Eye Changes: Involvement of the eyes was a very common manifestation of the vitamin A deficient state. It was characterized by night blindness, a reddening of the eyelids (blepharitis - due to inflammation of the eyelids) which in some rats led to the formation of blood-stained crusts on the margins of the eyelids, loss of eye secretions (due to effects on the conjunctivae and lacrimal glands) and xerophthalmia and, in some cases, keratomalacia and actual ulceration of the cornea with subsequent blindness of the animal. These latter severe eye changes in the deficient rat were seen only very late in the deficient state in both delayed deficient and rapidly deficient rats. When the rapidly deficient rats were given vitamin A replacement doses, the eye lesions were markedly improved except of course for those eyes showing severe corneal ulceration and blindness. Even the smallest replacement dose (ten i.u. per week) usually resulted in a return to normal of less severely affected eyes, but the higher doses were more rapidly effective.

Nasal Discharge: Another late sign of the vitamin A deficient state that was noted in this investigation was a frequently occurring blood-stained nasal discharge. This usually was seen after the onset of the eye changes, but long before the latter had progressed to corneal ulceration. In severely deficient rats, this discharge was very obvious, since the blood in the discharge had clotted and resulted in crusts being formed around the animal's nares. Replacement therapy was effective in overcoming this condition.

Oral Signs: Vitamin A deficient signs in the oral cavity were of very frequent occurrence. The absence of enamel pigment in the labial surfaces of the upper and lower incisor teeth was observed in all deficient rats. At first there was a gradual decrease of the normal yellow and orange pigment, then the newly-formed enamel gradually became paler until the teeth were finally and completely white. Not all the incisors were affected at the same rate, and it was common to see one or both lower incisors completely white while the upper incisors were still only pale. The appearance of non-pigmented enamel was noted early in the deficiency, often before the onset of the eye changes. In some cases, especially the delayed deficient rats, the incisors were quite pale before ocular changes became obvious. However, defects in the structure of these teeth, due to the deficiency affecting either directly or indirectly the ameloblasts and odontoblasts, were seen late in the deficient state.

The degree of vitamin A deficiency produced in the rapidly deficient rats did not generally prevent the restoration of normally-appearing enamel on the administration of vitamin A to these rats. Because the enamel takes some weeks to erupt into the mouth, the enamel remained white for about three weeks after the institution of replacement therapy. Gradually after this time, in most cases pigment was incorporated into the enamel so that at the end of the study period, the incisors again revealed their normal yellow and

orange enamel pigment. The exceptional cases were most probably the result of irreversible changes in the enamel-forming cells, since Jolly (1964) had found that vitamin A deficiency may cause irreversible damage to these cells so that even prolonged vitamin A administration may only partly restore the normal pigmented enamel.

Also noted in the oral cavity of many of the vitamin A deficient rats was the presence of xerostomia, and its presence was exemplified by the concomitant appearance of soft food particles. These two factors probably accounted for the formation of calculus on the labial surfaces of the maxillary incisors. Xerostomia and food particles were usually seen from quite an early stage in the deficient period, following on the weight loss. The food deposits were especially obvious around the gingival margin of the lower incisors, and undoubtedly were at least a predisposing factor to the appearance, very late in the deficient state, of gingival inflammation and periodontal pocketing around these teeth. Consequently, it would appear that vitamin A deficiency, either directly through its action on the gingival and periodontal tissues, or indirectly by supplying predisposing causes such as xerostomia, food deposits and calculus, or probably by a combination of both these actions, may result in gingival and periodontal disease. Because periodontal pocketing and irreversible salivary gland damage may have been caused by the deficient state, replacement therapy was not always effective in

overcoming these oral signs of vitamin A deficiency.

Miscellaneous Signs: Other signs were also obvious during the deficient period of the animals, but were seen late in this period and were not of frequent occurrence. The rats lost the normal smooth sheen of their coats and their hair became rough and unruly. Some rats showed respiratory distress and occasionally muscular weakness and an unsteady gait.

6.22 Dental Investigations.

In order to evaluate changes in the eruption rates of the incisor teeth of vitamin A deficient rats, it was first necessary to examine the attrition and eruption rates in rats receiving normal quantities of vitamin A. When these studies on normal, control and delayed and rapidly deficient rats were completed, the effect of replacement therapy on the eruption rates of the rapidly deficient rats was determined.

The procedure of removing the left mandibular incisor from occlusion in order to study the unimpeded eruption rate did not cause any untoward effect on this tooth in either control or deficient animals, and all animals tolerated the operation very well. The unopposed tooth did become somewhat paler, apparently due to the greatly increased eruption rate of the tooth not allowing the ameloblasts their accustomed time for incorporating pigment into the enamel, with the result that a decreased amount of pigment

occurred in the labial enamel of this unopposed tooth. The experimental procedure had no effect on the direction of eruption of the unopposed incisor, since it continued to erupt along the same line as its neighbouring (right) tooth.

The eruption and attrition rates of all four groups have been placed, in tabulated form, in the Appendix. When required, the mean eruption rates of each group will be introduced into the Findings and Discussion to avoid excessive back-reference to the Appendix.

(a) Normal Rats (Group 1)

As with the other groups of rats, blood samples for vitamin A estimation were taken from members of this group. At the end of the study period, blood samples were taken from two males and two female rats of this group, and when analyzed, these samples confirmed that these normal rats had satisfactory vitamin A stores. The vitamin A content of these blood samples were as follows:

Rat Number	Vitamin A content (i.u. per 100 ml. plasma)
11	103
12	39
18	63
20	53

In each rat of this group, over a period of approximately 20 weeks, incisal and gingival measurements of the left and right lower incisors were made each week to determine the weekly impeded eruption and attrition rates of these functionally occluding teeth. Although dealt with much more fully in the Discussion (7), it must be pointed out at this time that both incisal and gingival measurements were required since it was realized that the continuously erupting incisor, even in the "mature" animal, compensates not only for the loss of tooth substance caused by attrition (measured from the incisal edge), but also allows an actual increase in length of the incisor. Thus, gingival measurements give the true impeded eruption rate of the incisor which, by virtue of the fact that the tooth increases in length, is significantly greater than the attrition rate of that tooth, as shown later.

The eruption rates and attrition rates of the normal and control rats, and some of the deficient rats, were statistically analyzed. The method of analysis of the results and the tests for significance between different groups of rats were similar for all comparisons of the measurements. Consequently, rather than repeating the method and results for each set of measurements, the author has included the mean and standard deviation of each set of measurements for each rat, as well as the mean and standard error of each set of measurements of each group of rats, in the tables in the Appendix. An example of how these results were determined,

and how they were tested for significance in comparing with other groups, will now be given.

For the normal rats, the following mean values, with their standard errors, were obtained (see Appendix pp. I and II):

Female attrition rate of left incisor	=	3.29 ± 0.036 mm./week
Female attrition rate of right incisor	=	3.28 ± 0.042 " "
Male attrition rate of left incisor	=	2.71 ± 0.030 " "
Male attrition rate of right incisor	=	2.69 ± 0.023 " "
Female impeded eruption rate of left incisor	=	3.40 ± 0.038 " "
Female impeded eruption rate of right incisor	=	3.42 ± 0.040 " "
Male impeded eruption rate of left incisor	=	2.88 ± 0.030 " "
Male impeded eruption rate of right incisor	=	2.86 ± 0.019 " "

These results allowed statistical comparisons to be made between measurements, to show:

(i) whether there was any significant difference between left and right incisors in their attrition rates and in their impeded eruption rates;

(ii) whether there was any significant sex difference in each of these rates; and

(iii) whether there was any significant difference between attrition and impeded eruption rates that would account for an increase in length of the incisors.

(i) As the example of the statistical method used for analyzing the results, it will now be shown that there was no significant difference between the impeded eruption rates of left and right incisors. The results of the five male rats will be used. In referring to the relevant table in the Appendix (p. II), the remarkable constancy of the weekly measurements in each rat should also be noted, by observing the small standard deviation of the mean impeded eruption rate (gingival measurements) of each rat.

For the left gingival measurements of the five males, a total of 107 measurements (approximately 21 weeks per rat) were made. The mean impeded eruption rate for the left incisor was obtained by dividing the total sums of these measurements by 107.

$$\text{Mean left impeded eruption rate} = \frac{\text{Total measurements of each rat}}{\text{Total number of measurements}}$$

$$= \frac{62.2 + 64.1 + 59.1 + 60.8 + 62.1}{107}$$

$$= \frac{308.3}{107}$$

$$= \underline{2.88}$$

$$\text{Now, Standard Deviation (S.D.) of mean} = \sqrt{\frac{N(\sum x^2) - (\sum x)^2}{N}}$$

where N = total number of measurements

$\sum x^2$ = sum of each squared measurement

$(\sum x)^2$ = square of total of N measurements

$$\therefore \text{S.D. of Mean left impeded eruption rate} = \frac{\sqrt{107(898.73) - (308.3)^2}}{107}$$

$$= \frac{\sqrt{1115.22}}{107}$$

$$= \underline{0.31209}$$

$$\text{Standard Error of Mean left impeded eruption rate} = \frac{\text{S.D.}}{\sqrt{N}}$$

$$= \frac{0.31209}{\sqrt{107}}$$

$$= \underline{0.03017}$$

$\therefore$ Mean left impeded eruption rate = 2.88 mm./week; S.D. = 0.31209; S.E. = 0.03017.

Similarly, for the right impeded eruption rate:

$$\text{Mean right impeded eruption rate} = \frac{66.7 + 60.7 + 57.3 + 59.3 + 59.4}{105}$$

$$= \underline{2.86}$$

$$\text{Standard Deviation of Mean right impeded eruption rate} = \frac{\sqrt{105(880.52) - (303.4)^2}}{105}$$

$$= \frac{\sqrt{403.04}}{105}$$

$$= \underline{0.19054}$$

$$\text{Standard Error of Mean right impeded eruption rate} = \frac{0.19054}{\sqrt{105}}$$

$$= \underline{0.01859}$$

$\therefore$ Mean right impeded eruption rate = 2.86 mm./week; S.D. = 0.19054; S.E. = 0.01859.

$\therefore$ Mean left impeded eruption rate (with its standard error) = 2.88 ± 0.030 mm./week

Mean right impeded eruption rate (with its standard error) = 2.86 ± 0.019 mm./week

To test for significance, the 't' test was used.

$$\text{t ratio} = \frac{\text{Difference of Means}}{\sqrt{\text{sum of squared standard errors}}}$$

$$\text{i.e. t} = \frac{2.88 - 2.86}{\sqrt{(0.03017)^2 + (0.01859)^2}}$$

$$= \frac{0.02}{\sqrt{0.001256}}$$

$$= \frac{0.02}{0.035}$$

$$= \underline{0.571}$$

Using t = 0.571, and degrees of freedom n = 210 (i.e. N-2), the level of significance was found to be $p > 0.5$, i.e. not significant.

Thus, there was found to be in this study no significant difference between the impeded eruption rates of the left and right lower incisors of the male rat.

In a similar manner, it was found that there was no significant difference between the impeded eruption rates of the left and right lower incisors of the female rat. The same conclusions were made concerning the attrition rates of both sexes, that is, there was no significant difference in the attrition rates of the left and right lower incisors of the male or of the female. Thus, both functionally

occluding lower incisors have the same impeded eruptive potential, and are worn down by attrition at the same rate. Consequently, as will be seen below, both must show corresponding quantitative increases in length per unit time. These statistical determinations can in fact, be confirmed clinically, since the two lower incisors invariably appear to be the same length, in normal rats.

(ii) A striking sex difference was noted in the eruption and attrition rates of the lower incisors of these normal rats. For example, as tabulated above, the mean female impeded eruption rate of the right lower incisor can be seen to have been determined as 3.42 ± 0.040 mm./week, yet the corresponding male rate was only 2.86 ± 0.019 mm./week, a difference of over 0.5 mm./week. This difference was found to be highly significant ($p < 0.001$). Likewise, there was a highly significant sex difference in the left impeded eruption rate, and in the attrition rates of the left and right lower incisors. With regard to the right incisor's attrition rate, the female value was 3.28 ± 0.042 mm./week, as opposed to the male right incisor attrition rate of 2.69 ± 0.023 mm./week, a difference of almost 0.6 mm./week.

(iii) It was shown statistically that there occurred a difference between the attrition and impeded eruption rate of the lower incisor of the rat. Taking the right incisor as the example, the impeded eruption rate of this tooth in the male was found to be 2.86 ± 0.019 mm./week, but the attrition rate was only 2.69 ± 0.023 mm./week.

The difference between these measurements, 0.17, was found to be highly significant ($p<0.001$). Similarly, there was a significant difference ($p<0.02$) of 0.14 in the female's attrition and impeded eruption rates of the right incisor, and in the corresponding rates of the left incisor of both sexes. This difference also could be shown in the right incisor of the control group (group 3) of rats, and even in some individual normal rats, a difference between the impeded eruption rate and attrition rate was observed to be significant. Although this aspect will be dealt with more fully in the Discussion (7), it must be pointed out that this shows the fallacy of determining the "rates of growth" of the incisor teeth, as done by Addison and Appleton (1915), by taking incisal measurements. Such measurements determine only the attrition rates of the teeth, which are not a true reflection of even the impeded "growth" or eruption of the tooth, let alone a true reflection of the tooth's eruptive potential, which can only be measured by determining the unimpeded eruption rate.

(iv) In support of the finding that the impeded eruption rate was greater than the attrition rate for a functionally occluding lower incisor, was the observation that over a period of approximately 20 weeks, the rat incisor was seen to increase in length by almost 3 mm. The weekly difference between the attrition and impeded eruption rates was found, when the mean difference of both sexes is taken collectively, to be 0.15 mm./week, which over a 20 week

period, would exactly account for the 3mm. increase in length of the incisor.

The initial lengths and final lengths (after 20 weeks) of the left and right lower incisors of the normal rats were noted, the difference in the measurements giving the gain in incisor length over the period of study. These measurements are shown in Table 1.

TABLE 1

Gain in the Length of the Lower Incisors of Normal Rats

Rat No.	Initial Length (mm.) Left Incisor	Right Incisor	Final Length (mm.) Left Incisor	Right Incisor
11	7.0	7.1	9.6	9.7
12	7.4	7.9	9.7	9.8
13	6.9	7.0	9.9	10.0
14	7.2	7.2	10.3	10.8
15	7.8	7.3	10.4	10.2
16	7.4	7.8	11.6	11.6
17	7.8	7.7	10.9	11.4
18	8.4	8.4	11.1	11.0
19	8.6	8.6	11.6	11.3
20	8.9	8.8	11.5	11.4
Total	77.4	77.8	106.6	107.2

The initial mean length was 7.76 mm. and the final mean length was 10.69 mm., a difference of almost 3.0 mm., which was highly significant ($p < 0.001$).

Thus, from findings (iii) and (iv), it can be concluded that, during the period of study, impeded eruption not only compensated for wearing away of the incisal tips of the lower incisors, but also allowed a marked increase in length of these teeth.

(b) Control Rats (Group 3)

The rats of this group were used as the controls for the delayed deficient rats (group 2). Consequently, blood samples were collected at times corresponding to those of the samples from the deficient rats. Because the plasma vitamin A levels of both deficient and control animals must be carefully compared, the results of the blood analyses for the control rats have been deferred to a later section so that they can be reported along with the results for the deficient animals.

Although the eruption and attrition rates of the control rats were measured for times similar to the delayed deficient rats (30-40 weeks), it was found to be quite sufficient just to tabulate and statistically analyze (by the same procedure as used for the normal rats) the results of the first 20 weeks after introduction to the synthetic diet. Since the left mandibular incisor was kept out of functional occlusion, the unimpeded eruption rates of this tooth, as well as the impeded eruption rates and attrition rates of the right lower incisor, were able to be measured and analyzed. The statistical method used for analysis of these measurements was the

same as used for the normal rats, and so will not be demonstrated again.

