

Response of the Midface to Treatment with Increased Vertical Occlusal Forces

G. Altuna

D. G. Woodside

treatment and posttreatment
effects in monkeys

Posterior occlusal bite blocks of varying thicknesses inserted in seven juvenile and six adolescent monkeys resulted in changes in maxillary position and dental intrusion.

KEY WORDS: • FUNCTIONAL APPLIANCE • GROWTH • OCCLUSAL FORCE •

Since ancient times, man has frequently shown interest in changing the craniofacial morphology for cultural and esthetic purposes (Fig. 1). In recent times, considerable attention has been focused on the response of maxillary position to orthodontic and orthopedic forces applied to the maxillary teeth. Experimental work has shown that forces applied to the teeth create tensile and compressive deformations and strains in the adjacent bones (ENDO 1970, HENRY 1973, FISHER ET AL. 1976, BROUSSEAU AND KUBISCH 1977, BRANDT ET AL. 1979, KRAGT ET AL. 1979, ALTUNA 1982). Primate experiments indicate that maxillary position is changeable and the circum-maxillary sutures are affected by forces applied to the maxillary teeth. It has also been shown that the maxilla can be displaced posteriorly as well as anteriorly (DELLINGER 1973, KAMBARA 1977, NANDA 1978, JACKSON ET AL. 1979) with the use of fixed orthodontic appliances.

Previous studies of the effects of functional appliances on maxillary position have not evaluated the force levels created within the stomatognathic system by different vertical openings used in the various types of functional appliances, the significance of changes in direction of occlusal forces generated by vertical open-

Author Address:

Drs. G. Altuna and D. Woodside
Orthodontic Department
Dental Faculty
University of Toronto
124 Edward Street
Toronto, Ontario
CANADA

Dr. Altuna is Assistant Professor, Orthodontic Department, Dental Faculty of the University of Toronto, Ontario, Canada. He holds a D.D.S. degree from the Dental Faculty of the University of Istanbul, Dr. Med. Dent. from the University of Bonn, Germany, Specialty degree from the University of Bonn, and Dip. Ortho. and M. Sc. from the University of Toronto.

Dr. Woodside is Professor and Chairman of the Orthodontic Department at the University of Toronto, Ontario. He is a Dental Graduate (D.D.S.) of Dalhousie University, Toronto, with M.Sc. (D) from the same University. He is a Diplomate of the American Board of Orthodontics

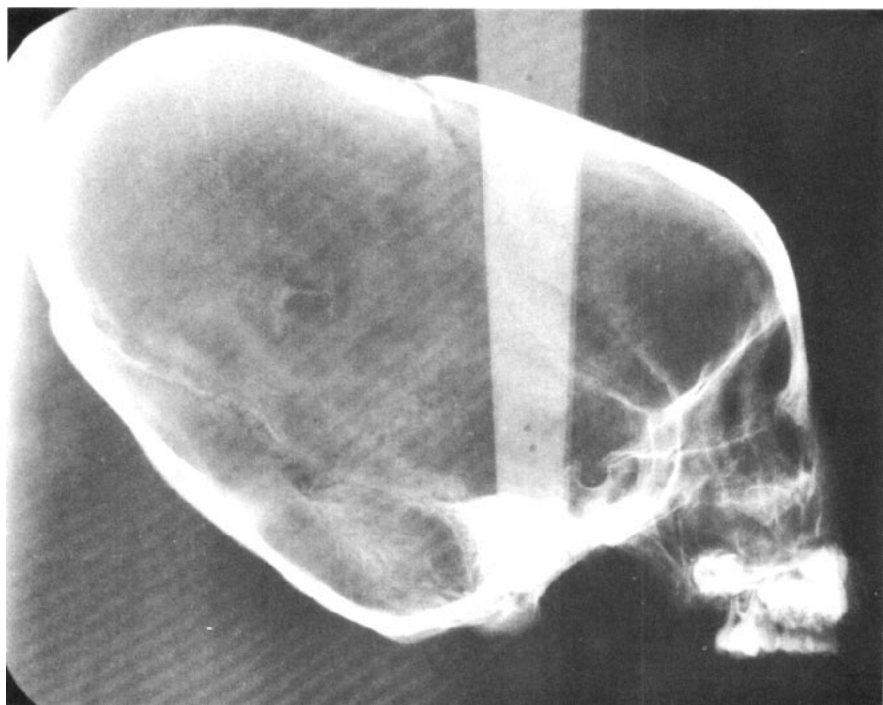


Fig. 1 Cephalometric radiograph of human skull from Mexico which has been warped for esthetic and cultural purposes.

