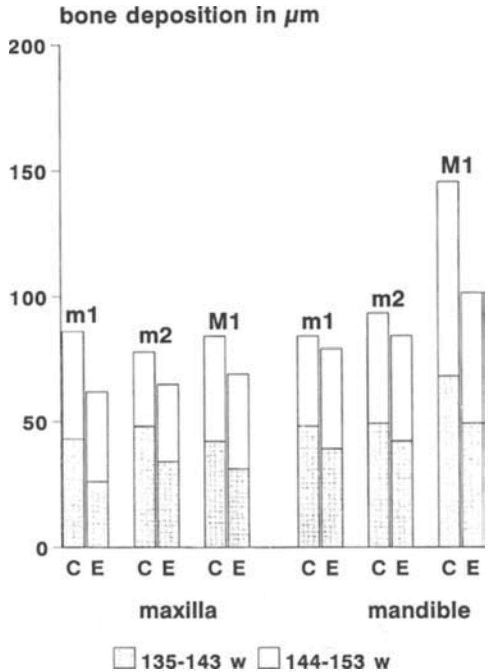

Figure 10 Histogram showing the mean distances between the marker lines in μm in a vertical direction indicating alveolar bone deposition. C = control group, E = experimental group, m_1 and m_2 = first and second deciduous molar, M_1 = first permanent molar.

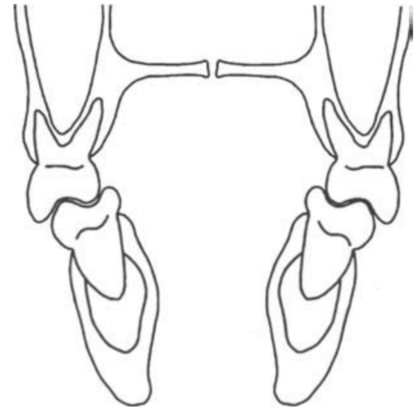

Figure 11 Schematic drawing illustrating the transverse jaw proportions in *M. fascicularis*.

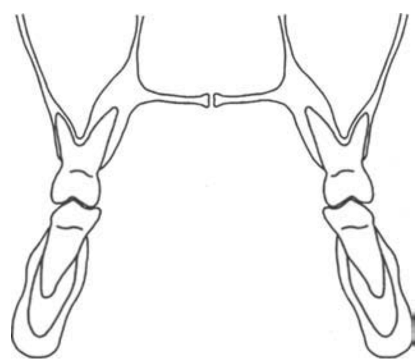

Figure 12 Schematic drawing illustrating the transverse jaw proportions in humans.

permanent molars under experimental conditions indicates a passive movement with the growing alveolar bone, the growth rate of which is unaffected by experimental intervention (Ostyn *et al.*, 1996). The passive movement in the absence of interdigitation indicates a restraining effect of the mandibular dentition in the control group (Ostyn *et al.*, 1996). No such findings, however, were encountered for the deciduous molars in the maxilla, probably due to wearing of the occlusal surface of the deciduous molars, which mimicked the experimental interference.

In contrast to the situation in *M. fascicularis*, in humans lack of vertical contact in the lateral segments is usually associated with a narrow maxillary dental arch. This can be explained by differences in the transverse proportions of the jaws in *M. fascicularis* and humans. In *M. fascicularis*, the maxillary base is wider than the mandibular one, while in humans the opposite is true. Assuming that the mandibular dentition acts as a mould for the development of the maxillary one (Van der Linden, 1986), this means that in *M. fascicularis* the posterior mandibular dentition has a restraining effect on the widening of the maxillary dental arch, while in humans the widening of the maxillary dental arch is favoured by the mandibular dentition. This phenomenon is also illustrated by the lingual inclination of the posterior teeth in the maxilla and the buccal inclination in the mandible, as found in *M. fascicularis* (Figure 11), and the reverse inclinations in humans (Figure 12).

Another situation seems to exist in the region of the deciduous canines and the first deciduous molars. The differences between the transverse growth rate of the maxilla and the mandible underwent a significant change from the first to the second period in the control group. In the experimental group, this phenomenon was not found and the rate of increase in inter-canine and first deciduous inter-molar widths was similar for the maxilla and the mandible in both sub-periods. These findings suggest that grinding of the cusps results in a relatively smaller maxillary c–c distance in the experimental than in the control group. This means that the maxillary canines in the control group possibly are pushed in a lateral direction by their erupting mandibular antagonists.

Measurements on dental casts revealed that the increase in maxillary dental arch depth tended to be faster in the experimental than in the control group, while for the mandibular dental arch these rates were similar in both groups.

The difference in mesialization between the control and the experimental animals also tended to be larger for the maxillary than for the mandibular teeth. This was in agreement with findings from a previous study (Ostyn *et al.*, 1995b) in which measurements on lateral radiographs revealed a tendency to a dental and skeletal Class III relationship after elimination of interdigitation, while this was not the case in normal animals. Grinding of the dentition therefore had an influence on its development in the transverse and in the antero-posterior direction. This contradicts the findings of Kantomaa and Rönning (1985), but supports the ideas of Petrovic and co-workers (Petrovic *et al.*, 1975; Stutzmann and Petrovic, 1976; Petrovic and Stutzmann, 1977). As the elimination of interdigitation apparently does not influence any of the mandibular parameters, it is likely that the mandibular dentition develops independently of interdigitation and that it usually acts as a mould or rail for the adaptive maxillary dentition. This finding is in favour of the rail-mechanism concept of Van der Linden (1986) and contradicts the hypothesis of Zingeser (1973) on this point.

An anterior open bite developed during the experimental period in all animals of the control group except one. Elimination of interdigitation in the experimental group seemingly impeded the development of an anterior open bite. The development of an anterior open bite during growth seems to be a normal feature in *M. fascicularis*, as was confirmed by additional observations in a sample of 27 normal *M. fascicularis* from 6 months to over 3 years of age. As the dental development in the control and the experimental groups agreed, the absence of this phenomenon in the experimental group is probably related to the fact that the normal vertical displacement of the maxillary structures in the experimental group was affected (Ostyn *et al.*, 1995b). This results in a more pronounced counter-clockwise rotation of the mandible and a more end-to-end relationship in the anterior region.

It can be concluded that elimination of interdigitation leads to changes in the development of the maxillary dental arch. The mandibular dental arch seems to develop independently of any occlusal interference and might play a guiding role in the normal development of the maxillary dental arch by means of interdigitation. This is in accordance with the rail-mechanism as suggested by Van der Linden (1986).

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