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MORPHOMETRIC RELATIONSHIPS BETWEEN SKULL TRAITS AND MALOCCLUSION IN THE DOMESTIC RABBIT

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Chi-Ming Huang (1987) Morphometric relationships between skull traits and malocclusion in the domestic rabbit. *Bull. Inst. Zool., Academia Sinica* 26(2): 123-131. Twenty six skull measurements obtained from a genetic study of mandibular prognathism in the rabbit were analyzed by a multivariate approach to examine the relationship between various skull measurements in normal and maloccluded animals. It was identified that nine skeletal measurements were found to be significantly different between normal and maloccluded animals. These were: (1) skull length. (2) superior premaxilla length. (3) maxillary diastema. (4) greatest length of mandible. (5) distance from pterygoid tuberosities to dorsal rim of incisor alveolus. (6) length of mandibular cheek teeth row. (7) mandibular diastema. (8) greatest height from the top of the first mandibular molar to the base of ramus resting upright on a flat surface in perpendicular angle, and (9) greatest height from the top of condyloid process to the base of ramus resting upright on a flat surface in perpendicular angle. It was found that mandibular components were significantly greater while the maxillary components were significantly shorter for the prognathic animals as compared to the normal ones. This finding supports the view that mandibular prognathism in the rabbit is due to the combination of underdevelopment of the maxilla and excessive growth of the mandible in addition to alteration in mandibular morphology.

Maloccusion is endemic and widespread throughout the world. It is defined as any disharmonious variation from the theoretically normal arrangement of the teeth (Graber, 1972). This condition can arise from an abnormal arrangement between the maxilla and the mandible or among the teeth in either the mandible or maxilla. According to Litton *et al.* (1970) mandibular prognathism in man may be caused by gross imbalances in jaw growth. The imbalances may result from excessive anterior mandibular growth, insufficient anterior maxillary growth, or a combination of both. Rubbrecht (1939) suggested that mandibular prognathism was due to retardation of the forward development of the maxilla and remained behind in relation to that of the mandible and was often due more to a forward swing of the mandible than to a notable difference between the size and shape of the jaws. Moore and Hughes (1942) suggested that mandibular prognathism may be caused by an underdevelopment of the maxilla or an increased obtuseness of the mandible angle which produces a protrusion of the mandible beyond the normal maxillary arch. Horowitz *et al.* (1969) analyzing the lateral roentgenograms of 52 adult individuals with mandibular prognathism reported that prognathic subjects have a significantly smaller cranial base and maxillary complex, and shorter posterior face height but the mandible is not significantly longer than that of normal subjects.

Malocclusion of the incisor teeth has been reported in many animal species, including rats (Addison and Appleton, 1915), dogs (Stockard, 1941), rabbits (Chai and Degenhart, 1962; Weisbroth *et al.*, 1967; Fox and Crary, 1971), sheep (Nordby *et al.*, 1945) and cattle (Gregory *et al.*, 1962). Stockard (1941) suggested that the genes determining length of maxilla and mandible are inherited independently. He also pointed out that modifications in the palate and the maxilla are more important in causing dental malocclusion than are changes in the width-length relations of the mandible. Nordby and coworkers (1945) suggested that the overshot maxilla resulted from interactions of several pairs of genes. They also found that sheep with overshot jaws had longer skulls and shorter mandibles than normal animals.

The purpose of the present study is to examine the relationships between various measurements of the skull, maxilla and man-occluded animals in the domestic rabbit.

MATERIALS AND METHODS

The rabbit colony used in this study was originally developed for a selection experiment of growth rate and feed efficiency (Vogt, 1979). Four breeds were used: Flemish giant, New Zealand, Siamese Satin and Dutch. The mating procedure, management of animals and preparation of skull have been described previously (Vogt, 1979; Huang *et al.*, 1981).

All animals were examined for occlusion status of the incisors at eight weeks of age. Examination was made by opening and closing the rabbit's mouth. Occlusion was recorded as normal when the point of contact of the tips of the lower incisors was between the primary and secondary upper incisors. Mandibular prognathism was recorded when the lower incisors protruded beyond the upper primary incisors.