Department of Anthropology, University of Toronto

ings, and their effects on maxillary position (HARVOLD AND VARGERVIK 1971, SERGL AND FRAMAND 1975, WOODSIDE ET AL. 1975, McNAMARA 1977, LUNDSTRÖM AND WOODSIDE 1980, BRECHTOLD ET AL. 1981).

Posterior occlusal bite blocks are one type of functional orthodontic appliance which has been used clinically at the University of Toronto since 1962 to reduce anterior open bite associated with excessive lower anterior face height. Correction is achieved by inhibition of buccal segment tooth eruption, creating an upward and forward autorotation of the mandible or a more horizontal mandibular growth direction. The thickness of the bite blocks usually exceeds the free-

way space by 3mm-4mm., although larger dimensions have been used in the past. Patients wear such appliances continuously, and are encouraged to eat with them in place. In a preliminary primate experiment, ALTUNA AND WOODSIDE (1977) have reported that such posterior occlusal bite blocks can create dramatic change in maxillary position as well as arrest of buccal tooth eruption.

The present study is a sequel to the above report, designed to test the effects of different vertical openings of bilateral posterior bite blocks on maxillary position of juvenile and adolescent primates. The stability of these changes in the posttreatment period is also examined.

— Material and Method —

Thirteen *Macaca fascicularis* monkeys, twelve females and one male, were used in these experiments (Tables 1 and 2). The monkeys were divided into two age groups, juvenile and adolescent, based on ages determined from the tables of HURME AND VAN WAGENEN(1953 AND 1961) AND SCHULTZ (1969). The animals in the juvenile group were approximately 24-36 months old, and those in the adolescent group approximately 48-60 months old. Special care was taken in the selection of the monkeys for each age group so that their dentitions exhibited rather uniform stages of eruption. In the juvenile group, the permanent first molars and incisors were present and the remaining teeth

were mostly deciduous teeth; in the adolescent group, all the permanent teeth were present and the molars were erupting.

Metal implants were inserted on the left side of the maxilla, on the mandible, on the midline of the cranium, and the cranial base, using the methods of BJÖRK (1955 AND 1972) AND MCNAMARA (1972),. Amalgam fillings were placed on the left maxillary and mandibular molars.

The experimental period ranged from 14 weeks to 68 weeks, with the first 14-32 weeks for each animal used as a control period. The next 18 weeks comprised the experimental period, followed by removal of the appliances and an 18-week post-experimental period. The control period for one animal was only 8 weeks long, so this control period was not included in the study.

Table 1

Juvenile Group, Age 2-3 years Superimposition on Anterior Cranial Base Implants Vertical and Horizontal Increments of Change as Measured at the Posterior Maxillary Implant Millimeters											
Serial Number	Age in Years	Bite block Thickness (mm)	Time in Weeks			HORIZONTAL			VERTICAL		
			Control	Exp.	Post Treat.	Control	Exp.	Post Treat.	Control	Exp.	Post Treat.
873	2-3	12.0	14	18	18	1.20	4.86	1.70	0.69	-1.69	0.64
222	2-3	8.0	14	18	18	1.38	3.03	0.41	0.23	-1.60	0.74
202	2-3	8.0	14	18	-	1.18	3.52	-	0.25	-1.88	-
50	2-3	2.0	32	18	18	2.39	0.31	1.91	1.66	-0.38	0.81
819	2-3	Control	14	-	-	0.93	-	-	0.44	-	-
819	2-3	Control	32	-	-	2.62	-	-	1.21	-	-
271	2-3	Control	14	-	-	1.37	-	-	0.76	-	-
955	2-3	Control	14	-	-	0.91	-	-	0.23	-	-
+ indicates Forward or Downward change - indicates Backward or Upward change											

The animals were fully documented at the beginning and at the end of each period. The details of the methodology were the same as described by ALTUNA (1979).

