Available Space For The Incisors During Dental Development - A Growth Study Based On Physiologic Age

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Traditionally, growth studies scale their findings on chronologic age. This method has the advantage of enhancing comprehension and application of the results, because the chronology of developmental events is readily associated with calendric age.

Although age offers a convenient yardstick for judging maturation, it may not be the most accurate one in the individual instances.[1] To match the timetable of individual growth, the concept of physiologic age is used as a measure of precision in growth diagnosis.[2] Various tissue systems, including the dentition, can be used for assessment of physiologic age,[3] but the choice of the most appropriate developmental indicator depends on the purpose for which the assessment is made.

Previous studies of dental development conducted at Forsyth were carried out according to the conventional approach by sampling observations at successive chronologic ages.[4] Subsequent efforts were based on tooth eruption as a parameter for describing changes in the developing dentition.[5] Increments were then measured between attainment of developmental events, such as the appearances of teeth, instead of being expressed in terms of whole-year intervals.[4]

This paper discusses one aspect of the new findings, namely, the available space for the incisors of the growing child.

MATERIALS AND METHODS

Serial dental casts of 184 North American white individuals, obtained between 3 and 16-18 years of age, supplemented by an incomplete series of 48 individuals incorporating no more than the incisor transition, were used to study spacing and crowding of the incisors.

The greater part of this material was made available by Dr. Harold C. Stuart, director of the longitudinal studies of child health and development at the Harvard School of Public Health. It included 132 children observed from infancy through adolescence. Dr. Richard H. Stucklen contributed longitudinal data of 52 children, students at the Bayard Public School in Wilmington, Delaware. This group collaborated in an investigation of dental development conducted privately by Dr. Stucklen during a period of approximately twelve years.

From this total of 184 serial dental casts, 78 maxillary and 70 mandibular dentitions were used for studying the available space in the incisor segment in conformance with the original selection on the basis of excellent tooth alignment.[4]

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This material was supplemented by data from 48 children who did not participate in the Stuart study long enough to record the eruption of their permanent canines and premolars. However, these children showed close to average amounts of crowding after emergence of the permanent incisors, and thus, qualified for the "normal" series.

A detailed description of material and methods of measuring has previously been reported.[4] A few essential aspects of methodology will be mentioned briefly. The data on available space in either the maxillary or the mandibular dental arch were recorded separately for the incisor, canine and premolar segments (Fig. 1).

The incisor segment extends from the mesial surface of the deciduous or permanent left canine to the mesial surface of its antimere. The canine segments extend from the mesial surface of the deciduous or permanent canine to the mesial surface of the deciduous first molar or first premolar on both the left and right sides of a dental arch. The premolar segments extend from the mesial surface of the deciduous first molar or first premolar to the distal surface of the deciduous second molar or second premolar on both the left and right sides of a dental arch.

The amount of interdental space at the level where approximal contact usually occurs was obtained by probing wires of known diameters. The amount of crowding was obtained by subtracting the space available for a tooth in the dental arch from its mesiodistal crown diameter.

Statistical description of the available space at successive whole-year age intervals suggested that the changes occurred at the time when the permanent teeth erupted.[4] These findings were not considered to represent dental development with sufficient precision, because differences in tooth eruption status are known to occur among children of the same chronologic age. If early and late emergence affected the pattern of mean changes in available space, it may also have constituted a spurious source of variance in both absolute dimensions and their increments.

AVAILABLE SPACE

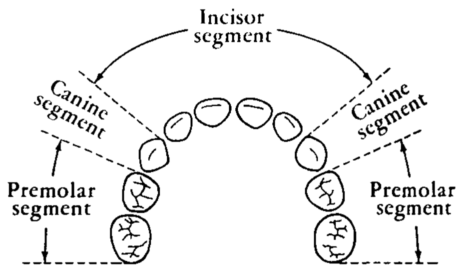

Fig. 1 The division of the maxillary or mandibular dental arches into the incisor, left and right canine, and left and right premolar segments.

The present study was undertaken to test the issue by grouping children at similar stages of dental maturation with reference to tooth eruption instead of chronologic age. Each tooth in an individual series of dental casts was classified according to one out of six stages, as follows: 1) deciduous tooth present, 2) extracted, or 3) exfoliated, 4) the permanent successor emerging, 5) one-half of the crown erupted, and 6) fully erupted. The difference between each stage and the previous one in the series for a child was also recorded. Thereby, events occurring during specific eruption phases, *i.e.*, between emergence and attainment of occlusal level, could be identified.