For the control rats, the following mean values were obtained (for reference, see Appendix pp. III and IV):

Female attrition rate of right incisor	=	3.00 $\pm$ 0.077 mm./week
Male attrition rate of right incisor	=	2.55 $\pm$ 0.051 mm./week
Female impeded eruption rate of right incisor	=	3.12 $\pm$ 0.042 mm./week
Male impeded eruption rate of right incisor	=	2.73 $\pm$ 0.055 mm./week
Female unimpeded eruption rate of left incisor (incisal measurement)	=	5.44 $\pm$ 0.086 mm./week
Male unimpeded eruption rate of left incisor (incisal measurement)	=	5.48 $\pm$ 0.056 mm./week
Female unimpeded eruption rate of left incisor (gingival measurement)	=	5.39 $\pm$ 0.079 mm./week
Male unimpeded eruption rate of left incisor (gingival measurement)	=	5.53 $\pm$ 0.044 mm./week

The gingival measurements of the left mandibular unopposed incisor also supplied the unimpeded eruption rate of that tooth. Its comparison with the incisal measurement of unimpeded eruption, as advocated by Bryer (1957) and described above (6.1), was needed to note if the vitamin A deficient state, which affects the gingiva,

actually resulted in a loss of accuracy for the gingival method of measuring the unimpeded eruption rate.

The attrition rate and impeded eruption rate of the right incisor (still in occlusion) generally were found to vary in the same respects as those of the normal rats. There was a highly significant ($p<0.001$) sex difference in each rate, and there was a significant difference ($p<0.02$) shown between the attrition and impeded eruption rates, in the male rats at least.

However, when these rates of this group are compared with the corresponding rates in the right incisor of the normal rats, it can be seen that significant differences existed between the two groups. The differences between the females of both groups were more highly significant than the corresponding differences in the male rats. The impeded eruption rate of the right incisor of male control rats was found to be 2.73 ± 0.055 mm./week, as against 2.86 ± 0.019 mm./week for normal males. This difference was significant at $p<0.006$, whereas the female rates, 3.12 ± 0.042 mm./week (control) and 3.42 ± 0.040 mm./week (normal), were different at a much higher level of significance ($p<0.001$). Similarly, the difference between the female attrition rates, 3.00 ± 0.077 mm./week (control) and 3.28 ± 0.042 mm./week (normal), was more highly significant ($p<0.002$) than the corresponding difference in the male rats, that showed a control value of 2.55 ± 0.051 mm./week, and a rate of 2.69 ± 0.023 mm./week in the normal rats, the

difference being only just significant at $p = 0.01$. The possible significance of this difference between both groups of rats is put forward in the Discussion (7).

With regard to the unimpeded eruption rates of the control rats, there was no significant ($p > 0.6$) difference between male (5.48 ± 0.056 mm./week) and female (5.44 ± 0.086 mm./week) rates. Apparently the male and female rats had the same eruptive potential, but the female rat showed greater attritional activity (see (a) (ii)), thus wearing away the incisors more rapidly and requiring a greater impeded eruption rate than the male.

Furthermore, there was no significant difference between the determination of the unimpeded eruption rate by using gingival measurements or by using incisal measurements (the method introduced by Bryer, 1957). In male rats, the values of 5.53 ± 0.044 mm./week for the gingival measurement, and 5.48 ± 0.056 mm./week for Bryer's method, showed that there was no significant difference ($p > 0.4$) between the methods. In female controls the difference between these measurements, 5.39 ± 0.079 mm./week (gingival) and 5.44 ± 0.086 mm./week (incisal), was also insignificant ($p > 0.6$). However, when these two methods were compared in deficient animals, in which the unimpeded eruption rates had fallen below 1 mm./week, the gingival measurement of the unimpeded eruption rate was no longer a satisfactory method.

In some of the delayed deficient rats, the gingival method was quite an inaccurate means of measuring this rate, since differences between the incisal and gingival methods were significant for values of $p < 0.01$. Apparently the vitamin A deficient state had affected the structural and functional integrity of the gingiva thus accounting for the inaccuracy of the gingival measurements.

(c) Deficient Rats (Groups 2 and 4)

These animals were especially used to study the effect of rapidly induced, and slowly induced, vitamin A deficiencies on the eruption rates of the lower incisors, and to relate, chronologically, this effect to the gross signs of vitamin A deficiency. Additionally, there were observations made upon the caries susceptibility of these vitamin A deficient rats, and the changes in dentine thickness of the incisors of these rats. Finally, an idea of the recuperative powers of the incisors of the rapidly deficient rats was gained by observing the effect of vitamin A replacement therapy on the incisor eruption rates of these deficient animals.

(i) Plasma vitamin A levels: As with the other groups of rats, blood samples were taken to check the vitamin A status of the rats. Blood samples were not taken from every rat, but samples from rats of each group were obtained. The rats used to supply these samples were five delayed deficient rats (group 2), five of their control rats (group 3) of corresponding age and sex, and nine rapidly deficient

rats (group 4). As will be shown later, vitamin A deficiency markedly affects the eruptive mechanism of the rat incisor, and blood samples were not only taken from rats already deficient, but also from these rats just as their unimpeded eruption rates had commenced to fall below their normal levels. This was done in order to see if there was any threshold plasma vitamin A level below which the unimpeded eruption rate began to decrease, or whether in fact the estimated plasma level of vitamin A was actually zero before this decrease occurred. Since it was thought that the latter might be the case, and since Dowling and Wald (1958) had shown that 22-24 day old rats possessed estimated vitamin A plasma levels of zero five to six weeks after placing them on a vitamin A deficient diet, it was also decided to take blood samples at this time (five to six weeks) and note whether there was in fact a depletion or fall in the plasma vitamin A, and whether there was a corresponding change in the unimpeded eruption rate. If this estimated plasma level proved to be zero, then the second blood sample (taken when the unimpeded eruption rate began to decrease) would be simply a confirmation of this, but if the vitamin A plasma level of the first sample was not zero and the unimpeded eruption rate was still normal, then the second blood sample would be indispensable in order to note at what plasma vitamin A level the unimpeded eruption rate began to fall.

The plasma vitamin A levels at the above-mentioned times are shown in Table 2.

TABLE 2

Plasma vitamin A levels (i.u./100 ml. plasma)

Delayed Deficient Rats	A. At commencement of fall in unimpeded eruption rate	B. At end of fall in unimpeded eruption rate
No. 21	0	0
26	0	0
27	0	- (died)
29	0	0
32	0	0
Control Rats		
No. 31	94	100
33	99	55
35	114	-
38	109	34
39	103	61

For the rapidly deficient rats, blood samples were also taken, as stated above, five to six weeks after placing these rats on the deficient diet (i.e. before the commencement of the fall in the unimpeded eruption rate). The plasma vitamin A levels for the rats used can be seen in Table 3.

TABLE 3

Plasma vitamin A levels (i.u./100 ml. plasma)

Rapidly deficient Rats	Prior to any fall in unimpeded eruption rate	At commencement of fall in unimpeded eruption rate	At end of fall in unimpeded eruption rate
No. 42	0		
44	21	0	0
46	0	0	0
48	0	0	0
50	0		
54	0	0	0
63	0	0	0
66	0		
84	0		

These results show that although the control vitamin A levels had remained within normal limits, the delayed deficient rats had estimated zero plasma vitamin A levels even as early as the decrease in the unimpeded eruption rate. In fact, the results from the rapidly deficient rats indicate that generally the plasma was depleted of its vitamin A well before this decrease in eruption, since all the plasma estimations, except one, showed zero vitamin A levels. This exception (rat 44) could be explained in the light of the findings of Dowling and Wald (1958). These workers noted that although the liver vitamin A level falls gradually in vitamin A deficiency, once the liver has been exhausted of its vitamin A, the

plasma level falls from its normal value to zero within the space of only a week. Consequently, it is quite likely that the blood sampling of rat 44, at six weeks after placing it on the deficient diet, was carried out when its plasma vitamin A was in the stage of rapid decline. The subsequent sample from this rat, at the commencement of the decrease in the unimpeded eruption rate, showed an estimated plasma level of zero.

Thus, it can be concluded that in those rats from which blood was collected, the unimpeded eruption rate did not begin to decrease in vitamin A deficiency until after the complete utilization of the plasma vitamin A. Generally, this was in fact, some time after the plasma had been totally depleted of its vitamin A.

(ii) Incisor Eruption Rates: Vitamin A deficiency caused striking retardation, in fact almost complete cessation, of the eruptive processes of the rat incisor. It did not matter at what rate the deficiency was induced, for both delayed deficient and rapidly deficient rats were affected. Reference to the Appendix (pp. V-X) will show that the eruption rates in both these groups of animals fell at much the same rate, although of course, the time of onset of this decrease in tooth eruption differed in both groups. A graph (figure 4) displaying the time course of the unimpeded eruption rate in both groups of rats was obtained by noting the mean times and unimpeded eruption rates at these times (I) at the start of the study, (II) at the commencement of the decrease in the unimpeded eruption

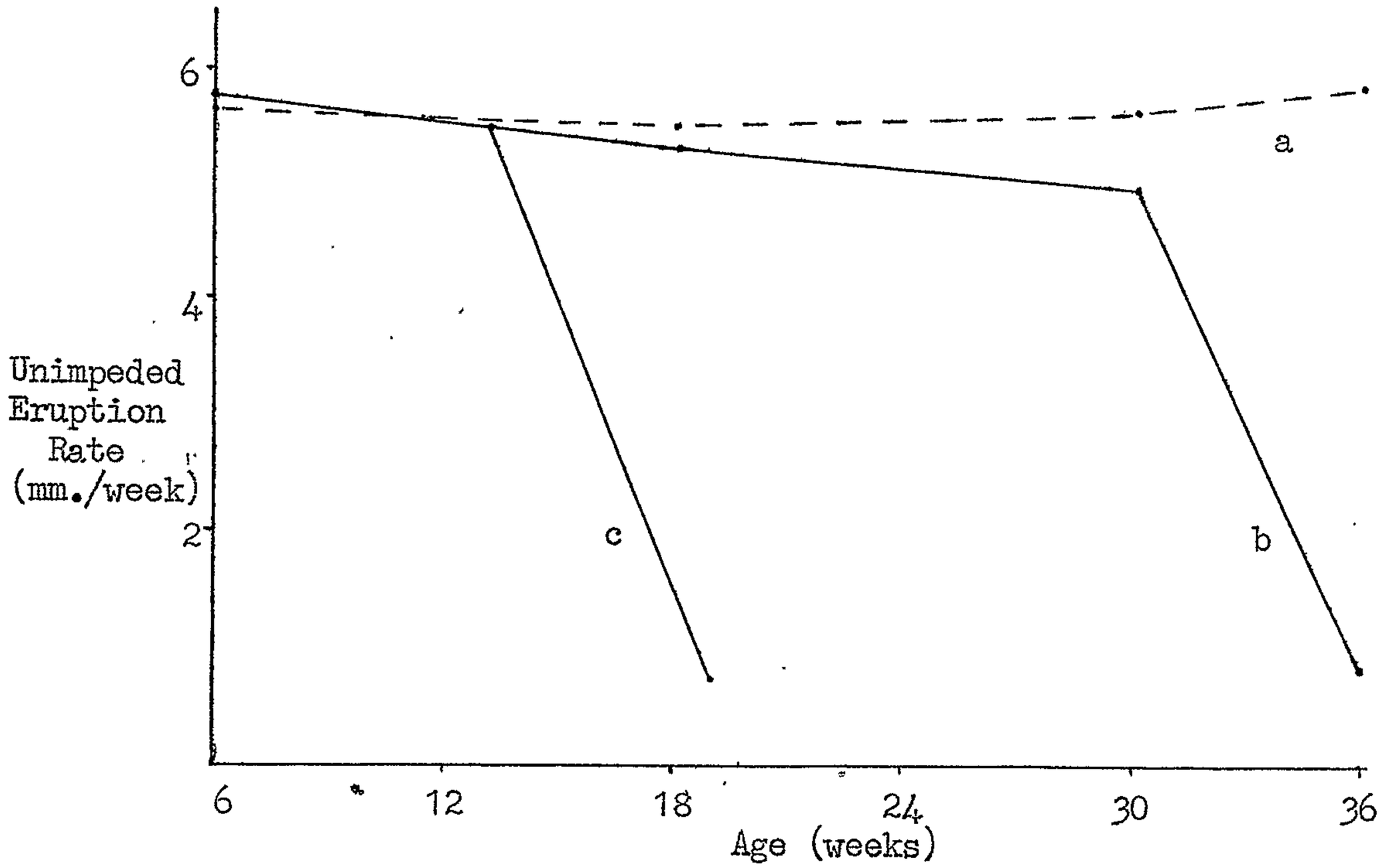

Figure 4 : Unimpeded eruption rate of lower left incisor in three groups of rats.

a : control rats.
b : delayed vitamin A deficient rats.
c : rapidly " " " " .

rate, and (III) at the stage when the unimpeded eruption rate had reached its deficient level. Also, because of the prolonged course of study of the delayed deficient rats, mean readings were also determined in these rats 12 weeks after their placement on the deficient diet. Corresponding mean determinations were obtained for the control group of rats. Reference to Table 4 will indicate the effect of vitamin A deficiency on the unimpeded eruption rate.

TABLE 4

Mean Unimpeded Eruption Rates of Lower Left Incisor of Three Groups of Rats at Certain Ages

	Rat Group					
	2 Delayed Deficient		3 Control		4 Rapidly Deficient	
	Age (weeks)	Rate (mm./week)	Age (weeks)	Rate (mm./week)	Age (weeks)	Rate (mm./week)
(I)	6	5.7	6	5.6	3.5	5.7
	18	5.3	18	5.5		
(II)	30	5.0	30	5.7	13	5.5
(III)	36	0.9	30	5.9	19	0.8

The decrease in the unimpeded eruption rate of the lower incisor occurred at approximately 24 weeks after placing the six-week old rats of group 2 on the deficient diet (i.e. delayed deficient rats); their control rats maintained a steady value. The rapidly deficient rats, placed on the deficient diet at about three and a half weeks of

age, began to reveal a decrease in the unimpeded eruption rate often as early as the eighth week after the commencement of the diet.

The unimpeded eruption rate of the left mandibular incisor, and the attrition rate and impeded eruption rate of the right mandibular incisor, began to decrease at approximately the same time in both groups of deficient animals, although the unimpeded eruption rate usually fell before the other rates in the delayed deficient rats. Since it has been shown previously in normal rats that the attrition rates and impeded eruption rates of left and right functionally occluding lower incisors do not differ significantly, it could be concluded that vitamin A deficiency markedly affects the attrition rate, impeded eruption rate and unimpeded eruption rate of the lower incisor of the rat.

(iii) Shortening of Incisor: Related to the retarding effect of vitamin A deficiency on the attrition and eruption rates of the rat incisor was the observation that the rat lower incisor shortens in vitamin A deficiency. Actual measurements of tooth lengths were carried out during the study, and below are included the initial and final (at deficiency) lengths of the right incisor of five rats from each of the delayed deficient and rapidly deficient groups of rats, as well as the maximum length of the incisor attained in each of these rats. The corresponding measurements of five control rats are also included, but whereas the maximum tooth lengths are given for the deficient

rats, the tooth lengths of the control incisors at ages corresponding to the ages at which these maximum incisor lengths were reached in the delayed deficient rats, are shown. Also, the incisor lengths of the rapidly deficient rats six weeks after the commencement of vitamin A replacement therapy are included, to note whether the deficient rat incisor was capable of recovering its normal length.

The length of the incisors at the appropriate times in the study are shown in Table 5.

TABLE 5

Lengths of Right Lower Incisor in Three Groups of Rats

Delayed Deficient Rats No.	Initial Length (in mm.)	Maximum Length attained (in mm.)	Final Length (in mm.)
21	6.5	9.2	7.5
25	7.4	11.0	7.5
27	6.5	10.3	7.6
29	6.9	10.2	7.2
32	6.5	10.0	7.7
Control Rats No.			
30	6.4	9.8	9.6
31	7.4	9.9	10.8
33	6.8	9.6	10.4
34	7.3	10.2	10.2
39	7.1	9.6	10.2
Rapidly Deficient Rats No.			
42	7.0	8.4	7.2 (8.0)*
55	6.4	8.4	7.7 (9.1)
62	7.1	8.4	7.3 (8.8)
67	6.1	7.8	7.6 (8.1)
87	6.4	7.9	7.7 (8.3)

* Figures in brackets show lengths after six-week vitamin A replacement therapy.