Impressions of the maxilla and the mandible were taken with specially designed trays, and bite registrations with 2.0mm, 8.0mm, and 12.0mm thicknesses were made for each animal. The casts were fixed on an articulator and bite blocks were carved out of wax. Special care was taken to make the occlusal surfaces flat. Chrome-cobalt castings made from the waxed bite blocks were cemented to the maxillary dentition of each animal. Ligature wires were used to also tie the castings to the teeth. The appliances were equilibrated in the mouth to make sure that there was maximal con-

tact of all the posterior teeth with the appliance. (Fig. 2)

A grid system was used to assess the changes in morphology and position of the various facial bones in respect to the cranial base. Tracings of the cranium, cranial base, midface, maxillary dentition and the metallic implants were made from all cephalographs. The tracings were then superimposed on the best fit of the anterior cranial base and the endocranial contours. The metallic implants in the cranium and the sphenoid bone were used to assist in the superimpositions, but it was not possible to use those implants in the occipital bone because of growth changes.

The sella-nasion line was drawn on the initial tracing of each series. A perpendicular to this line was then drawn

Table 2

Adolescent Group. Age 4-5 years Superimposition on Anterior Cranial Base Implants Vertical and Horizontal Increments of Change as Measured at the Posterior Maxillary Implant Millimeters											
Serial Number	Age in Years	Bite block Thickness (mm)	Time in Weeks Control Exp. Post Treat.			POSTERIOR MAXILLARY IMPLANT					
						HORIZONTAL			VERTICAL		
						Control	Exp.	Post Treat.	Control	Exp.	Post Treat.
330	4-5	12.0	14	18	18	0.86	3.24	0.17	0.27	-0.99	0.53
483	4-5	8.0	14	18	18	0.79	3.04	0.97	0.23	-1.22	0.33
30	4-5	8.0	-	18	-	-	3.23	-	-	-1.79	-
871	4-5	2.0	32	18	18	0.73	0.60	0.23	0.34	-0.71	0.36
492	4-5	Control	32	-	-	1.14	-	-	0.36	-	-
492	4-5	Control	14	-	-	0.64	-	-	0.18	-	-
329	4-5	Control	14	-	-	0.51	-	-	0.25	-	-
+ indicates Forward or Downward change - indicates Backward or Upward change											

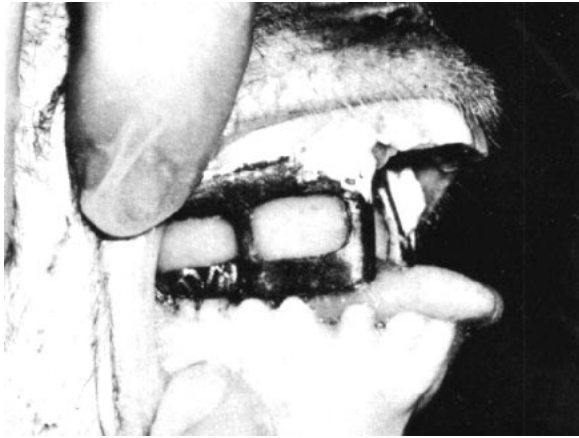


Fig. 2 Monkey with 12.0mm posterior occlusal bite block

through the sella point. The S-N horizontal and vertical lines were then transferred from the initial cephalograph to each remaining cephalograph of the series, which had been superimposed as described above. Thus, the skeletal changes were measured against the template of the initial cephalograph and the increments of change in the vertical and horizontal planes between the cephalographs were calculated by subtraction.

The same type of template was used to assess the maxillary dentoalveolar changes. In the initial tracing, a reference line was drawn on the occlusal surfaces of the maxillary dentition and a perpendicular was drawn to this line. The remaining tracings of each series were superimposed on the maxillary implants, and the occlusal reference plane and the vertical plane transferred from the initial cephalograph of the series by registering on the implants of the maxilla. Dentoalveolar changes were then measured against the template of the initial cephalograph and the increments of change in

the vertical and horizontal planes calculated by subtraction.

The direction of the biting forces was assessed by the angle formed between the line drawn on the occlusal surfaces of the maxillary teeth and the occlusal plane of the bite blocks (Beta angle (β)). In addition, a line was drawn from the center of the amalgam fillings of the mandibular first permanent molars to the bifurcation point and the angle between this line and the occlusal plane was also measured (Alpha angle (α)). This measurement was taken both before and immediately after the insertion of the bite blocks (Figs. 3 and 4).