Twenty six linear measurements were made on each skull with a helios precision dial caliper (J & S Precision Scientific Measuring Instrument Company, New York) and recorded in millimeters. Reference points on skull measurements were obtained according to Craigie (1960) and Mclaughlin (1970) and are illustrated in Fig. 1. Of these measurements, 13 had two recorded values representing right and left sides of the skull. These twenty-six skull measurements consisted of two major components, a cranial and maxillary component (measurements 1 to 17) as well as a mandibular component (measurements 18 to 26). A detailed description of each of these characters is given below. Asterisks denote both right and left sides of skull measurements being taken. These included skull measurements 2 to 6 and 18 to 25.

1) Skull length- the greatest length of skull not including incisors, from external occipital protuberance to anterior tip of premaxilla.
2)* Superior premaxilla length.
3)* Greatest nasal length.
4)* Maxillary diastema- from anteriormost rim of alveolus of first cheek tooth to the anterior rim of the second incisors.
5)* Length of maxillary cheek tooth row.
6)* Length from external occipital protuberance to the alveolar edge of the third molar.
7) Basal length- from the anterior edge of the premaxillae to the anterior most point on the ventral border of the foramen magnum.
8) Basilar length- from the posterior margins of the alveoli of the first upper incisors to the anteriormost point on the lower border of the foramen magnum.

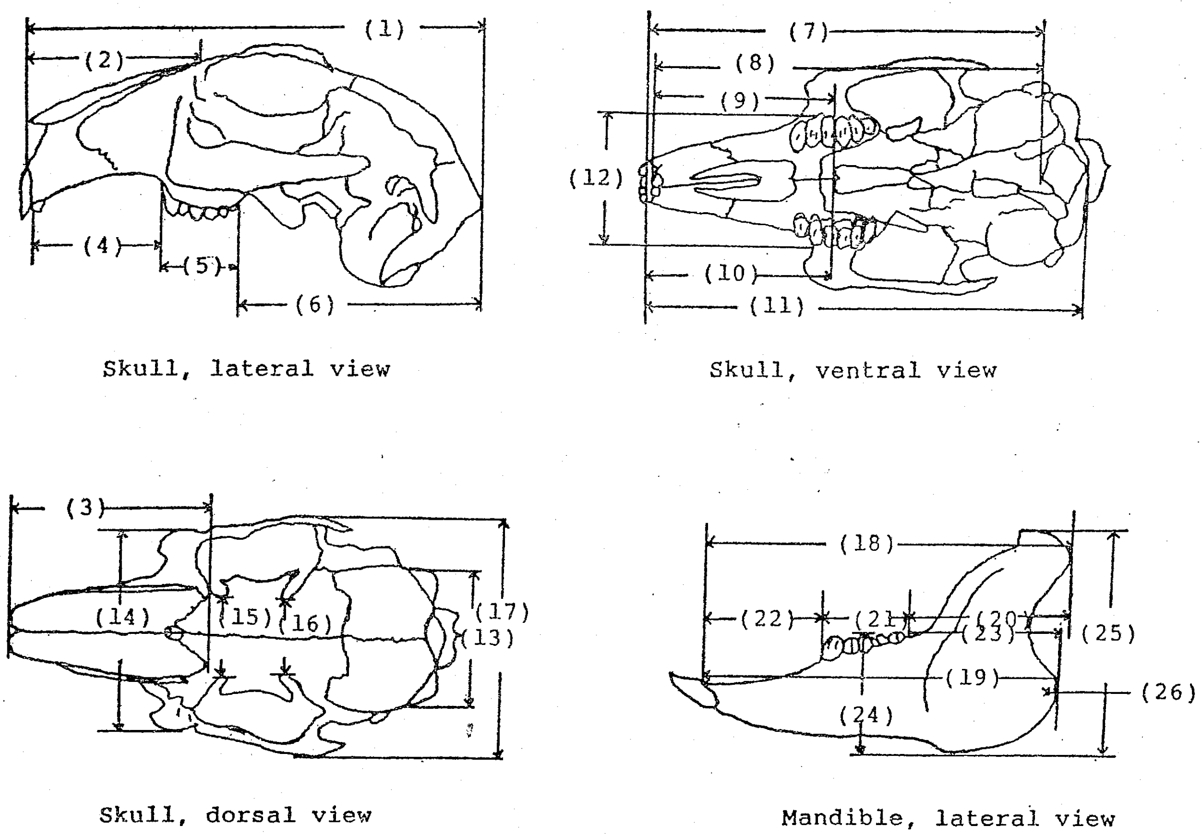

Fig. 1. Landmark for rabbit skull measurement.