A graph (figure 5) was obtained from these figures and shows that the rat incisor was decidely shortened in vitamin A deficiency. From the graph, it can be seen that there was a marked difference in the effect on the rapidly deficient rats and on the delayed deficient rats. Due to the long period of time preceding the onset of deficiency in the latter rats, the incisors of these rats were able to increase in size almost to their ultimate in length before their vitamin A stores became exhausted. When vitamin A deficiency did occur the incisors shortened considerably compared with their maximum length. On the other hand, however, because of the rapid onset of the deficient state in the rapidly deficient rats, the incisors of these rats did not have the time to greatly increase in length. Consequently their shortening during the deficient period was not as great as the incisor shortening in the delayed deficient rats, although the final deficient lengths were very similar in both groups. Replacement therapy in the rapidly deficient rats allowed their incisors to recover and regain the normal pattern of increase in length of the lower incisors.

It has been shown before, in the group of normal rats, that the impeded eruption rate of the lower incisor slightly exceeds the attrition rate each week (by approximately 0.15 mm.), and as a result, the lower incisor increases in length. Consequently, it could be argued that the shortening of the rat incisor, as seen in vitamin A deficiency, might be the result of the attrition rate slightly exceeding

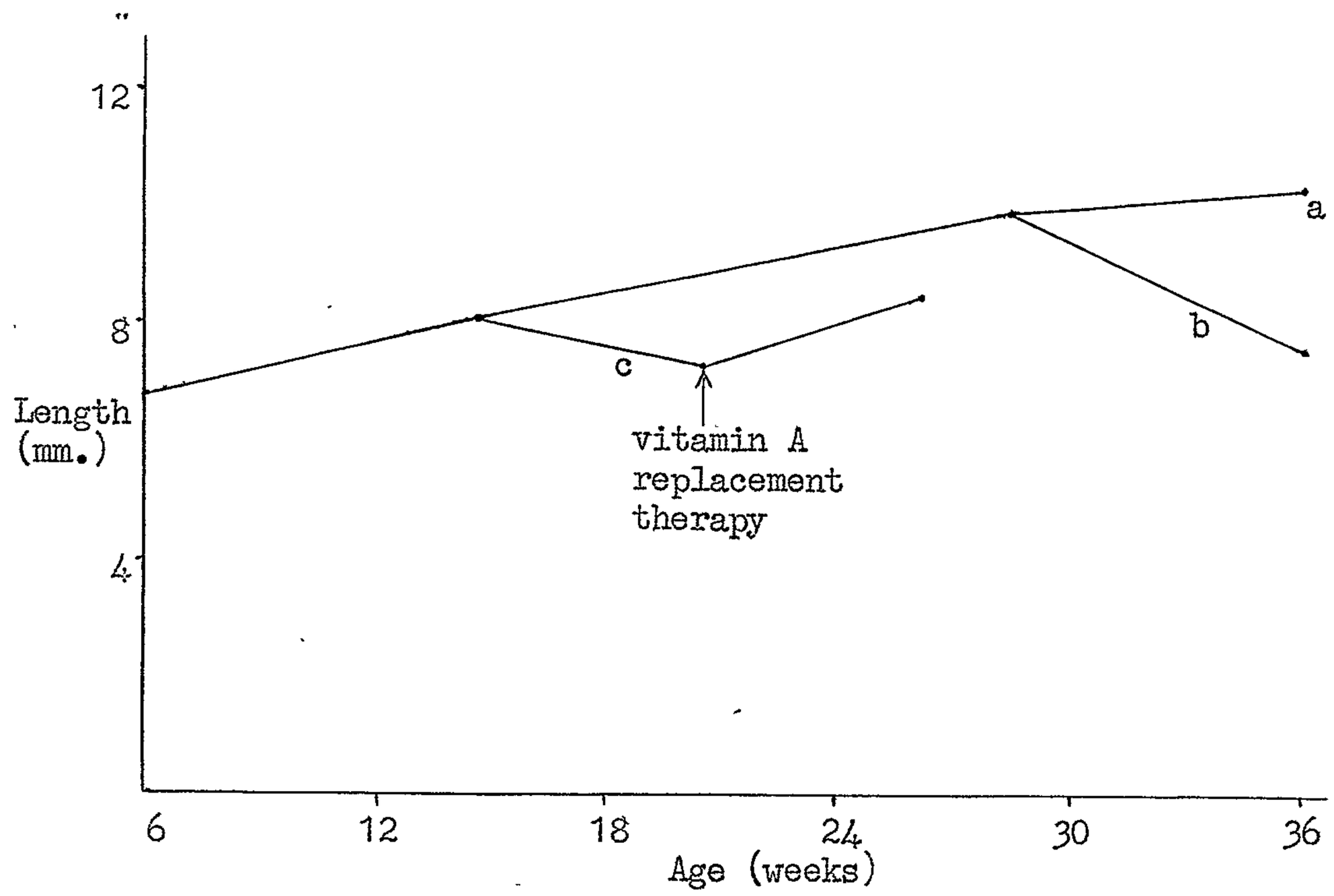

Figure 5 : Length of lower right incisor in three groups of rats.

a : control rats.
b : delayed vitamin A deficient rats.
c : rapidly " " " " .

the impeded eruption rate, during the deficient period. That this was in fact the case can be seen by observing (Appendix pp. V-X) the attrition and impeded eruption rates of both groups of deficient rats during the period from the commencement of the decreases in the eruption and attrition rates to the completion of these decreases (i.e. when rates have reached their deficient level). It will be noted that the attrition rate generally exceeds the impeded eruption rate over this period of time, thus accounting for the shortening of the incisors as produced by the vitamin A deficient state.

(iv) Change in Dentine Thickness of Incisor: One of the characteristic features of vitamin A deficiency in the rat incisor is an apparent increase in thickness of the labial dentine when compared to the lingual dentine. Schour and his colleagues (1941) have suggested that it may be a compensatory thickening, since the labial dentine has to carry most of the masticatory load. Although the study had not been set up to test this hypothesis statistically, the writer nevertheless decided to measure the cross-sectional gingival width of the lower incisors of the delayed deficient rats and their controls, to see if there had been in vitamin A deficiency, a compensatory thickening of the labial dentine of the lower left incisor which had been relieved of any functional masticatory stress.

It was observed that the right lower incisor (retained in functional occlusion) when compared to the right incisor of the control

group, did actually show the characteristic disproportionately thick labial dentine in the deficient state, as might be expected from the observations of other workers. However, in the unopposed, unimpeded left lower incisor, the ratio of labial: lingual dentine thickness was quite similar in both deficient and control rats, indicating that masticatory stress was the factor accounting for the increase in thickness of the labial dentine of the right incisor.

It must be re-emphasized that there were not enough measurements to enable a statistically valid conclusion to be drawn. Still, the results do indicate that the stress of functional occlusion apparently was the main factor responsible for the disproportionate thickening of the labial dentine of the rat incisor, when compared to the lingual dentine. These results certainly suggest that Schour and his co-workers were correct in their hypothesis.

(v) Caries Susceptibility: Although clinical studies seem to indicate that there is no relationship between vitamin A deficiency and an increased susceptibility to dental caries, the paucity of experimental studies concerned in investigating such a possible relationship is marked. For this reason, and the fact that xerostomia may be a factor predisposing to caries and is a characteristic feature of vitamin A deficiency, it was decided to use the delayed deficient rats and their controls as a "pilot" study, preliminary to a more extensive statistical investigation if this study indicated an increased susceptibility to caries.

However, the preliminary study indicated no difference in the caries susceptibility of the control and deficient rats. Thus, although a statistically valid conclusion cannot be made on the basis of the results of this study, it would appear that vitamin A deficiency is not a predisposing factor in the production of dental caries in the rat.

(vi) Vitamin A Replacement Therapy: Four different doses of vitamin A were given to the animals in the four sub-groups of rapidly vitamin A deficient rats in order to gain some knowledge of the ability of the tissues necessary for tooth eruption to recover from the vitamin A deficient state.

The attrition rate and impeded eruption rate of the right lower incisor and the unimpeded eruption rate of the left lower incisor were determined throughout the whole study period, including the six-week period of replacement therapy, of the rapidly deficient rats (see Appendix pp. VII-X). However, only the unimpeded eruption rate of the left lower incisor will be considered as an indication of the recovery powers of the eruptive processes of the rat incisor, since only this rate is the true expression of the eruptive processes.

At the commencement of the replacement therapy the average unimpeded eruption rate of the four sub-groups of rapidly deficient rats was 0.75 mm./week, and the average time since the animals had been placed on the deficient diet was 16 weeks. The effect of

weekly vitamin A replacement therapy was then studied for the next six weeks, by the end of which time the unimpeded eruption rates of the four sub-groups of rats had reached a steady value.

For every one of these six weeks the unimpeded eruption rates of the six rats of each sub-group were grouped together so as to give the mean unimpeded eruption rate of the sub-group for that particular week. Thus, the time course of the effect of each replacement dose on the unimpeded eruption rate of its respective sub-group could be studied graphically (see figure 6) over the six week period. The mean unimpeded eruption rates of each sub-group are shown in Table 6.

TABLE 6

Unimpeded Eruption Rates at Four Doses of Vitamin A Replacement Therapy

Week No. (Since replacement began)	Sub-group I 10 i.u. /week	Sub-group II 160 i.u. /week	Sub-group III 40 i.u. /week	Sub-group IV 640 i.u. /week
1	1.3 mm. /week	1.45 mm. /week	1.2 mm. /week	1.8 mm. /week
2	1.95 mm. /week	2.25 mm. /week	2.35 mm. /week	2.1 mm. /week
3	1.85 mm. /week	2.9 mm. /week	2.55 mm. /week	2.15 mm. /week
4	2.15 mm. /week	3.1 mm. /week	2.75 mm. /week	2.3 mm. /week
5	2.4 mm. /week	3.1 mm. /week	2.65 mm. /week	2.1 mm. /week
6	1.8 mm. /week	3.45 mm. /week	2.55 mm. /week	2.3 mm. /week

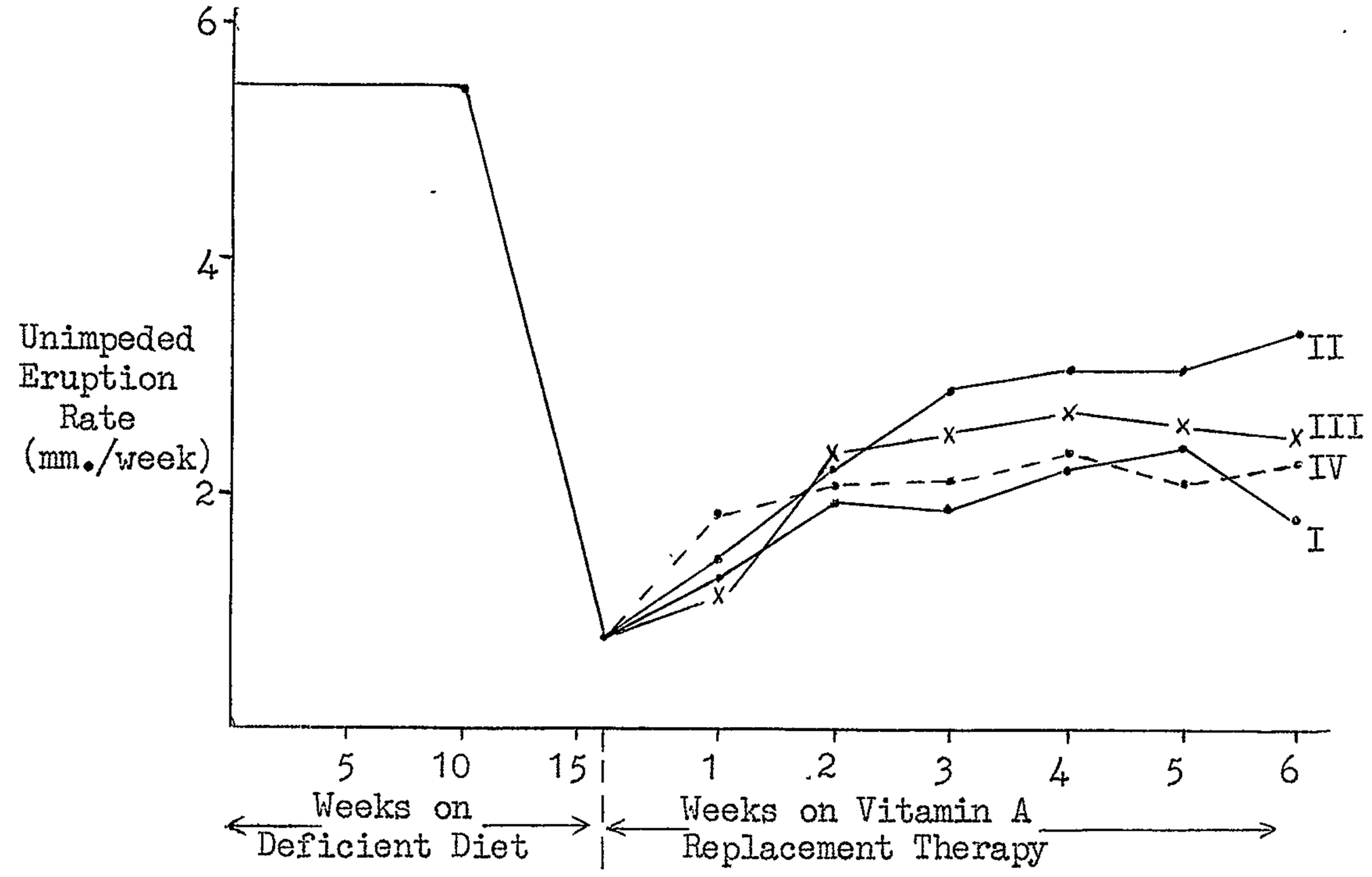

Figure 6 : Effect of four levels of vitamin A replacement therapy on the unimpeded eruption rate of the lower left incisor of rapidly vitamin A deficient rats.

I : rats receiving 10 i.u. of vitamin A/week.
II : " " 160 " " " " " .
III : " " 40 " " " " " .
IV : " " 640 " " " " " .

Reference to figure 6 and Appendix pp. VII-X will show that there was not much difference in the overall effect of the replacement therapy on unimpeded eruption between the four sub-groups, although the dose of 160 i.u./week was the most satisfactory in returning the unimpeded eruption rate towards a normal value. These results would indicate that irreversible damage to the tissues responsible for tooth eruption had occurred; this is especially the case when the unimpeded eruption rates of each sub-group are considered. This rate in some rats was not even able to reach 1 mm./week - for example, rat 83, receiving 640 i.u./week, had an unimpeded eruption rate which never recovered to more than 0.8 mm./week. The unimpeded eruption rate in many rats, irrespective of the replacement dose, never reached a value of more than 50 per cent of its normal (predeficient) weekly rate. In many cases, the deficient unimpeded eruption rate showed an immediate increase in response to the first two or three weekly supplements of vitamin A, but after this time, especially in those rats receiving the lower vitamin A supplements, it reached a steady value or may even have begun to decrease.

Thus, these results support the findings of Jolly (1964) who noted "a slow and uneven response in the growth of the incisor teeth" after prolonged vitamin A therapy to deficient rats. It was noted in the present study that in some individual rats the labial enamel of the incisor never recovered its normal pigmented appearance.

This effect was also noted by Jolly, and together with the partial recovery of the unimpeded eruption rate, would indicate that Jolly was correct in suggesting that the ameloblastic epithelium may undergo irreversible changes in vitamin A deficiency, since this epithelium appears to be an important factor in the eruption, and the incorporation of pigment into the enamel, of the rat incisor.

(d) Chronology of General and Dental Effects.

Some conclusions can now be made concerning the chronological arrangement of those general and dental effects of vitamin A deficiency observed by the author in the rat. The onset of the appearance of the signs obviously differed in the delayed deficient and rapidly deficient rats. However, the order in which these signs appeared was quite similar for both groups of deficient rats, except for the onset of the weight changes. In the rapidly deficient rats, the weights became steady and began to fall only after a previous fall in the unimpeded eruption rates. The delayed deficient rats, on the other hand, showed that their weights became steady before any decrease in the unimpeded eruption rate, but these rats began to lose weight only after this rate had commenced its decline. Thus, except for the differences in the pattern of weight changes, the following chronological description can be applied to both groups of rats.