All measurements were made with an optical digitizer by the same investigator at least three different times, and the average values then used.

Inter-investigator and intra-investigator error studies to determine errors involved in measuring the distances and angles between metal implants, between metal implants and skeletal points, and between skeletal points showed a method error less than 0.3mm (ALTUNA 1979).

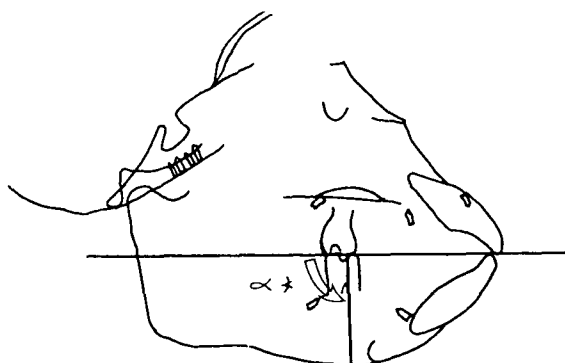


Fig. 3

α angle, measured between the axis of the lower first molar and the original occlusal plane, before insertion of the bite block

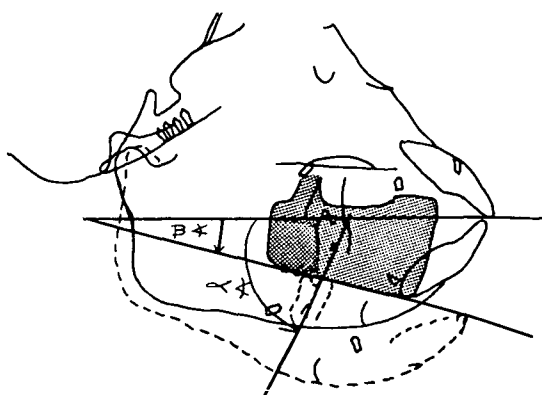


Fig. 4

β angle, between original occlusal plane and new occlusal plane of the bite block, and the α angle with bite block in place

— Results —

Skeletal Changes

The translation of the midface during normal growth was determined by measuring the changed positions of the posterior maxillary implant relative to the implants in the anterior part of the cranial base. In both the juvenile and the adolescent groups, the maxilla translated horizontally, with minimal vertical displacement (Tables 1 and 2) (Figs. 5-8)

During the 18-week experimental period, in those animals with 8.0mm and

12.0mm bite blocks, the movement of the posterior maxillary implant indicated that the maxilla was displaced in a forward and upward direction in relation to the cranial implants.

This displacement was 2 to 3 times more than seen at the end of the control period for the juvenile group, and 2 to 4 times more for the adolescent group.

Two animals, one juvenile and one adolescent, were fitted with bite blocks only 2.0mm thick. After the 18-week experimental period, the forward displacement of the maxilla in both of these animals

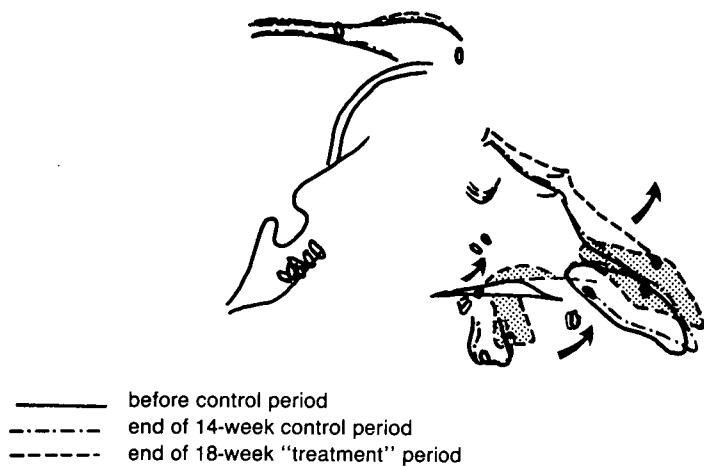


Fig. 5 Overall superimposition on the anterior cranial base implants of an adolescent animal with a 12.0mm bite block. Arrows indicate the directions of movement during the control and experimental periods.