9) Palatilar length- from the anterior edge of alveolus of second incisors to anteriormost point on posterior edge of palate.
10) Palatal length- from anterior edge of premaxillae to anteriormost point on posterior edge of palate.
11) Condylobasal length- from the anterior edge of the premaxillae to the posteriormost projection of the occipital condyles.
12) Greatest outside width between the second premolars of maxilla.
13) Mastoid breadth- greatest outside width between the mastoid processes.
14) Greatest outside width between two spina masseterica.
15) Least interorbital breadth- least distance between the orbits anterior to the supraorbital processes.
16) Postorbital constriction- least distance across skull posterior to the postorbital process.
17) Zygomatic breadth- greatest outside width between two zygomatic bones.
18)* Greatest length of mandible- from posterior edge of condyloid process to dorsal rim of incisor alveolus.
19)* Distance from pterygoid tuberosities to dorsal rim of incisor alveolus.
20)* Length from posterior edge of condyloid process of mandible to posterior border of alveolus of the third molar.
21)* Length of mandibular cheek teeth row.
22)* Mandibular diastema- from anteriormost rim of first cheek tooth alveolus to dorsal rim of incisor.
23)* Length from pterygoid tuberosities to posterior border of alveolus of the third molar.
24)* Greatest height from the top of the first molar to the base of ramus resting upright on a flat surface in perpendicular angle.

25)* Greatest height from the top of condyloid process to the base of ramus resting upright on a flat surface in perpendicular angle.

26) The outside width between two masseteric tuberosities.

A total of 540 skulls were measured. Because all animals were not sacrificed at the same age, it was expected that skull measurements would vary with age. In addition, sex difference and the effects of occlusion status on measurement should be taken into consideration. Skull measurements were adjusted for the effects of sex, occlusion status and age at sacrifice by fitting polynomial model. The model specified the age as a continuous variable. There were two sex classes, male and female, and two occlusion classes of normal and maloccluded individuals. The actual age of each individual at the time of sacrifice was used as an independent variable for regression analysis. Using a stepwise approach this variable was allowed to form additional terms, including squared, cubic, etc. for inclusion. At each stage, a test of significance for the additional term of increasing power was made. If the term of the kth power was not found to be significant, the preceding model that included age variables up to the $(k-1)$th degree was chosen.

The polynominal regression model is

$$Y=a+B_1X_1+B_2X_2+B_3X_3+B_4X_3^2+\cdots+B_iX_3^k+e$$

where a=regression intercept,
B=partial regression coefficient,
X_1=effects of the sex class,
X_2=effects of the occlusion class,
X_3=age of animal at sacrifice,
X_3^2=age squared,
⋮
X_3^k=the kth power of age class,
e=random errors

The adjustment of age effects and sex differences was made on a within litter basis, with the effects of occlusion status being held constant. Sex adjustment was made on male basis.

Statistical analyses used to study the relationship between skull measurements and mandibular prognathism included multiple regression and discriminant analysis (Cooley and Lohnes, 1971). Discriminant analysis is used to construct a linear discriminant function composed of a set of variables which will maximize the difference between two or more groups. There were two groups of animals, normal and maloccluded, with N_1 and N_2 individuals respectively. On each animal were measured k variables, X_1, X_2, ·····, X_k. By putting all observations into one group, the multiple regression of Y on X_1, X_2, ·····, X_k can be run. This provides a linear function of the X's which maximizes the difference in Y and gives for each animal of each group an expectation.

$$Y=a+B_1X_1+B_2X_2+\cdots\cdots+B_kX_k$$

Where Y is the occlusion status, a is the constant, B_k, k=1, 2, ·····, k, are partial regression coefficients, and X_1, X_2, and X_k refer to separate, independent variables (skull measurements). A stepwise procedure was used to select from a set of twenty six variables. Thirteen left-side skull measurements, thirteen single measurements, as well as thirteen right-side and thirteen single measurements were analyzed. The classification equation was of the form.

$$C_i=C_{i1}V_1+C_{i2}V_2+\cdots\cdots+C_{ip}V_p$$

Where C_i is the classification score for group i, the C_{ij}'s are the classification coefficients and the V's are the raw scores on the discriminating variables. $P(H_j/X_i)$ is the probability of hypothesis j given the score vector X_i. The nine significant variables derived from the discriminant analysis were used for calculating probabilities of classification.