The order of appearance of these effects was as follows:

1. Once the plasma vitamin A had been completely exhausted, the next observation of the onset of vitamin A deficiency was a decline in the eruption and attrition rates of the rat incisor, the unimpeded eruption rate often being affected before the impeded eruption rate and attrition rate.

2. This decrease in incisor eruption was soon followed by a corresponding fall in the rat's weight. As pointed out above, the rate of weight increase in the delayed deficient rats usually became zero before the decline in eruption, but this rate did not become negative until after the decrease in unimpeded eruption.

3. Xerostomia, food deposits and the beginning of calculus formation usually became obvious at this stage, and by the time the animal had suffered severe weight losses and almost cessation of incisor eruption, periodontal disease was a consequence in some rats.

4. Although the dental cells responsible, to some degree at least, for tooth eruption had been affected by the deficiency as shown by the reduced eruption rates, it was not until now that the effects of the deficiency on the ameloblasts became macroscopically obvious by the gradual appearance of non-pigmented enamel. When the deficiency had progressed to the stage where the unimpeded eruption rate was only one mm./week, the incisor teeth were usually quite pale. It was still some weeks later before white enamel and areas of enamel hypoplasia became obvious.

5. Involvement of the eyes by the deficiency was usually a little later than the appearance of the enamel pigment changes, but in some cases, the earliest eye changes (e.g. blepharitis) were observed before these enamel changes. Generally, the incisors were quite pale and often white before eye involvement became strikingly obvious. The more severe eye lesions (keratomalacia and corneal ulceration), if they occurred, were noted only at a very late stage in the deficiency.

6. The appearance of a blood-stained nasal discharge was next seen, following the onset of the eye changes. As the deficiency progressed, this sign became more and more apparent since clotting of the blood in the discharge had resulted in crust formation around the rat's nostrils.

7. A rough, untidy coat, respiratory distress and muscular weakness were sometimes, seen, but always occurred very late in the deficiency.

Thus, it can be seen that the earliest dental indication of vitamin A deficiency in the rat was a decrease in the unimpeded eruption rate of the lower incisor. Calculus formation and the appearance of non-pigmented enamel occurred quite soon after the commencement of this decrease, and represented the first macroscopic signs of vitamin A deficiency in the rat.

6.3 The Experimental Investigation - References

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7. DISCUSSION.

It has been pointed out (Bryer, 1957) that the effects of various experimental conditions on the eruptive mechanism of the continuously erupting rat incisor have been repeatedly interpreted from studies on functionally occluding incisors. This however, does not distinguish between influences having a direct action on the eruptive mechanism itself and those having an effect on the attrition rate of the incisors. For this reason, Bryer advocated the use of the unimpeded eruption rate since it gave the true indication of the effect of a certain experimental condition on the eruptive mechanism or eruptive force itself.

Incisor Attrition and Eruption Rates in Normal and Control Rats.

Results obtained from functionally occluding incisors may in fact contribute to incorrect conclusions concerning the incisors' eruptive processes, or may not give a true reflection of the effect of an experimental condition on the eruptive mechanism of the incisors. This was evident in the study of the eruption rates in the vitamin A deficient rats and even in the normal and control rats. For example, in the normal and control rats, the female was found to have highly significantly ($p < 0.001$) greater attrition rates and impeded eruption rates than the male; with these findings from functionally occluding lower incisors, it might have been concluded,

if the concept of unimpeded eruption had not been recognized, that the eruptive potential of the lower incisors of the female rat is greater than that of the male rat. However, when the unimpeded eruption rates of the male and female control rats were determined, it was noted that there was no significant difference between the male and female unimpeded eruption rates. Thus, it could be concluded that the lower incisors of male and female rats have the same eruptive potential, but the female rat shows greater attritional activity than the male rat. This illustrates how incorrect conclusions could be drawn from studies of the eruption rates of functionally occluding incisors. Furthermore, in the vitamin A deficient rats, it was generally noted that not only did the unimpeded eruption rate become affected by the deficiency state before the attrition and impeded eruption rates, but it also showed a much more gradual and steady decline, suggesting that it was more indicative of the influence of the deficiency on the processes concerned in tooth eruption. These two examples in vitamin A deficient rats and in normal and control rats certainly emphasize the rationale of using the unimpeded eruption rate in studies of the effects of various experimental conditions on the eruptive mechanism of the rat incisor.

The determination of the attrition rates and impeded eruption rates in the control and normal rats have also shown that a significant difference existed in both these groups of rats concerning

each of these rates. The normal rats, in which all incisors were in functional occlusion, showed significantly greater impeded eruption and attrition rates of the right lower incisors than the corresponding rates in the right lower incisors of the control rats, in which the left lower incisor had been removed from occlusion. This effect may be the result of the voluntary or involuntary avoidance of unnecessary incisal contact in the right lower incisor of the control rat, since this remaining functional tooth was carrying all the incisal load of the lower jaw. Consequently, the attrition rate was somewhat smaller, thus requiring a smaller impeded eruption rate to replace the reduced amount of tooth substance worn away by attrition.

The findings from the normal group of rats are of further interest, since they serve to illustrate a misconception that has found its way into the literature on tooth eruption. This misconception may have contributed to the present uncertainty regarding the physiological processes in tooth eruption. The pioneer studies of Addison and Appleton (1915) on the normal histology of the rat incisor have indeed proved the stepping-stone upon which many later studies on the physiology and pathology of the rat incisor have been based. Investigators frequently quote the work of Addison and Appleton when they note that these workers found the eruption rates of the upper and lower rat incisors to be 2.2mm./week and 2.8 mm./week respectively. However, Addison and Appleton actually quoted these

figures to represent the weekly "rates and growth". They did not define what they mean by "growth", but apparently they were referring to eruption. Moreover, they appear to have equated growth (or eruption) with attrition, since these "rates of growth" were measured by making a mark on the labial enamel, measuring its distance from the incisal edge of the tooth, and remeasuring this distance a week later. Thus, they were not measuring an eruption rate, but were in fact measuring the attrition rate of the tooth. They would have been correct however, if, as they stated when referring to the "growth" of the incisor, "During the post-eruptive period, which continues throughout life, this outward growth is continued at a regular rate, and at the same rate the outer end has to be worn away." The studies by the author have shown, however, that this is not the case, since the impeded eruption rate (measured from the gingival margin) is significantly greater than the attrition rate (measured from the incisal edge) and this allows the incisor to increase in length. Addison and Appleton seemed to have lost sight of the fact that the length of the rat incisor increases throughout the life of the animal. They had shown early in their paper that, even after ten months of age, the rat incisor continues to increase in length, and they continually referred to the fact that "throughout life, growth continues." Yet, they came to the conclusion that, once the incisors have come into functional occlusion (in the first two or

three weeks after birth) "the extra-gingival length of the tooth is kept constant, however, by the attrition of the occlusal surface, either through use in gnawing or by the action of the opposing teeth." The author recognizes the fact that the rate of increase in length of the rat incisor is reduced considerably after the animal is about five months old. However, the fact remains that the incisor still increases in length after this time. This was noted by the author and by Addison and Appleton in their study. Moreover, it must be realized that the majority of studies on rat incisor eruption have been carried out on animals younger than five months, and so this misconception, as introduced by Addison and Appleton and carried over to other studies on eruption, is quite relevant to these other studies, and may have been a factor adding to the confusion and contradications of the various theories of tooth eruption. Perhaps this aspect of their paper would not have been so confusing and contradictory within itself if Addison and Appleton had made clear what they meant by the terms "growth", "eruption" and "length", and what relation each of these had to the others.

These "rates of growth" of Addison and Appleton (actually attrition rates) have been repeatedly quoted by other workers as representing the eruption rates of functionally occluding incisors. For example Bryer (1957), who introduced the concept of unimpeded eruption as representing the true reflection of the tooth's eruptive force, quoted the "rates of growth" of Addison and Appleton as

representing what he called the "eruption-attrition" rates, and he accepted these as being the eruption rates of functionally occluding incisors. When one of these incisors is removed from occlusion he stated "the eruptive force is capable of a very high rate of eruption but in the intact animal this movement is inhibited by functional occlusion and the eruptive force is only allowed to express itself in the amount of attrition that takes place". Thus Bryer also had erred by saying that eruption of a functionally occluding incisor allows only for the amount of attrition that has occurred. This misconception, carried over from the work of Addison and Appleton, has led to errors in the conclusions drawn by Bryer on unimpeded eruption. Unless this misconception is appreciated; it will undoubtedly find its way into future research on the rat incisor, since Bryer's concept of unimpeded eruption will certainly be an invaluable asset in future studies on tooth eruption. Bryer said "the eruption - attrition rate of functionally occluding incisors is not a full reflection of the eruptive force but is in reality the resultant expression of two antagonistic forces; the eruptive force and the inhibiting force of functional occlusion." Thus Bryer has expressed the results of Addison and Appleton as the "eruption-attrition" rates, being "2.2 mm. and 2.8 mm. per week for the upper and lower incisors of the rat, respectively." These he said are the resultant expression of the eruptive force and the force of functional occlusion. However, these rates are in fact the attrition rates, which reflect

in no way the eruptive force, but only the "inhibiting force of functional occlusion". Attrition wears away the incisal edge of the tooth, but at a rate slower than the true impeded eruptive force, so that lengthening of the incisor may occur. It is this impeded eruption rate which is the resultant expression of the eruptive force and the force of functional occlusion. The author found this rate to be approximately 0.15 mm./week greater than the attrition rate, in the lower incisor.

Consequently, although these studies of Addison and Appleton (1915) and Bryer (1957) are extremely noteworthy contributions to the histology, anatomy, and physiology of eruption of the rat incisor, a misconception has nevertheless arisen from their studies. By revealing this misconception, the author hopes to aid, in some way, the removal of the uncertainty of the physiology of tooth eruption that exists at the present time.

This aspect of the discussion could be summarized by concluding that the unimpeded eruption rate is the full reflection of the eruptive force of the rat incisor. Although the impeded eruption rate does not represent the full eruptive potential of the rat incisor, it does indicate the actual eruption rate of a tooth in functional occlusion. The "rates of growth" of Addison and Appleton do not in fact indicate "growth" or eruption, but only the attrition rate of the tooth.

Vitamin A Deficiency Effects on the Rat Incisor

The difference between the impeded eruption rate and attrition rate was also obvious in the rats placed on the vitamin A deficient diet. Before they became deficient, the impeded eruption rate was greater than the attrition rate, but once deficient, the situation was reversed. With the delayed deficient and rapidly deficient rats both showing generally an incisor attrition rate greater than the impeded eruption rate, vitamin A deficiency was characterized by a shortening of the lower incisor. The incisor of the delayed deficient rats, at first sight, appeared to be more affected than that of the rapidly deficient rats, but only because the former were older and so their teeth had a much longer time in which to lengthen. Consequently, when the deficient state became obvious, the incisors of the delayed deficient rats had reached a length greater than the incisors of the rapidly deficient rats and so their decrease in length occurred at a greater rate and was more noticeable than the decrease in the rapidly deficient rats.

Bryer's method for measuring the unimpeded eruption rate of the rat incisor was found to be, in healthy rats (the control group), no more accurate than a gingival measurement. However, this latter measurement was not found to be sufficiently accurate in some of the vitamin A deficient rats. This inaccuracy was no doubt due to the involvement of the supporting structures of the teeth by the vitamin

deficiency since gingival inflammation and peridontal pocketing were often seen in the vitamin A deficient rats, along with the retardation of tooth eruption. The deficient state not only brought about these inflammatory changes by its action on the gingival tissues, but was most probably aided by the xerostomia, food deposits and calculus which were commonly seen in the deficient animals.

Because of the changes in the gingival condition and oral environment it was thought that these predisposing factors may likewise cause the deficient state to increase the susceptibility of the vitamin A deficient rats to dental caries. Although this caries study was not designed for statistical evaluation, the results certainly indicated no increased susceptibility to dental caries in vitamin A deficiency. Still, it must be pointed out that the rats used were not in a state of extreme vitamin A deficiency. It is possible that very severely deficient rats, or rats kept in a state of prolonged chronic deficiency, could show an increased susceptibility to caries.

The findings on the eruption rates of the vitamin A deficient rats show that vitamin A deficiency markedly affects the eruptive mechanism of the lower rat incisor. The unimpeded eruption rate was the most noticeably affected, falling from its normal value of almost 5.5 mm./week to well below 1 mm./week. Because of the difference in the vitamin A stores of the delayed deficient and the rapidly deficient rats, the unimpeded eruption rate of the former did

not begin to decrease until approximately 24 weeks after the rats were placed on the deficient diet. The rapidly deficient rats, however, showed retardation of their unimpeded eruption rate as early as eight weeks after placement on the deficient diet. Once initiated, the retardation of eruption occurred at the same rate in both groups of rats, for, as the unimpeded eruption rate did not begin to fall until after the vitamin A content of the plasma had been completely utilized, the same degree of deficiency existed in both groups of animals at this time, despite the differences in the time of onset of the deficient state. Such findings appear to agree well with the studies of Dowling and Wald (1958) which indicated that the signs of vitamin A deficiency do not begin appearing until after the estimated plasma vitamin A level has reached zero. The decrease in the unimpeded eruption rate of the rat incisor was observed to occur before any of the macroscopic signs of vitamin A deficiency became apparent, and even before the characteristic fall in the deficient animal's weight. The presence of non-pigmented enamel usually became apparent before the onset of the characteristic eye changes. However, such enamel was only seen after the decrease in eruption in the same tooth. This is to be expected, since the effect of the deficient state on the cells responsible for tooth formation and eruption is immediately reflected by a retardation of the unimpeded eruption rate. But because the newly-formed enamel takes some weeks to erupt into the mouth, the decrease in the enamel pigment

is not seen until about three or four weeks after the eruptive mechanism of the tooth has been affected.

Since there is no generally accepted explanation of the mechanism of tooth eruption at the present time, it is not possible to explain the mechanism by which eruption is retarded in vitamin A deficiency. However, as vitamin A deficiency acts at an epithelial level, and since the ameloblastic epithelium is undoubtedly responsible for the incorporation of pigment into the labial enamel of the rat incisor, it is quite probable that vitamin A deficiency results in retarded tooth eruption and non-pigmented enamel by an action on the ameloblasts. This view receives added support from the fact that the odontogenic epithelium, which includes the ameloblasts, is said to stimulate the formation of dentine in the rat incisor (Schour, 1960), and the striking retardation of eruption of the incisor in vitamin A deficiency must surely involve a reduction in both enamel and dentine formation.

Also, because it is such a characteristic finding in the rat incisor in vitamin A deficiency, mention must be made of the disproportionate thickening of the labial dentine of this tooth, and the apparent cause of this thickening. The lower right functionally occluding incisor did show this thickening, but the lower left incisor, kept out of functional occlusion did not reveal any such thickening. Although this study was not designed for statistical analysis, these observations do suggest that Schour and his colleagues (1941) were

correct in thinking that, in vitamin A deficiency, the disproportionate thickening of the incisor's labial dentine is a compensatory effect since the labial dentine has to carry most of the occlusal stress.

Vitamin A Replacement Therapy

It is apparent from the studies of vitamin A replacement therapy on rapidly deficient rats that vitamin A deficiency can cause irreversible damage to most of the tissues studied, although there is quite a deal of variation between individual rats.

The characteristic weight loss of the vitamin A deficient rat is immediately reversed by vitamin A administration, while the blood-stained nasal discharge of the deficient state is not seen after replacement therapy. However, as discussed below, evidence of irreversible changes can be noted in the eyes, the salivary glands, the incisor teeth and the supporting tissues of the teeth.

Severe eye lesions are little improved by vitamin A supplements but less severe changes such as blepharitis can soon be reversed. Because of little improvement in salivary flow in some rats, it is apparent that irreversible changes can occur in the salivary glands; such a finding supports the observations of Jolly (1964) who actually found histological evidence of widespread salivary gland damage after vitamin A deficiency. Periodontal changes produced in vitamin A deficiency are often not reversed by vitamin A administration.