Statistical analysis of the available space in the incisor segments was performed twice. First, data were obtained at each developmental stage of each maxillary and mandibular, right and left tooth, separately. Second, data were obtained by considering the eruption status of two teeth. The latter procedure was necessary because the eruption of teeth frequently overlapped. By grouping various combinations of progress toward the attainment of occlusal level for two teeth, findings could be interpreted to determine when the changes in available space actually occurred. The pairings involved: M_1 and I_1, I_1 and I_2, as well as different eruption sequences of posterior teeth encountered in man.[5]

Observations pertaining to the deciduous dentition before the shedding of a deciduous incisor or the emergence of a permanent first molar were sampled repeatedly on each dental cast of an individual series. The numbers of observations in the tables referring to the deciduous dentition, therefore, seem extraordinarily large.[5]

Only the information on available space in the incisor segment is reported in this paper, because its increments are influenced by growth of the alveolar processes and by the size of the permanent teeth. In contrast, changes in the premolar and canine segments are mainly dependent on the relation between mesiodistal crown diameters of deciduous and permanent teeth ($dc + dm_1 + dm_2 : C + Pm_1 + Pm_2$). The principal source in their variances is therefore known and can be quantitated in individual instances by measuring the size of unerupted permanent teeth on radiographs.[7]

In the graphs the findings were scaled with reference to Hurme's standards of tooth emergence,[8] because they furnish the best estimate of the universal mean ages for Whites of Northwest European ancestry. Curves were

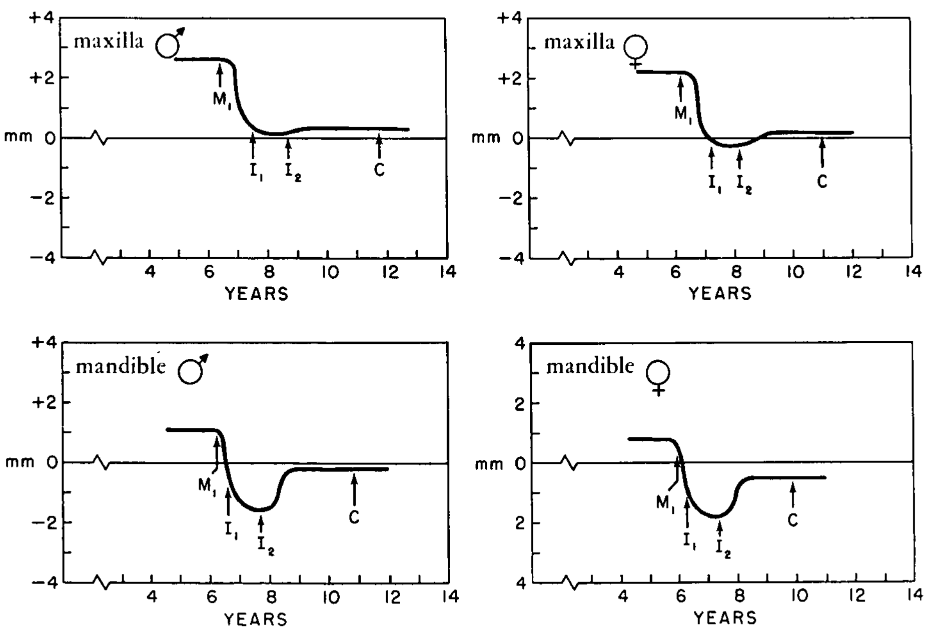

Fig. 2 Average amounts of spacing or crowding for the maxillary and mandibular incisor segments of males and females obtained with reference to dental age. The arrows refer to the mean ages of emergence of the permanent teeth.[8]