Data analyses for polynomial and multiple regression were performed using computer programs of Mi *et al.* (1977). Statistical package for the social sciences (Nie *et al.* 1975) was used for discriminant analysis. Statistical analyses were performed on IBM 370.

RESULTS

The means and standard deviations of all skull measurements for normal and affected animals are shown in Table 1. All measurements were expressed in millimeters. Measurement 1 to 17 were on the maxilla and 18L to 26 on the mandible. The observed differences between normal and affected animals for each skull measurement were tested independently and separately for significant differences by analysis of variance. Few measurements on the maxilla showed significant differences between the two groups. However, the differences were significant on most measurements of the mandible between normal and affected animals.

The results of stepwise multiple regression analysis of skull measurements between normal and maloccluded animals are presented in Table 2. There were 26 skull measurements taken, 13 of which represented bilateral measurements. When 13 single measurements for the test animals were analyzed simultaneously, 9 measurements were found to be significantly different between normal and affected animals. These measurements were: skull length (1), superior premaxilla length (2L), maxillary diastema (4L), greatest length of mandible (18L), distance from pterygoid tuberosities to dorsal rim of incisor alveolus (19L), length of mandibular cheek teeth row (21L), mandibular diastema (22L), greatest height from the top of the first molar to the base of ramus resting upright on a flat surface in perpendicular angle (24L), and greatest height from the top of the condyloid process to the base of ramus resting upright on a flat surface in perpendicular angle (25L). For bilateral measurements, analyses made separately on each side gave consistent results.

The discriminant analysis was used to consider all the variables simultaneously as potential determinants of occlusion status in

TABLE 1
Mean and standard deviation for normal and affected animals

Measurement[1]	Normal		Affected		Measurement	Normal		Affected	
	Mean	SD	Mean	SD		Mean	SD	Mean	SD
1	92.70	3.63	92.48	4.26	16	12.49	0.89	12.52	0.72
2L	53.32	2.37	53.15	2.76	17	45.94	1.78	46.57	1.61
2R	53.31	2.40	53.14	2.77	18L	72.77	2.94	74.15	3.32
3L	46.72	2.69	46.90	3.17	18R	72.71	2.91	74.16	3.29
3R	46.81	2.67	46.94	3.12	19L	66.96	2.66	67.73	3.02
4L	29.13	1.56	29.21	1.91	19R	66.81	2.61	67.50	2.95
4R	29.04	1.52	29.11	1.92	20L	35.00	1.75	35.21	1.87
5L	15.94	0.56	15.90	0.52	20R	34.99	1.78	35.33	1.83
5R	15.91	0.54	15.88	0.50	21L	15.70	0.62	15.76	0.67
6L	48.92	1.99	48.84	1.97	21R	15.73	0.60	15.75	0.64
6R	48.78	1.99	48.67	1.94	22L	22.66	1.15	23.64	1.41
7	76.35	3.41	75.98	3.92	22R	22.68	1.14	23.60	1.38
8	74.12	3.32	73.95	3.80	23L	29.46	1.50	29.70	1.54
9	38.81	2.04	38.95	2.05	23R	29.33	1.50	29.54	1.41
10	40.63	1.96	40.47	2.24	24L	21.50	1.06	22.41	1.37
11	83.64	3.50	83.24	4.43	24R	21.58	1.09	22.50	1.43
12	23.53	0.99	23.27	1.22	25L	46.04	2.27	45.97	2.51
13	33.72	1.60	34.14	1.60	25R	46.07	2.25	45.99	2.52
14	45.23	1.98	45.76	1.80	26	45.44	2.45	45.69	2.44
15	15.59	1.07	15.80	0.94					

[1]The letters L & R referred to measurements taken on the left and right side respectively.
N=485 (normal animals), N=55 (affected animals)

TABLE 2
Regression coefficients of skull measurements between normal and maloccluded animals