Table 3											
Juvenile Group, Age 2-3 years											
Superimposition on Maxillary Implants											
Vertical and Horizontal Increments of Change											
as Measured at First Permanent Molar Amalgams											
Millimeters											
FIRST PERMANENT MOLAR TEETH											
Serial Number	Age in Years	Bite block Thickness (mm)	Time in Weeks			HORIZONTAL			VERTICAL		
			Control	Exp.	Post Treat.	Control	Exp.	Post Treat.	Control	Exp.	Post Treat.
873	2-3	12.0	14	18	18	0.36	1.27	0.18	0.48	-1.35	0.81
222	2-3	8.0	14	18	18	0.33	1.20	0.43	0.21	-0.78	0.41
202	2-3	8.0	14	18	-	0.40	0.71	-	0.33	-1.61	-
59	2-3	2.0	32	18	18	0.62	0.21	0.53	0.73	-0.42	0.89
819	2-3	Control	14	-	-	0.21	-	-	0.17	-	-
819	2-3	Control	32	-	-	0.32	-	-	0.23	-	-
955	2-3	Control	14	-	-	0.21	-	-	0.19	-	-
271	2-3	Control	14	-	-	0.31	-	-	0.21	-	-
+ indicates Forward or Downward change											
- indicates Backward or Upward change											

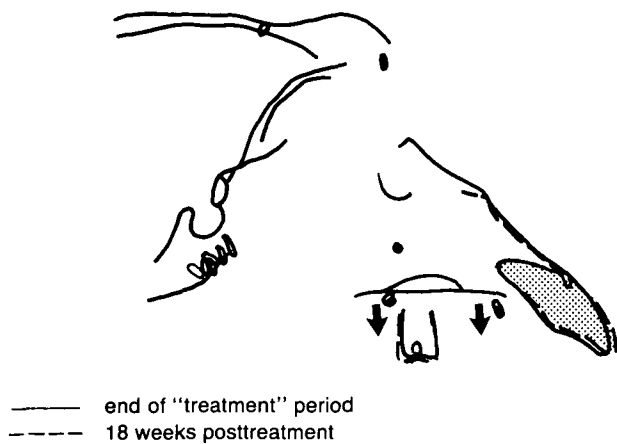


Fig. 6 Overall superimposition on the anterior cranial base implants of an adolescent animal during the post-experimental period, after the removal of the 12.0mm bite block.

Adolescent Group. Age 4-5 years Superimposition on Maxillary Implants Vertical and Horizontal Increments of Change as Measured at First Permanent Molar Amalgams Millimeters											
FIRST PERMANENT MOLAR TEETH											
Serial Number	Age in Years	Bite block Thickness (mm)	Time in Weeks			HORIZONTAL			VERTICAL		
			Control	Exp.	Post Treat.	Control	Exp.	Post Treat.	Control	Exp.	Post Treat.
330	4-5	12.0	14	18	18	0.18	1.14	0.15	0.13	-2.31	1.18
483	4-5	8.0	14	18	18	0.35	0.60	0.23	0.30	-2.52	1.09
30	4-5	8.0	-	18	-	-	0.64	-	-	-1.91	-
871	4-5	2.0	32	18	18	0.21	0.15	0.25	0.32	-0.35	0.46
492	4-5	Control	14	-	-	0.19	-	-	0.16	-	-
492	4-5	Control	32	-	-	0.36	-	-	0.28	-	-
329	4-5	Control	14	-	-	0.15	-	-	0.38	-	-
+ indicates Forward or Downward change - indicates Backward or Upward change											

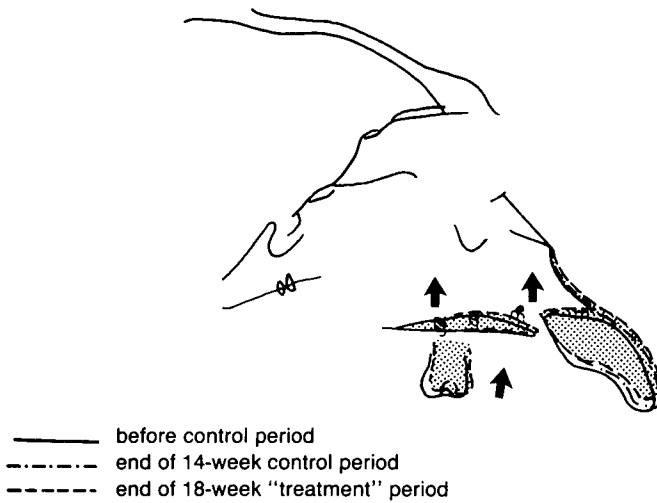


Fig. 7 Overall superimposition on the anterior cranial base implants of an adolescent animal with a 2.0mm bite block. Arrows indicate the directions of movement during the control and experimental periods.