Apparently vitamin A deficiency can produce irreparable damage to the supporting structures of the teeth and, together with the observation that salivary gland function may not return to normal, probably accounts for the persistence of periodontal disease.

Irreversible changes are also apparent in the incisor teeth. Even large doses of vitamin A supplements cannot return the incisor eruption rates of all deficient rats to normal. Although in most rats there is some degree of recovery of tooth eruption, this recovery varies between individual rats, and some rats may show relatively no recovery of tooth eruption at all. Additionally, a recovery of the normal orange and yellow pigment of the labial enamel of the rat incisors is not always seen after vitamin A administration to deficient rats. Consequently, since the ameloblastic epithelium seems to be vitally concerned in tooth eruption and tooth formation, including the incorporation of pigment into the labial enamel, the relevant findings of Jolly (1964) and the author could be concluded in Jolly's own words - "the slow and uneven response in the growth of the incisor teeth and in the redevelopment of normal-coloured enamel after prolonged vitamin A therapy indicated that the ameloblastic epithelium too may undergo irreversible changes in vitamin A deficiency."

8. SUMMARY AND CONCLUSIONS

A. Eruption and Attrition Rates of Normal and Control Rats

1. The unimpeded eruption rate is the full reflection of the eruptive force of the rat incisor.

2. The impeded eruption rate indicates the eruption rate of a functionally occluding incisor. It is expressed by the interaction of the eruptive force and the force of functional occlusion.

3. The attrition rate of a rat incisor expresses only the force of functional occlusion.

4. There is no significant difference in the one sex between left and right

(a) Attrition rates - in the normal male rat, the attrition rate of the left lower incisor is 2.71 mm./week, while the corresponding rate in the right lower incisor is 2.69 mm./week. In the normal female rat, the attrition rate of the left lower incisor is 3.29 mm./week, and of the right incisor is 3.28 mm./week.

(b) Impeded eruption rates - in the normal male rat, this rate is 2.88mm./week in the left lower incisor, and 2.86 mm./week in the right lower incisor. In the normal female rat, the impeded eruption rate is 3.40 mm./week in the left lower incisor, and 3.42 mm./week in the lower right incisor.

5. There is a significant difference between male and female

(a) Attrition rates and

(b) Impeded eruption rates, in normal rats.

Since the female rat shows a greater attrition rate and a greater impeded eruption rate than the male rat, the female apparently has greater attritional activity than the male.

6. There is however, no significant difference in the unimpeded eruption rates between male and female rats. The male unimpeded eruption rate of the left mandibular incisor is 5.48 mm./week, and the corresponding rate in the left mandibular incisor of the female is 5.44 mm./week.

Since the unimpeded eruption rate is the expression of the eruptive force of the rat incisor, this indicates that male and female rats have the same eruptive potential. However, this similarity is markedly changed by functional occlusion.

7. There is a significant difference, in both male and female rats, between the attrition rate and the impeded eruption rate of the lower incisor. Consequently, continual eruption of the rat incisor not only compensates for the attrition of the tooth, but allows a significant increase in length. This increase is especially apparent in approximately the first six months after birth, but is still obvious long after this time.

8. If one lower incisor is cut out of occlusion (as in the control group of rats), the attrition rate and impeded eruption rate of the

contralateral tooth is less than these rates in rats with both lower incisors in functional occlusion. This may be the result of the rat, with only one lower incisor in functional occlusion bearing all the incisal masticatory load of the lower jaw, avoiding all unnecessary use of this tooth.

9. There is in healthy rats (control group) no significant difference between the unimpeded eruption rates determined by the method of Bryer (1957) or by a gingival measurement. However, in a disturbance affecting the structural and functional integrity of the gingiva - vitamin A deficiency, the gingival measurement is no longer an accurate means of determining the unimpeded eruption rate.

B. Retarded Eruption and Other Characteristics in Vitamin A Deficient Rats

1. The unimpeded eruption rate, impeded eruption rate and attrition rate are markedly reduced in vitamin A deficiency.

2. There is generally no difference between delayed deficient and rapidly deficient rats in the rate of reduction of the above rates, but there is obviously a marked difference in the time of onset of retardation in rates - the delayed deficient rats begin to show a reduced unimpeded eruption rate at approximately 24 weeks after being placed on the vitamin A deficient diet, whereas the same rate in the rapidly deficient rats commences to decrease as early as eight weeks after placement on the deficient diet..

3. The eruption and attrition rates only fall after the plasma shows no more vitamin A content.

4. Vitamin A deficiency results in shortening of the rat incisor. Such an effect is the exact reverse of the increase in length of the incisor in normal rats, since in the vitamin A deficient state the attrition rate generally exceeds the impeded eruption rate in the one incisor, thus producing a shortened tooth.

5. The reduction in the unimpeded eruption rate of the rat incisor is a very early sign of the vitamin A deficient state, occurring before all the gross deficiency signs, including weight loss.

6. The common gross signs of deficiency observed in the study were weight loss, xerostomia, soft food deposits and calculus formation, the presence of non-pigmented enamel of the incisors, ocular changes, and a blood-stained nasal discharge, in that order of appearance. Enamel and dentine hypoplasia, and gingival and periodontal involvement, were seen quite late in the vitamin A deficient state, while a rough, untidy coat, respiratory complications and muscular weakness were occasionally seen.

7. The presence of a retarded unimpeded eruption rate and non-pigmented enamel of the incisor indicate involvement of the cells responsible for tooth formation and eruption by the deficient state. However, because the newly-formed enamel takes some weeks to

erupt into the oral cavity, the retarded eruption rate occurs long before the non-pigmented enamel appears. Consequently it is an immediate indication of involvement of the cells by the deficiency, whereas the non-pigmented enamel is a past record of this effect of the vitamin A deficient state.

8. There appears to be no relationship between vitamin A deficiency and an increased susceptibility to dental caries.

9. The characteristic disproportionate thickening of the labial dentine of the rat incisor can probably be attributed to incisal loading, since this portion of the tooth has to carry most of the stress of functional occlusion.

10. Vitamin A deficiency in the rat can cause irreversible damage to the eyes, the salivary glands, the incisor teeth, and the supporting structures of the teeth, since vitamin A replacement therapy is not always effective in overcoming the changes produced by the deficient state in these tissues.

11. Studies of replacement therapy especially on the unimpeded eruption rate and the enamel pigment of the rat incisor indicate that irreversible changes occur in the ameloblastic epithelium in vitamin A deficiency.

8.1 Discussion and Summary and Conclusions - References

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APPENDIX.

NORMAL FEMALE RATS

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right(rt.) INCISORS.

Rat No.	11				12				13				14				15			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	3.4	3.4	3.6	3.4	2.9	3.8	3.8	3.5	2.9	3.4	2.9	3.2	3.1	2.4	3.8	3.3	2.8	2.7	2.5	3.4
2	2.9	3.0	3.6	3.4	3.0	2.6	3.0	2.9	2.0	2.3	2.8	3.3	2.9	2.4	3.2	2.8	3.4	2.9	3.0	3.2
3	3.1	3.2	3.5	3.8	3.2	3.4	3.3	3.3	3.1	3.2	3.2	3.3	3.2	3.0	3.0	3.0	3.5	3.4	3.7	3.5
4	3.6	3.7	3.4	3.4	3.4	3.4	3.4	3.3	3.2	3.1	3.4	3.3	3.3	3.2	3.4	3.9	2.6	2.5	2.5	3.0
5	3.6	3.8	3.6	4.2	2.8	3.4	2.6	3.7	3.1	2.9	3.6	3.5	4.2	3.7	4.1	4.0	2.8	2.8	2.9	3.1
6	3.7	4.1	3.9	4.3	3.3	3.3	3.6	3.0	3.6	3.7	3.5	3.6	3.3	3.0	3.6	2.8	2.8	2.6	3.2	3.0
7	3.1	3.2	3.3	3.7	3.3	3.1	3.3	3.7	3.2	3.1	3.4	3.3	3.3	3.0	3.4	3.4	2.8	3.3	2.8	3.2
8	3.8	4.3	4.0	4.2	3.7	3.7	3.7	3.7	3.3	3.3	3.4	3.5	3.4	3.2	3.7	3.4	3.4	2.7	3.3	3.2
9	3.4	4.1	3.7	4.2	3.3	3.4	3.6	3.6	4.1	3.7	3.9	3.4	3.2	2.8	3.6	3.2	3.1	3.0	3.2	2.7
10	3.8	4.0	3.9	4.2	3.4	3.7	3.6	3.7	3.4	3.6	3.3	3.7	3.5	3.4	3.4	3.5	3.0	3.6	3.2	3.5
11	4.2	4.6	3.6	4.4	3.5	3.4	3.3	3.1	3.6	3.2	3.9	3.4	3.2	2.9	3.7	3.2	3.2	3.0	3.4	2.8
12	3.4	3.8	3.6	4.0	3.2	3.4	3.3	3.4	3.5	3.4	3.9	3.3	3.5	3.3	3.0	2.8	3.1	3.0	3.2	3.4
13	4.9	5.0	4.6	4.6	3.3	3.6	3.4	3.9	4.0	3.2	3.8	3.4	3.4	2.9	3.6	3.3	3.2	3.2	3.2	3.1
14	3.4	4.0	4.3	5.0	2.9	2.9	3.0	3.2	3.6	3.2	4.2	3.4	3.0	2.8	3.5	2.9	3.2	3.2	3.4	3.3
15	2.9	2.8	3.2	3.4	3.0	3.4	3.1	3.3	3.1	3.0	3.2	3.3	3.1	3.1	3.2	3.6	2.9	2.9	2.9	2.9
16	4.1	3.9	3.2	3.4	3.5	3.5	3.0	3.6	3.6	3.2	3.2	3.4	3.5	3.3	3.2	3.1	3.5	3.2	3.4	3.1
17	3.5	3.5	3.8	4.3	3.2	3.3	3.6	3.3	3.5	3.1	4.2	3.7	2.8	2.9	3.4	3.2	3.2	3.2	3.4	3.5
18	3.6	3.6	3.8	3.6	3.3	3.7	3.2	3.6	-	-	2.2	2.9	3.7	3.4	3.1	3.2	3.1	3.1	3.4	3.0
19	3.6	3.6	3.8	3.6	2.9	3.4	3.6	4.1	-	-	2.2	2.9	2.9	2.5	3.6	3.1	3.0	3.0	3.1	3.3
20	3.6	3.6	3.5	3.6	3.4	3.4	3.2	3.2	3.3	3.2	3.5	3.4	3.1	2.9	3.2	3.2	3.1	3.0	3.4	2.9
21	3.6	3.6	3.5	3.6	3.4	3.4	2.8	2.8	3.3	3.2	3.5	3.4	3.5	3.1	3.6	3.6	2.9	3.2	3.2	2.8
22	3.4	3.7	3.9	3.9	2.9	3.5	3.5	3.8	2.9	3.1	3.1	3.3	3.0	3.1	3.7	2.9	3.1	2.9	3.2	3.0
TOTAL	78.6	82.5	81.3	86.2	70.8	74.7	72.9	75.7	66.3	64.1	74.3	73.9	72.1	66.3	76.0	71.4	67.7	66.4	69.5	68.9
MEAN	3.57	3.75	3.70	3.90	3.22	3.40	3.31	3.44	3.32	3.21	3.38	3.36	3.28	3.01	3.45	3.25	3.08	3.02	3.16	3.13
S.D.	0.430	0.492	0.325	0.442	0.237	0.260	0.30	0.326	0.432	0.294	0.52	0.19	0.304	0.315	0.273	0.324	0.237	0.259	0.289	0.234

ATTRITION RATE OF LEFT INCISOR (total mean of left incisal measurements) = 3.29 ± 0.036 mm./week.
ATTRITION RATE OF RIGHT INCISOR (" " " right " ") = 3.28 ± 0.042 " "
IMPEDED ERUPTION RATE OF LEFT INCISOR (" " " left gingival ") = 3.40 ± 0.038 " "
IMPEDED ERUPTION RATE OF RIGHT INCISOR (" " " right " ") = 3.42 ± 0.040 " "

(S.D. :- Standard Deviation)

NORMAL MALE RATS

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right(rt.) INCISORS.

Rat No.	16				17				18				19				20			
Week No.	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	2.1	2.2	2.7	2.5	2.1	1.9	2.9	2.8	3.4	3.0	3.1	3.0	2.9	2.9	3.0	2.8	3.0	3.2	3.1	2.8
2	2.5	2.3	2.9	2.7	2.7	-	2.3	-	2.9	2.8	3.3	3.2	2.4	2.3	3.0	3.1	3.1	2.7	3.4	3.4
3	3.2	3.1	3.5	3.4	2.8	2.8	3.0	3.2	2.8	2.4	2.9	2.1	2.7	2.7	2.8	2.8	2.9	2.9	3.1	3.1
4	2.9	3.0	3.0	3.2	2.8	2.8	2.8	3.3	3.5	3.3	3.5	3.6	2.8	2.6	3.3	3.4	2.6	2.4	2.9	2.9
5	2.8	3.0	3.2	3.6	3.5	3.3	4.1	3.3	1.9	2.3	2.9	3.1	3.1	3.2	3.1	3.2	3.3	3.1	3.2	3.2
6	2.6	3.1	3.5	3.0	3.2	2.9	3.2	4.1	2.3	2.5	3.4	2.8	2.8	2.8	3.4	3.0	2.7	2.9	3.0	3.3
7	2.3	2.6	2.8	3.2	2.8	2.8	3.2	3.2	2.9	2.8	3.1	2.9	3.1	3.1	3.2	3.0	3.1	3.2	3.5	3.2
8	2.8	3.2	3.1	3.2	2.8	2.5	2.9	2.9	2.8	2.9	2.8	2.9	3.2	3.2	3.5	3.3	2.9	2.7	2.9	3.0
9	3.2	3.3	3.2	3.4	2.8	2.8	2.8	3.2	2.8	2.7	3.1	2.9	2.5	2.4	2.8	2.9	2.8	2.5	3.1	2.8
10	2.5	2.9	2.8	3.2	2.9	2.9	3.0	2.8	2.5	2.4	2.5	2.6	2.9	2.9	3.1	3.2	3.1	2.7	3.3	2.8
11	2.7	2.8	2.7	3.0	3.0	2.6	3.0	2.8	2.4	2.5	2.7	2.6	3.1	2.7	3.0	2.8	2.6	2.5	2.8	2.8
12	2.5	2.8	2.8	3.0	2.8	2.5	3.1	2.7	2.1	2.4	2.5	2.6	2.5	2.6	2.8	2.7	2.8	2.7	2.8	2.5
13	2.5	2.8	2.6	2.8	2.8	2.8	2.5	2.8	2.7	2.7	2.7	2.4	3.1	3.0	2.7	2.6	2.6	2.5	2.4	2.5
14	2.5	3.0	2.5	3.1	3.1	2.8	3.1	2.7	2.5	2.5	2.8	2.7	2.6	2.4	3.0	2.6	2.8	2.7	3.0	3.0
15	2.7	2.9	2.7	3.0	2.5	2.2	2.9	2.4	2.5	2.3	2.5	2.2	2.4	2.4	2.5	2.7	2.8	2.7	2.8	2.6
16	2.2	2.4	2.5	2.7	2.7	2.6	2.7	2.8	2.6	2.8	2.6	3.0	2.8	2.4	2.8	2.3	2.6	2.3	2.6	2.6
17	2.5	3.3	2.8	3.0	2.9	2.8	2.9	3.2	2.5	2.4	2.4	2.3	2.7	2.5	2.5	2.5	2.7	2.6	3.3	2.4
18	2.8	2.8	2.5	2.9	3.1	2.8	2.9	2.4	2.5	2.3	2.7	2.8	2.1	2.4	2.7	2.8	2.5	2.3	2.8	2.8
19	2.3	2.8	2.5	3.0	2.5	2.3	2.8	2.8	2.7	2.8	2.7	2.7	2.6	2.5	2.5	2.4	2.6	2.3	2.8	2.5
20	2.3	2.6	2.5	2.8	2.7	2.4	2.8	2.5	2.0	2.0	2.4	2.2	2.2	2.2	2.5	2.4	2.8	2.8	2.8	2.7
21	2.4	2.8	2.7	2.9	2.7	2.2	2.7	2.5	2.6	2.7	2.5	2.7	2.5	2.6	2.6	2.8	2.5	2.4	2.5	2.5
22	2.7	3.1	2.7	3.1	2.8	2.4	2.5	2.3												
TOTAL	57.0	62.8	62.2	66.7	62.0	55.1	64.1	60.7	54.9	54.5	59.1	57.3	57.0	55.8	60.8	59.3	58.8	56.1	62.1	59.4
MEAN	2.59	2.85	2.83	3.03	2.82	2.62	2.91	2.89	2.61	2.59	2.81	2.73	2.71	2.66	2.90	2.82	2.80	2.67	2.96	2.83
S.D.	0.281	0.29	0.299	0.249	0.269	0.307	0.339	0.50	0.381	0.289	0.320	0.356	0.303	0.290	0.295	0.297	0.118	0.269	0.280	0.285

ATTRITION RATE OF LEFT INCISOR (total mean of left incisal measurements) = 2.71 ±0.030 mm./week.
ATTRITION RATE OF RIGHT INCISOR (" " " right " ") = 2.69 ±0.023 "
IMPEDED ERUPTION RATE OF LEFT INCISOR (" " " left gingival ") = 2.88 ±0.030 "
IMPEDED ERUPTION RATE OF RIGHT INCISOR(" " " right " ") = 2.86 ±0.019 "

(S.D. :- Standard Deviation)

CONTROL FEMALE RATS

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right(rt.) INCISORS.