Measurement[1)]	Left-side b S. E.	Right-side b S. E.
1	0.031±0.012*	0.039±0.013**
2	0.045±0.011**	0.039±0.011**
4	0.067±0.027**	0.088±0.022**
18	−0.045±0.021*	−0.108±0.022**
19	0.055±0.019**	0.077±0.021**
21	−0.058±0.026*	— —
22	−0.235±0.028**	−0.195±0.027**
24	−0.095±0.019**	−0.084±0.019**
25	0.041±0.011**	0.043±0.019**
R-square	0.392	0.408

1) 1=Skull length
2=Superior premaxilla length
4=Maxillary diastema
18=Greatest length of mandible
19=Distance from pterygoid tuberosities to dorsal rim of incisor alveolus
21=Length of mandibular cheek teeth row
22=Mandibular diastema
24=Greatest height from the top of the first molar to the base of ramus resting upright on a flat surface in perpendicular angle
25=Greatest height from the top of condyloid process to the base of ramus resting upright on a flat surface in perpendicular angle
* $p<0.05$
** $p<0.01$

TABLE 3
Standardized discriminant function coefficient of significant skull measurement

Measurement[1)]	Left-side Coefficient	Rank	Right-side Coefficient	Rank
1	0.871	4	1.032	4
2	0.490	8	0.487	8
4	1.029	3	1.102	3
18	−1.853	1	−2.452	1
19	0.780	5	0.960	5
21	−0.169	9	−0.119	9
22	−1.456	2	−1.364	2
24	−0.649	7	−0.539	7
25	0.747	6	0.760	6

1) 1=Skull length
2=Superior premaxilla length
4=Maxillary diastema
18=Greatest length of mandible
19=Distance from pterygoid tuberosities to dorsal rim of incisor alveolus
21=Length of mandibular cheek teeth row
22=Mandibular diastema
24=Greatest height from the top of the first molar to the base of ramus resting upright on a flat surface in perpendicular angle
25=Greatest height from the top of condyloid process to the base of ramus resting upright on a flat surface in perpendicular angle

order to determine the relative significance of several variables to the occlusion status of an animal. The final forced model of discriminant functions is shown in Table 3. The ranking order and absolute magnitude for both left- and right-side measurements were identical. The highest rank was greatest length of mandible (18), followed by mandibular diastema (22) and maxillary diastema (4). Skull length (1) was the fourth most significant variable, followed by length from pterygoid tuberosities to dorsal rim of incisor alveolus (19), and greatest height from the top of condyloid process to the base of ramus resting upright on a flat surface in perpendicular angle (25). Greatest height from the top of the first molar to the base of ramus resting upright on a flat surface in perpendicular angle (24) ranked seventh and superior premaxilla length (2) ranked eighth in importance. Among these nine variables, mandibular cheek teeth row (21) contributed the least to the discriminant function. The three highest ranked measurements, 18, 22 and 4 were of particular importance for discriminating animals associated with malocclusion.

Classification of animals into normal or affected group was based on the discriminant scores. Probabilities associated with classification for normal and affected animals using nine significant measurements derived from discriminant analysis are shown in Table 4. These nine measurements were successful in classifying correctly 95% of the animals:

TABLE 4
Probabilities of classification for normal and maloccluded animals[1)]

Measurement	% correct classification	P(N̂/N)	P(Â/N)	P(Â/A)	P(N̂/A)	P(N/Â)	P(A/N̂)
Left-side	95.0	0.996	0.004	0.529	0.471	0.004	0.047
Right-side	95.1	0.996	0.004	0.538	0.462	0.004	0.046

[1)] N and N̂ are actual and predicted normal occlusion.
A and Â are actual and predicted malocclusion.

When all twenty six measurements were included in the model the percentages of correct classification were 96.1 and 95.6 respectively for left- and right-side measurements indicating that very little improvement in classification could be made by including other measurements in discriminant analysis. This showed that discrimination between normal and affected animals based on these nine measurements could be effective. The last two columns in the table are probabilities of misclassification. Misclassification probabilities for affected animals were very small and for those normal animals slightly higher.

DISCUSSION

The results of this study showed that most measurements on the mandible were longer and most measurements on the maxilla were shorter for the maloccluded rabbit as compared to the normal ones. This indicated that the growth of mandible may be excessive and faster than that of the maxilla in the maloccluded rabbit. The significant differences for greatest height from the top of the first molar to the base of ramus in perpendicular angle (24) and greatest height from the top of condyloid process to the base of ramus in perpendicular angle (25) probably may also lead to changes in the angle of mandibular configuration. Therefore, relatively faster growth of the mandible compared to that of the maxilla, and an alteration in mandibular angle, may be important in causing mandibular prognathism in the rabbit. This differential growth of the mandible and maxilla causes malalignment of the jaws and results in mandibular prognathism.