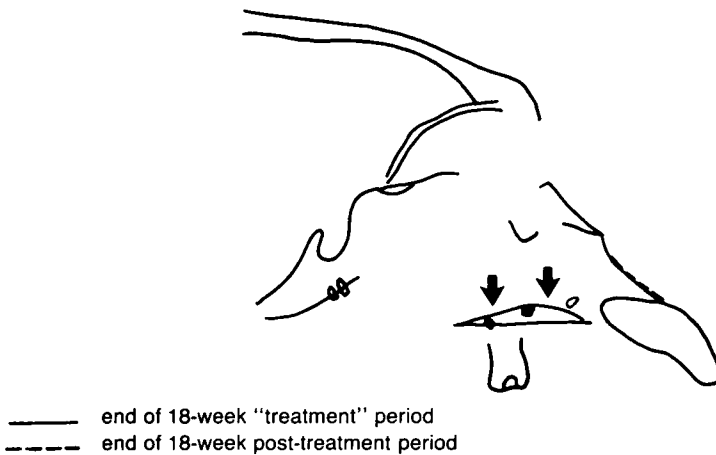


Fig. 8 Overall superimposition on the anterior cranial base implants of an adolescent animal during the post-experimental period, after the removal of the 2.0mm bite block.

was less than that recorded after the 14-week control period.

The bite blocks were removed at the end of the 18-week experimental period in three juvenile and three adolescent animals. In the following 18 weeks, the growth that took place was documented and the stability of the changes resulting from the wearing of the bite blocks was assessed. During the experimental period, the maxilla was displaced in an upward direction. In the posttreatment period, the growth was once again in a downward and forward direction. After the 18-week posttreatment period, the vertical displacement, as measured at the posterior maxillary implants relative to the cranial base implants, was almost twice as much as that observed during the 14-week period for most of the animals.

Maxillary Dentoalveolar Changes

During the 14-week control period, there was a downward and forward migration of the maxillary first molars. This forward migration was minimal in both groups (Tables 3 and 4).

During the 18-week experimental period, the maxillary first permanent molar was intruded or its eruption inhibited in all experimental animals. This intrusion was greatest in the adolescent group and least in the juveniles. The intrusion was least in the group with 2.0mm bite blocks and it was largest in the groups with 8.0mm and 12.0mm bite blocks.

The mesial movement of the maxillary first permanent molars in the groups with 8.0mm and 12.0mm bite blocks was 1 to 3 times more during the experimental period than during the control period. In the group with 2.0mm bite blocks, the mesial movement of the maxillary first permanent molars was proportionately less.

During the 18-week posttreatment period, the maxillary first permanent mo-

lars were extruded more than that which was observed during the 14-week control period.

Direction of Biting Forces

Before the insertion of the bite blocks, the observed direction of the biting force was primarily in a vertical direction (β 0° , α 85° – 92°). The 8.0mm and 12.0mm bite blocks added a horizontal component to the biting force (β 9° – 14° , α 50° – 75°) (Figs. 3 and 4). The insertion of the 2.0mm bite block brought about no noticeable change in the direction of the biting force (β 1° , α 85° – 89°).

— Discussion —

The authors are aware that there are inherent limitations in the application of findings from primate studies to human therapy. In spite of these limitations, nonhuman primates provide the best available model for the investigation of the effects of some orthodontic appliances. With the help of cephalometrics, histology and electromyography, the results can provide a clearer understanding of the basic biological principles underlying the etiology of malocclusion.

The results of this study show that maxillary position is highly plastic and easily changed by the forces created by the insertion of posterior occlusal bite blocks of varying thickness in both juvenile and adolescent animals. Those with 8.0mm and 12.0mm bite blocks showed 3 to 6 times more forward maxillary translation relative to the cranial base than was observed during the control period (Figs. 5 and 6).