Rat No.	30				31				33				39				40			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	5.4	3.5	5.1	3.9	3.7	2.1	3.7	3.7	5.6	3.8	5.0	4.1	8.4	5.6	5.9	4.7	4.9	3.1	5.2	3.2
2	4.5	2.9	4.6	4.0	4.7	2.7	4.6	3.0	5.6	3.7	5.2	3.7	6.4	3.6	6.4	4.1	5.8	2.8	5.7	3.4
3	4.7	2.4	4.8	2.9	4.7	2.3	4.8	2.7	5.4	3.6	5.7	3.6	6.9	4.3	6.6	4.4	4.7	2.4	5.3	3.4
4	5.9	4.0	5.2	3.3	5.9	3.4	5.0	3.1	6.2	3.9	5.7	3.8	6.3	3.7	6.2	4.0	5.9	2.6	6.2	2.4
5	5.6	3.4	4.9	3.7	6.4	4.1	5.1	3.6	5.9	3.9	4.4	3.4	7.2	4.3	7.3	4.1	5.7	2.5	6.1	2.9
6	4.2	1.7	5.0	2.5	5.6	3.3	5.0	3.2	5.4	3.7	5.1	3.9	6.9	3.0	7.4	3.5	5.6	2.8	5.8	2.8
7	4.5	2.4	5.0	2.6	4.6	2.2	5.4	3.3	5.2	2.8	5.1	3.2	6.3	3.0	6.3	3.0	5.6	2.1	6.2	2.6
8	5.1	2.8	4.9	2.9	4.5	1.8	5.1	2.5	5.8	3.2	5.4	3.2	6.6	3.3	6.3	3.3	6.0	2.5	5.8	2.7
9	4.4	2.6	4.3	2.7	4.1	2.5	4.4	2.8	5.0	2.7	5.1	3.0	6.3	3.0	6.7	2.9	5.6	2.6	5.7	2.7
10	4.7	3.0	4.2	2.9	6.9	5.3	-	-	6.1	4.4	5.1	3.6	6.2	2.6	6.4	2.6	5.8	2.4	6.1	2.7
11	4.3	2.4	4.6	2.6	6.3	4.7	6.0	4.6	3.7	1.7	5.2	2.5	5.9	2.4	4.9	2.2	5.9	2.5	5.9	2.5
12	4.8	2.7	4.4	2.6	5.3	3.7	5.4	4.1	4.8	2.7	4.6	3.1	6.3	3.6	6.4	3.2	6.5	2.6	6.6	2.6
13	4.5	2.6	4.6	2.5	5.7	4.0	5.7	4.0	5.1	2.9	5.2	2.9	6.2	3.0	6.0	3.2	5.5	2.3	5.6	2.3
14	4.5	2.4	4.4	2.7	5.7	3.7	5.2	4.1	4.5	2.4	4.7	2.8	5.9	2.5	6.6	2.8	5.8	2.7	5.2	2.5
15	4.5	2.4	4.4	2.4	5.6	4.1	5.3	4.2	4.9	2.8	4.8	2.8					5.7	2.4	5.8	2.6
16	4.4	2.5	4.6	2.7	5.4	2.9	6.0	3.0	5.2	3.3	5.1	3.1					5.4	2.4	5.6	2.5
17	4.0	1.4	2.9	1.7	5.4	3.4	5.0	2.2	4.4	2.4	3.5	2.0					4.8	2.3	5.0	2.3
18	5.9	3.4	6.2	3.3	5.3	3.5	7.1	4.5	4.4	2.4	6.0	3.3					6.7	3.5	5.9	3.2
19	4.6	2.5	4.6	2.8	5.6	3.5	5.8	3.3	4.6	2.6	4.7	2.7					6.2	3.1	6.0	2.9
20	-	-	-	-	5.8	3.2	5.6	3.8	5.5	2.6	5.6	2.7					5.5	3.2	5.7	3.0
21	4.8	2.5	4.8	2.7			-	3.6												
22							5.6													
TOTAL	95.3	53.5	93.5	57.4	107.2	66.4	105.8	69.3	103.3	61.5	101.2	63.4	91.8	47.9	90.4	48.0	113.6	52.8	115.4	55.2
MEAN	4.77	2.68	4.68	2.87	5.36	3.32	5.29	3.47	5.17	3.08	5.06	3.17	6.56	3.42	6.46	3.43	5.68	2.64	5.77	2.76
S.D.	0.527	0.58	0.587	0.529	0.767	0.872	0.682	0.65	0.625	0.668	0.529	0.508	0.624	0.833	0.583	0.71	0.486	0.343	0.381	0.328

ATTRITION RATE OF RIGHT INCISOR (total mean of right incisal measurements) = 3.00 ± 0.077 mm./week.
IMPEDED ERUPTION RATE OF RIGHT INCISOR (" " " " gingival ") = 3.12 ± 0.042 " "
UNIMPEDED ERUPTION RATE OF LEFT INCISOR (" " " left incisal ") = 5.44 ± 0.086 " "
UNIMPEDED ERUPTION RATE OF LEFT INCISOR (" " " " gingival ") = 5.39 ± 0.079 " "

(S.D.:- STANDARD DEVIATION)
(INCISAL measurement: in left incisor=unimpeded eruption rate; in right incisor =attrition rate)

CONTROL MALE RATS

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right(rt.) INCISORS.

RAT No.	34				35				36				37				38			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	6.1	4.1	5.4	4.0	5.3	3.5	5.0	3.9	5.4	3.6	5.3	3.6	5.3	3.1	5.2	3.3	5.0	3.1	5.6	3.4
2	5.7	3.3	5.5	3.6	4.8	2.9	5.0	3.3	4.9	3.0	5.4	2.4	5.1	2.9	5.7	3.5	4.7	2.7	5.1	3.2
3	5.0	2.9	4.6	3.5	5.1	3.0	5.5	3.6	4.8	2.8	5.8	3.7	5.2	3.1	4.9	2.8	5.1	2.7	5.0	32
4	5.3	3.0	5.3	3.5	6.3	3.2	6.6	3.2	5.8	3.0	5.4	3.1	5.9	3.0	5.6	3.2	5.7	2.7	6.0	3.3
5	5.4	2.9	6.0	3.1	5.3	2.5	5.6	2.9	5.5	2.5	5.8	3.4	5.6	2.6	6.1	3.1	4.9	2.3	5.3	2.7
6	5.7	2.3	5.6	3.3	5.8	2.7	5.9	3.2	5.9	2.8	6.3	3.0	5.7	3.1	5.9	3.1	7.1	2.7	5.6	2.9
7	6.2	3.0	6.0	2.8	6.3	2.8	6.1	2.9	5.8	2.8	6.2	2.8	5.8	3.1	5.5	3.2	5.4	2.5	5.7	2.8
8	5.4	2.4	5.4	2.9	5.6	2.4	6.1	2.7	5.3	2.4	-	2.6	4.8	2.5	5.6	3.2	4.9	2.2	5.2	2.6
9	5.6	2.6	5.4	2.7	5.8	2.7	5.7	2.7	5.8	2.5	5.8	2.1	5.7	2.8	5.4	2.8	5.5	2.3	5.4	2.4
10	5.6	2.8	5.6	2.8	6.1	2.6	6.0	2.5	5.7	2.5	5.9	2.4	5.9	2.6	5.6	2.8	5.5	2.3	5.3	2.3
11	5.5	2.8	5.0	2.8	6.2	2.3	6.1	2.4	5.6	2.0	5.5	2.1	6.0	2.9	6.0	2.8	5.5	1.9	5.8	2.2
12	5.7	3.0	5.5	3.1	6.3	2.6	6.2	2.5	6.1	2.4	6.7	2.4	6.2	3.1	5.9	2.9	5.6	2.1	5.6	2.7
13	5.6	2.8	5.7	3.0	4.9	1.4	5.7	2.0	-	-	-	-	4.5	2.1	5.1	2.6	4.8	2.1	5.2	2.1
14	5.2	2.1	5.4	2.6	5.4	2.7	5.2	2.0	4.9	2.5	5.1	2.6	5.6	2.5	4.8	2.4	5.2	2.2	5.0	2.2
15	5.0	2.6	5.4	2.8	6.3	2.1	6.3	3.2	6.2	2.2	6.2	1.7					5.5	2.2	5.7	2.4
16	6.0	3.0	5.4	2.6	6.0	1.6	5.7	1.9	5.2	1.8	5.5	2.0					5.5	2.1	5.3	2.3
17	4.6	2.0	5.9	2.5	6.0	2.4	5.3	1.7	4.5	1.9	4.2	1.8					4.5	1.9	4.9	1.8
18	5.1	2.5	5.0	2.7	5.5	2.0	5.6	2.4	5.5	1.6	5.3	1.8					5.2	2.0	5.1	2.7
19	5.9	3.2	5.4	2.9	6.1	2.4	5.9	2.6	5.7	2.0	5.5	1.6					5.6	2.3	5.3	2.3
20	4.0	1.3	5.1	1.6	5.5	2.7	5.0	3.1	3.7	1.1	5.3	2.0					4.6	2.1	5.3	2.2
21	5.4	2.6	5.5	2.4																
22	6 .2	3.1	5.4	2.7																
TOTAL	120.2	60.3	119.5	63.9	114.6	50.5	114.5	54.7	102.3	45.4	101.2	47.1	77.3	39.4	77.3	41.7	105.8	46.4	107.4	51.7
MEAN	5.46	2.74	5.43	2.90	5.73	2.53	5.73	2.74	5.38	2.39	5.62	2.48	5.52	2.81	5.52	2.98	5.29	2.32	5.37	2.59
S.D.	0.512	0.55	0.318	0.482	0.524	0.483	0.448	0.569	0.594	0.561	0.538	0.626	0.465	0.30	0.388	0.029	0.548	0.309	0.29	0.432

ATTRITION RATE OF RIGHT INCISOR (total mean of right incisal measurements) = 2.55 ± 0.051 mm./week.
IMPEDED ERUPTION RATE OF RIGHT INCISOR (" " " " gingival ") = 2.73 ± 0.055 " "
UNIMPEDED ERUPTION RATE OF LEFT INCISOR (" " " left incisal ") = 5.48 ± 0.056 " "
UNIMPEDED ERUPTION RATE OF LEFT INCISOR (" " " " gingival ") = 5.53 ± 0.044 " "

(S.D.:-STANDARD DEVIATION)

(INCISAL measurement: in left incisor = unimpeded eruption rate; in right incisor = attrition rate)

IV

DELAYED DEFICIENT RATS

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right (rt.) INCISORS.

Rat No.	21				25				26				27				29				32			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	5.6	3.3	5.1	3.7	5.9	3.9	5.4	4.0	5.9	3.7	5.1	5.0	5.2	2.9	5.2	3.3	6.1	3.8	5.6	3.5	5.6	2.8	5.3	3.0
2	4.8	2.4	5.5	2.9	5.4	3.3	5.5	3.6	4.9	2.5	6.0	3.6	5.1	2.4	5.2	3.0	5.3	2.7	6.2	3.5	5.2	2.1	5.5	2.6
3	5.8	3.5	5.7	3.7	5.5	2.8	6.0	3.1	6.2	2.1	5.0	2.4	5.7	4.4	5.4	4.8	5.3	2.5	5.4	2.8	5.2	2.3	5.3	2.7
4	4.9	2.4	5.2	2.7	5.1	2.5	5.5	2.8	5.3	2.0	5.5	2.3	4.8	2.0	5.4	2.7	4.9	2.7	5.2	3.2	5.1	2.9	4.6	2.5
5	5.5	2.8	5.8	3.0	5.4	2.9	5.9	3.1	5.1	2.2	5.1	2.4	5.4	2.5	5.5	2.5	5.4	2.5	5.2	2.4	5.5	2.3	5.2	2.4
6	4.9	2.5	5.4	2.7	6.0	2.8	5.8	2.8	5.7	2.0	5.5	2.2	5.1	2.1	5.3	2.3	5.2	2.4	5.1	2.7	5.1	2.3	4.8	2.4
7	5.6	2.9	5.1	2.9	5.4	1.9	5.4	2.5	5.1	2.2	5.3	2.4	5.5	2.4	5.0	2.4	5.3	2.5	5.5	2.6	5.0	2.1	4.8	2.2
8	5.1	2.7	5.1	2.6	5.6	2.8	5.5	2.7	5.3	2.3	5.2	2.2	5.7	2.4	5.1	2.4	5.5	2.8	5.5	2.7	5.8	2.2	4.6	2.3
9	5.4	2.9	4.8	3.1	5.5	2.8	6.0	2.6	5.0	2.0	5.3	2.1	5.2	2.3	4.8	2.3	4.5	1.5	5.1	2.1	5.0	2.1	5.2	2.3
10	4.9	2.5	5.7	2.8	5.4	2.4	5.0	2.7	3.8	1.4	4.1	2.0	4.3	1.7	5.1	2.2	5.4	2.6	4.6	2.4	4.6	1.6	4.3	1.7
11	5.4	3.3	4.5	3.0	5.8	2.7	5.3	2.5	6.2	2.7	5.0	2.1	6.1	3.7	4.7	3.0	5.0	2.3	5.1	2.4	5.1	1.9	4.6	2.0
12	5.1	2.8	4.9	2.9	5.1	2.4	5.3	2.7	5.1	2.4	5.5	2.4	5.3	2.7	4.9	2.8	5.5	2.4	5.0	2.6	5.3	2.0	5.6	2.0
13	5.1	2.9	4.9	3.0	5.1	2.4	-	-	5.7	2.7	5.0	2.6	5.6	2.5	5.1	2.6	5.3	2.4	5.1	2.4	5.2	2.0	4.2	2.0
14	5.1	2.5	4.9	2.8	5.3	2.4	5.2	2.4	5.2	2.0	5.2	2.4	5.9	2.7	5.0	2.7	4.8	1.6	5.0	2.1	5.1	2.3	5.0	2.1
15	5.7	3.4	5.1	3.2	5.0	2.0	5.5	2.3	5.5	2.1	4.9	2.2	4.5	1.6	5.0	2.3	5.2	2.0	5.0	2.1	4.3	1.8	4.3	2.0
16	5.5	3.2	5.1	3.3	5.2	2.4	5.4	2.3	4.8	2.1	4.7	2.7	5.1	2.2	4.9	2.2	5.4	2.4	5.7	2.2	5.2	2.0	4.7	2.0
17	5.5	3.3	5.1	3.3	6.5	2.6	5.2	2.6	5.2	2.3	5.2	2.0	5.5	2.4	5.1	2.3	4.5	1.5	4.6	1.8	4.5	2.0	5.1	2.0
18	4.7	2.7	5.1	3.0	5.3	2.6	5.8	2.8	5.0	1.9	5.1	2.0	4.4	1.7	4.7	2.0	5.2	2.1	4.3	1.8	4.2	1.8	4.7	1.9
19	6.2	3.1	5.1	2.8	5.0	2.6	5.2	2.8	5.1	2.5	5.2	2.5	4.8	1.9	4.5	1.7	6.9	3.3	5.2	2.4	4.8	2.1	4.4	2.2
20	5.2	3.3	5.2	3.1	5.5	3.3	5.2	3.3	5.4	2.6	4.8	2.0	5.8	3.0	4.6	3.0	5.4	2.5	5.1	2.4	5.7	2.3	5.3	2.2
21	4.9	2.5	5.2	2.8	5.3	3.0	5.2	2.7	5.8	2.3	5.2	2.6	4.5	2.5	4.5	2.6	5.4	2.5	5.0	2.1	4.6	1.9	4.0	2.2
22	5.6	3.5	5.3	3.0	5.1	3.3	4.9	2.9	5.1	2.4	4.8	1.8	3.7	2.1	3.9	2.0	4.9	2.6	4.7	2.9	5.4	2.2	5.4	1.8
23	4.7	2.8	5.1	3.0	5.4	2.7	5.4	2.8	4.6	2.6	4.1	2.8	3.3	2.6	3.2	2.0	4.3	2.3	4.7	2.3	5.4	2.4	5.0	2.2
24	5.1	3.2	5.0	2.9	4.2	2.7	4.3	2.3	3.5	1.9	-	2.0	2.1	1.6	1.9	1.6	4.6	2.3	4.3	2.1	5.0	2.9	4.8	2.8
25	6.1	4.9	5.3	4.3	4.2	2.9	4.4	2.4	3.6	2.5	3.9	1.9	1.2	1.5	1.2	1.4	3.3	2.0	4.0	2.3	4.7	1.5	4.5	1.4
26	3.8	2.3	4.8	2.8	2.9	2.5	2.9	2.4	2.4	1.9	2.6	1.9	2.1	2.1	1.1	1.7	2.4	2.4	2.3	2.3	5.0	2.2	4.5	2.1
27	2.7	2.1	3.7	2.4	2.2	2.5	1.7	2.0	1.2	1.4	1.4	1.4	0.8	2.0	0.4	1.8	2.3	2.1	2.2	1.9	4.3	1.5	4.7	1.8
28	2.5	2.4	2.5	2.3	0.8	1.6	0.8	1.2	1.3	1.4	1.2	1.1	0.5	1.1	0.5	0.9	1.8	2.3	1.6	2.0	3.1	1.7	4.8	1.4
29	1.7	1.8	1.6	2.0	0.9	1.7	0.6	1.3	1.0	1.5	0.8	1.0	0.7	-	0.1	0.8	1.1	1.9	0.7	1.6	2.2	2.2	1.9	1.8
30	1.3	2.4	1.1	2.0	0.8	1.9	0.5	1.3	0.8	1.1	0.6	0.9					1.0	2.1	0.5	1.6	1.7	1.8	1.5	1.3
31	1.2	2.2	0.9	1.9	0.8	1.3	0.5	1.0	0.7	0.8	0.5	0.4					0.7	1.6	0.6	1.2	1.0	1.6	0.7	1.3
32	0.7	1.5	0.6	1.2	0.5	1.2	0.4	1.1	0.7	0.9	0.3	0.4					0.7	1.2	0.6	1.5	0.9	1.4	0.4	1.1
33	0.5	1.3	0.4	1.6					0.4	0.7	0.7	0.4					0.9	0.2	0.5	0.0	0.6	1.2	0.4	1.2
34	0.5	-	0.4	-					0.1	0.0	0.1	0.2									0.8	0.8	0.9	1.1