From a study of sheep skulls, Nordby *et al.* (1945) suggested that prognathism may be due to either a normal mandible and a short maxilla or a long mandible and a normal maxilla, or to an exaggerated development in the mandible and underdevelopment in the maxilla. Horowitz *et al.* (1969) reported a smaller cranial base and maxillary length and a shorter ramus height in man with mandibular prognathism than those with normal occlusion. Studies in man suggest that mandibular prognathism may be caused by an underdeveloped maxilla (Rubbrecht, 1939; Moore and Hughes, 1942; Sanborn, 1955; Hopkin, 1963; Horowitz *et al.*, 1969; Litton *et al.*, 1970); underdevelopment of the maxilla while the mandible remains unchanged (Horowitz *et al.*, 1969); excessive development of the mandible (Joffe, 1965; Litton *et al.*, 1970), or a combination of insufficient maxillary growth and excessive mandibular growth (Litton *et al.*, 1970). A more recent study (Enlow, 1975) has suggested that if the mandibular corpus is long, the result is mandibular protrusion. A horizontally short maxillary arch also has the same effect.

The present study of rabbit skulls appears to support the hypothesis that mandibular prognathism may be caused by the combination of both underdevelopment of the maxilla and excessive growth of the mandible. It also suggests that while relative size of the maxilla and the mandible are important causes for mandibular prognathism, relative morphologic configuration of the mandible as shown by measurements 24 and 25, also make great contribution to this defect. These results are consistent with Bjork's (1950) hypothesis that alterations in the size and angular relationships of the cranial base as well as enlargement of the mandible may give rise to mandibular prognathism in man.

In the present study, nine measurements were found to be significantly associated with mandibular prognathism and were used as variables for discriminating between normal and affected rabbits. Among these nine measurements, measurement 18 is found to be the best discriminator. If certain maxillary and mandibular measurements can be identified in man to be significantly different between normal and prognathic subjects, these measurements may be useful in discriminating prognathic subjects from normal subjects in the general population. This approach had been applied in the study of craniofacial relationships in mandibular prognathism in man (Horowitz *et al.*, 1969).

In a previous paper (Huang *et al.*, 1981) it was reported that mandibular prognathism is inherited as an autosomal recessive trait with incomplete penetrance. The recessive gene might act pleiotropically affecting two or more traits on the maxilla or the mandible or other parts of the skull. Thus, if the gene is segregating it causes simultaneous variation in the traits it affects. Other modifying genes could add further variation in the expression of mandibular prognathism. There is evidence from both human and animal data that heredity plays an important role in the etiology of mandibular prognathism. An understanding of the genetic mechanism in this defect could lead to a more effective strategy in its prevention in human populations.

The similarity of the mode of mandibular growth between man and rabbit (Bang and Enlow, 1967) and the observation that mandibular prognathism in rabbits is similar to Class III malocclusion in man (Weisbroth *et al.*, 1974) suggests some possible usefulness of this species as an animal model for the study of human dental malocclusion.

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REFERENCES

ADDISON, W. H. F. and J. L. APPLETON (1915) The structure and growth of the incisor teeth of the albino rat. *J. Morphology* **26**: 43–96.

BANG, S. and D. H. ENLOW (1967) Postnatal growth of the rabbit mandible. *Archs. Oral Biol.* **12**: 993–998.

BJORK, A. (1950) Some biological aspects of prognathism and occlusion of the teeth. *Acta Odont. Scand.* **9**: 1–40.

CHAI, C. K. and K. H. DEGENHARDT (1962) Developmental anomalies in inbred rabbits. *J. Hered.* **53**: 174–182.

COOLEY, W. W. and P. R. LOHNES (1971) Multivariate data analysis. John Wiley and Sons. New York.

ENLOW, D. H. (1975) Handbook of facial growth. W. B. Saunders Company.

FOX, R. R. and D. D. CRARY (1971) Mandibular prognathism in the rabbit: genetic studies. *J. Hered.* **62**: 23–27.

GRABER, T. M. (1972) Orthodontics, principles and practice. W. B. Saunders Company.