In addition, the usual downward growth of the maxilla was redirected upward in a rotational manner, with the upward displacement of the anterior segments larger than that seen in the posterior segments. Upward vertical displacement of the maxilla has been reported in

clinical patients with the Milwaukee brace (THORS 1964, ALEXANDER 1966) and in animal experiments with posterior occlusal bite blocks (SERGL 1975, McNAMARA 1977, HURME 1953). The results of this study support the above findings.

In contrast to the above findings and the work of others, the animals wearing 2.0mm bite blocks showed less forward maxillary translation in the experimental period than during the control period, while in the vertical plane the normal downward growth of the maxilla was changed to an upward direction (Figs. 7 and 8). This difference in maxillary response to different levels of vertical opening of the jaws indicates that the direction of occlusal force delivery may influence maxillary position. With the insertion of bite blocks, ranging from 8.0mm to 12.0mm in thickness, an anterior component is added to the occlusal forces. However, in the animal wearing a 2.0mm bite block, the direction of occlusal forces is not changed by the appliance.

These results show that the direction of occlusal forces is an important factor in change in maxillary position, and this should be taken into consideration in functional appliance treatment planning. Some orthodontic appliances used on patients during the course of orthodontic treatment may change the direction of the occlusal forces delivered to the jaws. This change should be analyzed in each individual case prior to the placement of functional appliances.

The results of this study also indicate the importance of the vertical distance between the maxillary teeth and the circum-maxillary sutures and the cranial base. In monkeys, the circum-maxillary sutures are nearer to the maxillary first permanent molars than they are in humans; therefore, forces applied to the maxillary teeth are much more directly transmitted to the sutures. On the other hand, according to BJÖRK AND SKIELLER

(1976), the maxillary molars in man at the age of 13 are almost 12.0mm to 14.0mm further away from the cranial base and the circum-maxillary sutures than they were at the age of 7 to 8 years. One might speculate then that the chances of affecting the circum-maxillary sutures may be better in younger subjects.

Histological analysis showed that the midfacial complex was displaced anteriorly by sutural modifications in growing and in young adult animals. At the end of the 18-week experimental period, the fibers in the zygomatico-temporal and the zygomatico-frontal sutures of the experimental animals showed some isolated areas of hyalinization, but there was no ankylosis of the sutures. These results support the findings of KAMBARA (1977) AND NANDA (1978).

There was a marked difference between the juvenile and adolescent animals in the amount of buccal tooth intrusion achieved with the bite blocks. The juvenile animals showed arrest of tooth eruption and slight intrusion, while the older animals showed extensive intrusion of buccal teeth in both arches. This difference between the two age groups is probably due to two factors —

First, inhibition of eruption in animals where the teeth are normally erupting rapidly produces a relative intrusion and minimizes the need for actual intrusion. *Second*, the maxillary translations may occur more rapidly in the younger animals, thus relieving the dentoalveolar region of the large occlusal forces.

The 18-week post-experimental period showed clearly that the maxillary translations which occurred during the experimental period were not reversed, indicating that a chronic environmental impact to the maxilla can produce a dramatic change in maxillary position which is not subsequently reversed (Figs. 6 and 8).

The findings show that manipulation of the vertical dimension can be an im-

portant factor in the achievement of mesiodistal occlusal changes, and this should be taken into consideration in functional appliance therapy. The use of posterior occlusal bite blocks resulted in dramatic skeletal changes in the anteroposterior and vertical position of the maxilla, with the direction of these changes varying with different vertical openings.

— Conclusions —

- Maxillary position in both young and adolescent monkeys is highly plastic in response to forces generated by alterations in the facial and masticatory neuromuscular system.
- Maxillary displacement in response to placement of thick posterior occlusal bite blocks occurred in both vertical and horizontal planes. It was rotational in nature, with the anterior portion displaced more than the posterior portion.

- The intrusion of buccal teeth with use of thick posterior occlusal bite blocks occurs more readily in mature animals, whereas the insertion of such bite blocks in growing animals results in inhibition of eruption with relative intrusion.
- A chronically applied environmental impact to the maxilla can create change in maxillary position which is stable following removal of that impact.

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