CONTROL RATS

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right (rt.) INCISORS.

Rat No.	30				31				33				34				35				39			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	5.4	3.5	5.1	3.9	3.7	2.1	3.7	3.7	5.6	3.8	5.0	4.1	6.1	4.1	5.4	4.0	4.5	2.8	5.4	3.9	8.4	5.6	5.9	4.7
2	4.5	2.9	4.6	4.0	4.7	2.7	4.6	3.0	5.6	3.7	5.2	3.7	5.7	3.3	5.5	3.6	5.3	3.0	5.1	3.5	6.4	3.6	6.4	4.1
3	4.7	2.4	4.8	2.9	4.7	2.3	4.8	2.7	5.4	3.6	5.7	3.6	5.0	2.9	4.6	3.5	5.3	3.5	5.0	3.9	6.9	4.3	6.6	4.4
4	5.9	4.0	5.2	3.3	5.9	3.4	5.0	3.1	6.2	3.9	5.7	3.8	5.3	3.0	5.3	3.5	4.8	2.9	5.0	3.3	6.3	3.7	6.2	4.0
5	5.6	3.4	4.9	3.7	6.4	4.1	5.1	3.6	5.9	3.9	4.4	3.4	5.4	2.9	6.0	3.1	5.1	3.0	5.5	3.6	7.2	4.3	7.3	4.1
6	4.2	1.7	5.0	2.5	5.6	3.3	5.0	3.2	5.4	3.7	5.1	3.9	5.7	2.3	5.6	3.3	6.3	3.2	6.6	3.2	6.9	3.0	7.4	3.5
7	4.5	2.4	5.0	2.6	4.6	2.2	5.4	3.3	5.2	2.8	5.1	3.2	6.2	3.0	6.0	2.8	5.3	2.5	5.6	2.9	6.3	3.0	6.3	3.0
8	5.1	2.8	4.9	2.9	4.5	1.8	5.1	2.5	5.8	3.2	5.4	3.2	5.4	2.4	5.4	2.9	5.8	2.7	5.9	3.2	6.6	3.3	6.3	3.3
9	4.4	2.6	4.3	2.7	4.1	2.5	4.4	2.8	5.0	2.7	5.1	3.0	5.6	2.6	5.4	2.7	6.3	2.8	6.1	2.9	6.3	3.0	6.7	2.9
10	4.7	3.0	4.2	2.9	6.9	5.3	-	-	6.1	4.4	5.1	3.6	5.6	2.8	5.6	2.8	5.6	2.4	6.1	2.7	6.2	2.6	6.4	2.6
11	4.3	2.4	4.6	2.6	6.3	4.7	6.0	4.6	3.7	1.7	5.2	2.5	5.5	2.8	5.0	2.8	5.8	2.7	5.7	2.7	5.9	2.4	4.9	2.2
12	4.8	2.7	4.4	2.6	5.3	3.7	5.4	4.1	4.8	2.7	4.6	3.1	5.7	3.0	5.5	3.1	6.1	2.6	6.0	2.5	6.3	3.6	6.4	3.2
13	4.5	2.6	4.6	2.5	5.7	4.0	5.7	4.0	5.1	2.9	5.2	2.9	5.6	2.8	5.7	3.0	6.2	2.3	6.1	2.4	6.2	3.0	6.0	3.2
14	4.5	2.4	4.4	2.7	5.7	3.7	5.2	4.1	4.5	2.4	4.7	2.8	5.2	2.1	5.4	2.6	6.3	2.6	6.2	2.5	5.9	2.5	6.6	2.8
15	4.5	2.4	4.4	2.4	5.6	4.1	5.3	4.2	4.9	2.8	4.8	2.8	5.0	2.6	5.4	2.8	4.9	1.4	5.7	2.0	4.9	2.8	5.2	4.4
16	4.5	2.5	4.6	2.7	5.4	2.9	6.0	3.0	5.2	3.3	5.1	3.1	6.0	3.0	5.4	2.6	-	-	-	-	5.8	3.1	5.7	3.2
17	4.0	2.1	4.3	2.5	5.4	3.4	5.0	3.2	4.4	2.4	4.7	2.0	4.6	2.0	4.9	2.5	5.4	2.7	5.2	2.0	5.6	2.8	5.8	2.8
18	5.9	2.7	6.2	2.5	5.3	3.5	5.5	3.5	4.4	2.4	4.8	3.3	5.1	2.5	5.0	2.7	6.3	2.1	6.3	3.2	5.9	2.5	6.2	2.4
19	4.6	2.5	4.6	2.8	5.6	3.5	5.8	3.3	4.6	2.6	4.7	2.7	5.9	3.2	5.4	2.9	6.0	1.6	5.7	1.9	5.7	2.5	6.1	2.9
20	-	-	-	-	5.8	3.2	5.6	3.8	5.5	2.6	5.6	2.7	4.0	1.3	5.1	1.6	6.0	2.4	5.3	1.7	4.7	2.4	5.3	3.4
21	4.8	2.5	4.8	2.7	5.5	4.4	-	3.6	5.0	2.6	4.7	2.3	5.4	2.6	5.5	2.4	5.5	2.0	5.6	2.4	5.6	2.1	6.2	2.6
22	4.9	2.4	5.0	2.7	5.1	1.9	5.6	2.5	-	-	-	-	6.2	3.1	5.4	2.7	-	-	-	-	6.0	2.6	5.8	2.7
23	4.6	2.1	4.9	2.4	4.0	1.0	5.5	2.0	4.9	2.5	5.6	2.7	5.2	1.9	5.7	2.2	6.1	2.4	5.9	2.6	5.6	2.6	5.7	2.7
24	5.0	2.7	4.9	2.5	5.7	2.8	5.0	2.5	5.8	2.8	5.5	2.4	6.3	3.0	4.9	2.6	6.6	3.0	6.2	2.9	5.8	2.7	5.2	3.4
25	5.6	2.5	6.0	2.6	5.6	2.4	4.8	2.4	6.0	3.2	5.7	3.2	5.8	2.4	5.9	2.6					5.9	2.5	5.9	2.5
26	4.8	2.1	4.9	2.1	4.6	1.8	5.2	2.3	5.5	2.6	5.9	2.8	5.3	2.2	5.8	2.3					6.5	2.6	6.6	2.6
27					5.6	2.4	5.3	2.1	5.7	2.5	5.4	2.7	5.6	2.7	5.5	2.5					5.6	2.3	5.6	2.3
28					5.0	1.6	6.0	2.0	5.8	2.1	5.9	2.3	5.8	2.5	6.0	2.4					5.8	2.4	6.0	2.7
29					6.1	2.3	5.7	2.3	5.4	2.4	6.2	2.5	6.2	2.6	5.4	2.6					5.7	2.4	5.8	2.6
30					5.7	2.3	5.1	2.1	5.9	2.5	5.4	2.6	6.0	2.5	6.0	2.9					5.4	2.4	5.6	2.5
31					5.4	2.0	5.3	2.3	5.0	-	5.3	-	5.7	2.4	5.9	2.3					-	-	-	-
32					5.1	2.4	5.0	2.4	5.7	2.0	5.0	2.0	4.9	2.8	4.9	2.7					5.5	3.2	5.7	3.1
33					6.3	3.5	5.5	2.7	5.4	2.2	5.6	2.1	5.6	2.4	5.7	2.1					6.2	3.0	6.0	-
34					4.3	1.1	5.2	2.0	5.2	1.8	5.7	2.2	5.9	2.3	5.8	2.5					6.6	3.5	5.9	3.2

VI

RAPIDLY DEFICIENT RATS - SUB-GROUP I

WEEKLY ERUPTION and ATTRITION RATES(in mm./week):- INCISAL and GINGIVAL measurements of left and right(rt.) INCISORS.

Rat No.	46				48				52				70				87				89			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	6.1	4.1	5.2	3.4	5.0	4.0	4.5	3.1	5.7	3.5	5.6	2.4	5.9	4.0	5.3	3.4	5.0	3.4	4.6	3.4	4.8	2.3	4.3	2.4
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	6.0	3.0	5.1	3.5	7.0	3.6	5.8	3.6	6.8	4.6	4.8	2.6	6.8	4.6	4.8	2.8	7.0	4.4	3.8	3.8	5.2	2.4	5.5	3.0
4	5.9	2.2	6.0	2.0	6.3	2.9	6.0	2.8	5.9	2.0	6.2	2.4	6.1	3.1	6.2	2.8	5.9	3.4	6.6	3.6	4.9	2.5	4.9	2.6
5	-	-	-	-	-	-	-	-	7.0	2.8	7.5	3.8	-	-	-	-	6.1	3.0	6.6	3.1	5.1	2.6	5.3	3.4
6	5.6	1.9	5.7	2.2	5.7	1.9	6.2	2.4	-	-	-	-	4.9	2.7	4.9	2.7	-	-	-	-	-	-	-	-
7	5.7	2.0	6.0	2.1	6.5	2.4	6.3	3.1	6.0	2.1	6.9	2.7	6.6	2.4	6.7	2.6	5.6	2.5	5.8	2.8	5.0	2.7	5.0	3.1
8	4.9	1.9	5.0	2.3	6.5	2.8	5.9	2.1	5.2	1.6	5.6	2.4	6.0	2.3	6.3	2.4	5.9	3.3	5.9	3.5	5.2	2.4	4.7	2.5
9	-	-	-	-	-	-	-	-	5.6	2.4	5.7	2.3	-	-	-	-	-	-	-	-	-	-	-	-
10	4.6	2.1	4.7	1.7	5.8	2.5	6.8	2.2	5.6	2.6	5.1	2.4	5.5	2.1	5.1	2.4	5.9	3.3	5.7	3.3	4.8	2.4	4.4	2.6
11	3.4	2.4	3.4	1.8	6.1	2.4	5.6	2.4	4.9	3.0	4.3	2.0	5.2	2.5	5.1	2.0	5.1	2.7	5.1	2.8	4.7	2.6	4.9	2.2
12	2.0	2.1	2.1	2.1	5.5	2.5	5.6	2.1	3.3	2.9	3.5	2.7	3.6	2.2	4.1	2.2	4.7	2.7	4.9	2.5	3.7	2.0	4.4	2.3
13	1.2	1.4	1.1	2.1	3.8	1.6	5.1	2.4	2.2	2.2	2.4	2.3	2.6	2.0	2.6	1.7	3.2	2.4	3.7	2.3	3.4	2.3	3.5	2.6
14	1.1	1.2	1.2	1.2	3.2	1.7	-	-	1.2	1.8	1.4	1.7	1.9	1.9	1.6	1.2	2.5	2.4	3.0	2.4	2.8	2.2	3.7	1.9
15	0.7	1.0	1.1	1.1	4.4	2.5	4.5	2.6	1.3	0.4	1.3	0.8	0.5	1.2	0.7	1.6	1.5	1.7	1.9	1.7	2.2	2.0	2.4	2.1
16					3.4	2.4	2.9	2.3	1.0	0.3	1.2	0.3					1.7	2.0	1.7	1.8	1.4	2.6	1.8	2.5
17					2.9	2.9	3.0	2.7									1.6	2.0	2.1	2.2	0.8	2.4	1.6	2.4
18					2.1	2.2	2.5	2.2									0.9	1.8	1.7	2.2				
19					1.0	2.5	1.2	2.4																
	Six-Week Vitamin A Replacement Therapy for Each Rat - 10i.u./week.																							
1	1.2	1.8	1.2	2.0	1.8	2.1	2.0	2.4	1.3	0.7	0.9	0.4	0.8	0.8	0.4	0.8	1.6	2.5	1.3	2.2	1.2	2.0	1.2	2.5
2	1.7	1.8	1.6	1.7	3.3	1.9	3.2	2.1	1.7	1.3	1.6	1.0	1.1	1.5	0.8	1.1	1.8	2.0	2.3	2.6	2.1	2.4	1.9	2.5
3	2.0	1.5	1.9	1.1	3.3	1.7	3.5	1.7	2.7	1.2	2.4	1.0	0.4	1.4	0.4	1.5	0.8	1.1	2.1	2.6	2.0	2.0	2.4	2.2
4	1.9	1.1	1.9	1.1	3.0	1.5	3.2	1.7	2.5	0.7	2.8	1.0	0.9	1.6	0.6	1.5	1.7	1.2	2.2	1.7	3.0	1.9	2.9	2.0
5	2.7	1.2	2.7	1.4	2.9	1.7	3.1	2.6	2.4	0.5	2.8	0.8	0.2	1.3	0.8	1.5	1.8	2.5	1.1	1.7	4.4	2.1	4.1	2.0
6	2.1	1.3	2.4	1.3	2.5	1.4	2.8	1.5	1.2	0.6	2.0	0.7	0.3	1.1	0.5	1.4	1.7	1.9	1.7	0.5	3.1	1.9	3.5	2.0