GREGORY, K. E., R. E. KOCH and L. A. SWIGER (1962) Malocclusion-a hereditary defect in cattle. *J. Hered.* **53**: 168–170.

HOPKIN, G. B. (1963) Hypoplasia of the middle third of the face associated with congenital absence of the anterior nasal spine depression of the nasal bones, and Angle Class III malocclusion. *Br. J. Plast. Surg.* **16**: 146–153.

HOROWITZ, S. L., J. M. CONVERSE and L. J. GERSTMAN (1969) Craniofacial relationships in mandibular prognathism. *Archs Oral Biol.* **14**: 121–131.

HUANG, C. M., M. P. MI and D. W. VOGT (1981) Mandibular prognathism in the rabbit: discrimination between single locus and multifactorial models of inheritance. *J. Hered.* **72**: 296–298.

Joffe, B.M. (1965) Cephalometric analysis of mandibular prognathism. *J. Dent. Ass. (S. Africa)* **20**: 145-156.

Litton, S.F., L.N. Ackerman, R.J. Isaacson and B.L. Shapiro (1970) A genetic study of Class III malocclusion. *Amer. J. Orthod.* **58**: 565-577.

Mi, M.P., S.M. Onizuka and J.C. Wong (1977) Computer programs for statistical analysis of biocmedical data. Cancer Center of Hawaii, Technical Report No. 5, 75 pp.

Moore, G.R. and B.O. Hughes (1942) Familial factors in diagnosis, treatment and prognosis of dentofacial disturbances. *Amer. J. Orthod. and Oral Surg.* **28**: 603-639.

Nakata, M., P. Yu, B. Davis and W.E. Nance (1974) Genetic determinants of craniofacial morphology. A twin study. *Ann. Hum. Genet.* **37**: 431-443.

Nie, N.H., C.H. Hull., J.G. Jenkins, K. Steinbrenner and D.H. Bent (1975) Statistical package for the social sciences. Second Edition, Mcgraw-Hill Book Company, New York.

Nordby, J.E., C.E. Terrill, L.N. Hazel and J.A. Stoehr (1945) The etiology and inheritance of inequalities in the jaws of sheep. *Anat. Record* **92**: 235-254.

Potter, R.H., W.E. Nance, P. Yu and W.B. Davis (1976) A twin study of dental dimension. II. Independent genetic determinants. *Amer. J. Phys. Anthrop.* **44**: 397-412.

Rubbrecht, O. (1939) A study of the heredity of the anomalies of the jaws. *Amer. J. Orthod. Oral. Surg.* **25**: 751-779.

Sanborn, R.T. (1955) Differences between the facial skeletal patterns of Class III malocclusion and normal occlusion. *Angle Orthod.* **25**: 208-222.

Stockard, C.R. (1941) The genetic and endocrine basis for differences in form and behavior. Amer. Anat. Memoirs 19. Wistar Institute of Anatomy and Biology, Philadelphia.

Vogt, D.W. (1979) Selection experiment with domestic rabbits I. Heritabilities of and genetic correlation between postweaning average daily gain and gross feed efficiency. *J. Hered.* **70**: 421-422.

Weisbroth, S.H. and L. Ehrman (1967) Malocclusion in the rabbit. A model for the study of development, pathology and inheritance of malocclusion. I. Preliminary note. *J. Hered.* **58**: 245-246.

兎子頭殼性狀與牙齒咬合不正的關係

黃 齊 明

牙齒正常咬合及不正常咬合的兎子，其頭殼及上、下顎共量度二十六種性狀，以研究這些性狀與牙齒咬合不正的關係。其中有九種性狀與牙齒咬合不正有顯著的關係，這九種性狀是：①頭殼長度，②上顎骨長度，③上顎牙齒空間，④下顎總長度，⑤下顎骨翼肌粗隆至門牙槽邊之長度，⑥下顎整排牙齒長度，⑦下顎牙齒空間，⑧下顎第一臼齒至 ramus 下底的高度，⑨下顎骨節至 ramus 下底的高度。牙齒咬合不正的兎子和正常的比較起來，前者下顎性顯著增長而上顎性狀顯著縮短，本研究所得結論支持一種看法，即牙齒咬合不正的兎子係由於上顎發展受抑制及下顎過度成長二種原因所組成。