(INCISAL measurement : in left incisor = unimpeded eruption rate; in right incisor = attrition rate)

RAPIDLY DEFICIENT RATS - SUB-GROUP II

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right (rt.) INCISORS

Rat No.	42				50				62				65				77				85			
Week No.	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	6.2	3.9	5.5	3.3	6.0	3.9	5.5	3.6	6.8	4.2	5.5	2.1	5.5	3.4	5.5	3.3	5.5	4.2	5.3	3.9	5.9	3.5	5.1	3.6
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	7.3	-	4.4	4.0	-	-	5.1	4.0	-	-	4.8	3.5	7.0	-	-	2.1	7.2	4.5	5.7	3.9	5.6	4.4	5.1	4.2
4	5.3	2.8	5.4	2.7	7.0	3.5	6.5	3.3	6.9	3.3	6.1	3.2	5.5	3.0	5.3	2.7	5.9	3.0	6.2	3.5	6.6	3.5	6.1	2.8
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	5.2	2.3	5.8	3.2	6.0	2.8	6.0	3.1	5.8	2.8	5.6	3.1	4.8	2.3	4.7	2.8	6.4	3.0	6.4	3.3	5.4	2.6	5.3	2.4
7	5.4	2.5	5.4	3.1	6.6	3.4	7.0	3.8	6.1	2.6	6.1	2.9	5.3	2.0	6.2	2.4	7.0	2.9	6.9	2.8	5.0	2.2	5.4	2.8
8	5.5	2.8	5.7	3.1	5.9	3.3	6.3	3.4	5.2	2.2	6.0	2.9	5.4	1.7	5.3	1.9	6.1	2.7	7.0	2.9	4.3	2.4	4.2	2.0
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	5.6	2.4	5.7	2.5	6.0	3.4	7.4	3.5	6.4	3.3	5.4	2.8	5.1	2.7	4.7	2.5	6.1	2.6	5.7	2.8	3.5	2.5	3.3	2.3
11	5.6	2.5	5.8	2.4	6.0	3.2	5.6	2.8	5.4	3.2	5.7	3.1	5.2	2.4	5.4	1.9	6.7	3.1	5.8	2.9	3.0	2.0	2.3	1.7
12	5.4	2.4	5.3	2.4	5.0	2.9	4.8	2.7	4.1	2.9	4.4	2.8	3.8	2.1	3.9	2.1	5.6	3.2	5.6	2.9	1.1	1.6	1.1	1.6
13	5.5	2.9	5.3	2.7	4.7	2.5	3.9	2.4	2.7	2.4	2.9	2.4	2.0	1.8	2.1	1.7	4.1	2.8	4.7	2.8	0.7	1.0	0.4	1.0
14	4.5	3.3	5.7	3.0	3.0	1.7	4.3	1.2	1.8	2.2	1.7	1.9	1.1	1.5	1.2	1.6	2.8	2.5	3.1	2.7				
15	1.9	1.9	2.6	1.8	1.4	1.2	2.5	1.5	1.4	2.3	1.2	1.8	1.2	1.5	1.2	1.2	2.2	2.4	2.8	2.6				
16	1.6	1.5	1.7	1.5	1.1	0.5	1.4	1.1	0.8	2.0	1.1	2.1	1.1	1.3	1.4	1.6	1.4	2.6	2.0	3.0				
17	1.9	1.6	1.5	1.5	1.0	0.2	1.8	0.2					1.0	1.7	0.8	1.2	1.9	3.0	1.7	2.6				
18	1.0	1.6	0.8	1.3													1.0	2.8	1.1	2.3				
Six-Week Vitamin A Replacement Therapy for Each Rat - 160 i.u./week																								
1	1.2	1.1	1.5	1.1	2.0	0.5	1.6	0.4	1.3	2.1	1.5	2.4	1.7	1.4	1.4	1.5	1.8	2.2	2.1	2.5	0.7	0.7	0.9	0.9
2	2.7	0.7	2.4	0.9	1.9	0.7	2.1	0.8	2.2	1.6	2.5	1.7	2.1	1.3	2.3	1.8	3.1	2.4	3.5	2.8	1.5	0.8	1.6	1.1
3	3.4	0.7	3.8	1.0	1.8	0.7	1.6	0.7	3.2	1.4	2.5	1.6	2.9	1.2	3.3	1.5	3.6	1.7	5.1	2.4	2.7	1.4	2.8	1.4
4	2.2	0.8	2.0	0.8	1.7	0.6	2.1	1.0	3.6	0.9	3.7	1.1	3.2	1.0	3.9	0.8	3.5	1.6	3.6	2.0	4.5	1.5	3.9	1.5
5	2.6	0.8	2.4	0.8	1.6	0.7	1.7	0.7	2.8	0.6	3.6	1.0	3.2	2.2	3.3	2.2	4.8	2.4	4.9	1.6	3.5	1.0	4.6	2.2
6	3.7	0.5	3.4	0.6	2.0	1.0	2.2	1.3	2.0	-	2.0	2.3	2.8	1.8	2.9	2.0	5.0	2.1	4.6	2.8	5.2	1.3	4.5	1.6

(INCISAL measurement : in left incisor = unimpeded eruption rate; in right incisor = attrition rate)

RAPIDLY DEFICIENT RATS - SUB-GROUP III

WEEKLY ERUPTION and ATTRITION RATES(in mm./week):- INCISAL and GINGIVAL measurements of left and right(rt.) INCISORS.

Rat No.	57				58				59				72				76				82			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	5.7	3.7	5.7	3.7	6.4	3.4	5.1	3.0	5.6	3.1	5.4	3.3	6.7	4.6	5.2	3.8	5.6	3.7	5.2	3.6	5.7	3.4	5.3	3.3
2	-	-	-	-	6.2	2.7	5.0	3.0	-	-	-	-	6.9	3.4	6.6	3.4	4.9	2.5	5.0	2.9	-	-	-	-
3	5.9	2.9	5.9	2.6	6.0	2.7	6.1	2.9	5.9	3.2	5.3	2.9	5.7	2.7	5.8	2.8	5.5	3.0	5.8	2.9	6.4	3.5	5.4	3.2
4	6 .0	3.2	5.8	3.2	5.4	2.2	5.6	2.5	5.9	2.8	5.6	2.7	6.1	2.5	6.9	3.0	5.6	3.6	5.4	3.2	5.9	3.2	5.9	3.2
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	5.3	3.1	5.3	3.1	5.4	2.1	5.6	2.3	5.1	2.2	5.8	2.8	5.2	2.8	5.5	2.9	5.2	2.5	5.1	2.4	5.0	2.7	5.3	2.6
7	4.6	2.7	4.8	2.7	5.8	2.0	5.9	2.1	5.6	2.3	6.1	2.5	5.8	2.2	6.2	2.6	5.0	2.6	5.3	3.0	4.6	2.8	4.6	-
8	4.4	2.4	4.3	2.5	5.3	2.2	5.6	2.2	4.8	2.4	5.3	2.8	6.1	2.6	5.8	2.3	4.6	2.6	4.7	2.7	4.9	2.9	4.6	2.5
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	3.3	2.2	3.8	2.3	5.7	2.9	5.1	2.8	4.6	2.1	5.0	2.1	5.8	2.5	6.0	2.3	5.0	3.0	4.8	2.4	3.5	2.7	3.4	2.5
11	2.1	2.1	2.1	2.0	5.4	2.7	5.4	2.2	4.1	2.8	4.3	2.7	4.8	2.4	4.7	2.4	4.0	2.6	4.8	2.3	2.1	1.9	2.7	2.0
12	1.3	1.7	1.5	1.6	4.8	2.2	4.7	2.3	3.4	2.6	3.5	2.3	4.8	2.5	4.6	2.2	1.8	1.6	2.5	1.6	1.3	1.5	1.5	1.6
13	0.5	1.7	0.6	1.5	3.7	1.9	4.1	2.0	2.3	1.9	2.7	1.9	4.5	2.5	4.7	2.6	1.2	1.2	0.8	1.3	1.5	1.4	0.9	0.9
14					2.6	1.9	2.9	1.4	2.1	1.7	1.6	1.4	3.4	2.3	3.9	2.1	1.6	1.4	0.6	1.1	1.2	1.3	0.9	1.0
15					1.6	1.2	1.9	1.2	1.2	1.8	1.4	1.7	2.2	2.2	2.3	2.2	1.4	1.4	1.1	1.1	0.9	1.1	0.8	0.8
16					2.0	1.1	2.0	1.1	0.3	0.1	1.5	1.4	1.9	1.8	2.0	1.9	1.3	1.3	1.4	1.6				
17					1.8	2.0	3.0	2.9					2.6	1.4	3.2	2.0	0.7	1.2	1.3	2.1				
18					1.0	1.6	1.2	2.1					2.9	2.4	3.3	2.1								
19													1.0	1.3	1.6	1.2								
	Six-Week Vitamin A Replacement Therapy for Each Rat - 40 i.u./week																							
1	0.6	0.1	1.1	0.7	1.4	1.3	1.2	1.5	0.7	1.1	1.7	2.4	1.6	1.3	1.8	1.2	2.8	2.8	2.0	1.6	0.0	1.3	1.0	1.5
2	1.9	0.9	1.5	0.1	2.7	1.2	2.9	0.9	2.9	3.0	2.0	1.9	2.4	0.8	3.4	2.0	2.6	1.7	2.3	1.9	1.6	0.8	1.2	0.8
3	2.4	1.4	1.8	0.5	2.5	1.7	2.7	1.6	2.1	2.8	1.7	2.5	3.2	1.2	1.8	0.8	3.0	1.4	3.5	1.3	2.1	0.5	2.8	1.2
4	1.4	0.7	1.5	0.3	3.1	1.2	3.2	1.1	2.1	1.9	1.9	2.0	2.6	1.2	2.6	0.9	3.3	1.3	3.5	1.6	4.0	0.7	4.0	0.5
5	1.6	0.8	1.4	0.8	4.8	1.3	4.2	1.0	1.1	1.3	1.7	1.8	2.9	-	2.5	-	2.5	0.8	2.8	1.1	3.0	0.4	3.2	0.8
6	1.2	0.6	1.4	0.8	4.5	0.7	4.1	1.3	1.9	2.2	1.7	1.8	3.0	-	-	-	--(died)				2.1	0.4	3.0	0.5

(INCISAL measurement : in left incisor = unimpeded eruption rate; in right incisor = attrition rate)

RAPIDLY DEFICIENT RATS - SUB-GROUP IV

WEEKLY ERUPTION and ATTRITION RATES (in mm./week):- INCISAL and GINGIVAL measurements of left and right (rt.) INCISORS.

Rat No.	45				47				55				61				67				83			
Week	INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL		INCISAL		GINGIVAL	
No.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.	left	rt.
1	5.6	4.2	4.9	3.8	5.0	3.2	3.9	3.6	5.6	3.0	5.8	3.6	5.3	3.5	4.6	2.9	4.7	3.0	4.5	2.9	5.3	3.7	4.4	3.4
2	5.6	2.9	5.0	3.4	-	-	-	-	5.1	2.6	5.2	2.9	-	-	-	-	-	-	-	-	-	-	-	-
3	5.9	3.3	5.7	3.3	7.0	-	4.4	3.7	5.6	2.6	5.7	2.9	7.0	-	-	4.0	5.7	3.3	5.5	3.6	6.6	3.9	5.0	3.1
4	5.8	2.3	6.1	3.2	4.9	2.2	4.7	2.4	5.7	2.7	5.8	3.1	6.0	3.8	5.3	3.8	5.2	2.6	5.0	3.1	5.6	3.2	5.5	3.3
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	5.8	2.5	5.7	2.6	4.7	2.2	5.4	2.6	5.1	2.2	6.2	2.8	5.0	3.2	4.8	3.2	4.9	2.9	5.0	2.6	4.8	2.6	5.0	2.7
7	5.9	2.8	5.0	2.7	5.0	2.0	5.5	2.5	6.4	3.0	5.7	2.7	4.9	3.3	4.4	3.7	5.2	2.8	5.0	3.4	5.0	3.1	5.0	2.9
8	6.5	3.7	6.8	3.6	4.7	2.2	5.5	2.3	5.3	2.7	5.7	2.9	4.9	2.7	4.4	2.3	4.8	2.7	5.0	2.5	4.3	2.1	4.8	2.4
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	6.3	3.7	6.0	3.2	5.7	2.3	4.8	2.3	5.6	3.1	5.2	3.1	2.5	2.7	2.6	2.0	5.0	2.3	5.0	2.3	4.4	2.4	4.3	2.3
11	5.4	2.9	5.0	3.1	4.8	1.9	5.1	2.3	4.4	2.4	5.2	2.7	1.7	2.2	1.5	1.7	4.8	2.1	5.1	2.6	3.6	2.3	3.4	2.1
12	4.5	2.8	4.7	2.3	5.1	2.2	4.8	2.1	4.2	2.4	4.0	2.5	1.1	1.6	1.0	1.3	4.9	2.8	4.7	2.6	1.9	1.7	2.5	2.0
13	2.4	2.4	2.8	2.5	4.5	2.2	4.9	2.3	2.7	2.3	2.8	2.0	0.4	0.9	0.4	1.1	4.4	2.7	4.3	2.5	1.4	1.3	1.1	1.0
14	1.5	1.8	1.4	1.7	3.7	2.1	4.1	2.0	2.0	2.2	1.9	2.1					3.6	2.3	3.8	2.6	1.2	1.6	0.7	1.1
15	1.5	1.6	1.6	1.3	3.0	1.9	3.3	2.1	1.1	2.0	1.2	1.9					2.7	1.3	3.2	1.2	1.1	2.0	0.4	1.6
16	0.0	0.7	1.0	2.4	2.7	2.3	2.1	1.8	0.6	0.9	1.2	1.0					2.4	0.2	2.7	1.1	0.7	1.3	0.8	1.2
17					1.6	1.6	2.0	2.0									1.8	0.6	2.0	0.0				
18					0.8	1.9	1.5	2.0									2.0	1.5	2.2	1.5				
19																	1.0	1.6	1.0	1.7				
	Six-Week Vitamin A Replacement Therapy for Each Rat - 640 i.u./week																							
1	2.0	2.5	1.2	2.2	2.1	2.3	1.2	1.6	2.5	0.9	2.4	1.1	1.9	1.0	1.3	1.0	1.7	1.7	1.8	1.6	0.8	1.1	1.3	1.2
2	1.5	0.6	2.2	0.9	2.0	1.8	1.9	-	3.2	1.1	3.1	1.0	3.2	1.9	3.0	1.3	2.0	2.2	2.3	2.5	0.7	0.6	1.2	1.1
3	2.0	0.4	3.1	0.7	1.8	1.6	1.9	1.5	2.8	0.7	3.1	0.9	3.3	1.9	2.7	1.3	2.5	2.0	2.6	1.8	0.4	0.7	0.7	1.2
4	3.4	1.4	1.7	1.2	1.6	1.2	1.8	1.1	2.1	0.4	2.5	0.8	3.8	1.8	4.1	2.3	3.3	1.9	3.1	2.2	0.4	1.5	1.1	2.1
5	1.7	1.3	2.0	1.3	1.2	1.4	1.3	1.4	2.8	0.4	2.2	0.2	3.2	1.0	3.2	1.8	3.2	2.0	3.5	2.4	0.5	2.1	0.7	1.7
6	2.0	1.8	1.8	1.5	1.6	1.6	1.4	1.7	2.6	0.7	2.6	0.2	3.9	0.7	4.8	1.5	3.6	1.9	3.7	2.1	0.3	1.1	0.5	1.7

(INCISAL measurement : in left incisor = unimpeded eruption rate; in right incisor = attrition rate)