AVAILABLE SPACE - INCISOR SEGMENT

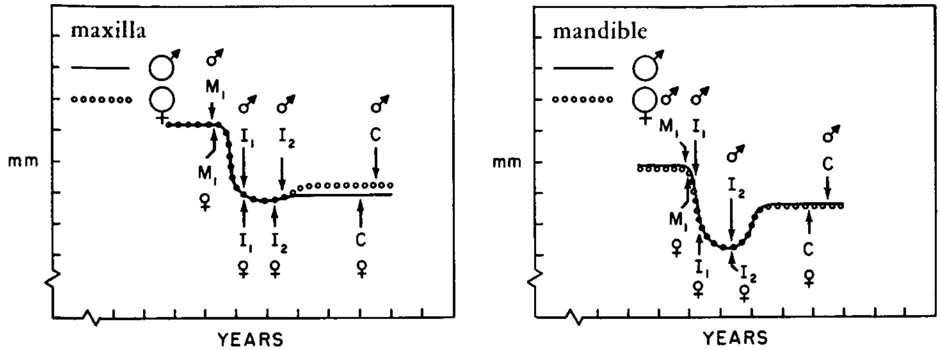

Fig. 3 Superposition of the average amounts of available space in the incisor segment of males and females in the maxillary and mandibular dentitions, respectively.

fitted by hand after weighting the mean findings in terms of the numbers of observations used in the computations.[5]

Findings for males and females were compared by superposition of the respective curves, keeping the axes of the two graphs parallel and oriented on the arrows indicating the emergence of the central incisors. Owing to differences in the time intervals between emergence of central and lateral incisors in the sexes, the arrows signalling the appearance of lateral incisors did not correspond.

Findings

The mean curves for spacing and crowding in the incisor segments, expressed as positive and negative amounts of available space, respectively, show a sudden change during the emergence of central and lateral incisors, resulting in 1.6 mm crowding in the mandibular dentition of males, and 1.8 mm crowding for females. In the maxilla of the average child, either a small excess or a small (0.2 mm) lack of space for the erupting permanent incisors was encountered (Fig. 2).

Increments in the intercanine distance and in arch length during the eruption of the lateral incisors provided sufficient space for the alignment of these teeth, except in the mandible where 0.2 and 0.5 mm crowding was noted for males and females, respectively. No changes were noted during the emergence of the permanent canines (Tables 1 and 3).

The pattern of change in the maxillary and mandibular dentitions of the sexes was quite similar, as shown by superposing the mean curves (Fig. 3). The average female recovered slightly better than the average male from the loss in available space. Moreover, the loss of space during the incisor transition also corresponded closely in the maxilla and mandible up to the time that the lateral incisor emerged. The similarity in developmental trends regardless of sex and jaw is also shown in Tables 2 and 4, pertaining to the increments in available space.

The graphs based on chronologic age differed markedly from those based on dental age, because they largely masked the severe changes and the amount of space lack encountered. After the eruption of the permanent canines the two methods of analysis gave similar end results for the mean space values in the incisor segments (Fig. 4).

The individual variations in absolute space values, or in their increments,

Table 1

Total available space in the maxillary incisor segment.

Tooth	Eruption stage	Sex	Mean (mm)	Standard deviation (mm)	Number of observations
deciduous —		M	+2.6	2.32	366
		F	+2.2	2.02	361
M_1	$E_{1/2}$	M	+2.6	2.51	45
		F	+2.2	2.07	44
I_1	$E_{1/2}$	M	+0.3	2.07	51
		F	0	2.61	57
	E_C	M	+0.1	2.07	44
		F	—0.2	2.13	46
I_2	$E_{1/2}$	M	+0.2	2.57	41
		F	—0.3	2.41	42
	E_C	M	+0.3	2.35	37
		F	+0.2	1.63	36
C	$E_{1/2}$	M	+0.3	0.91	13
		F	+0.2	1.21	15
	E_C	M	+0.3	1.21	12
		F	+0.2	1.43	18

Table 2

Increment in available space in the maxillary incisor segment.

Tooth	Eruption stage	Sex	Mean (mm)	Standard deviation (mm)	Number of observations
deciduous —		M	—0.13	0.89	265
		F	—0.21	0.92	257
M_1	$E_{1/2}$	M	—0.37	1.47	42
		F	—0.44	1.22	40
I_1	$E_{1/2}$	M	—2.08	1.90	47
		F	—2.15	2.51	54
	E_C	M	—0.55	1.57	44
		F	—0.61	1.76	46
I_2	$E_{1/2}$	M	—0.74	2.13	42
		F	—0.62	2.45	42
	E_C	M	+0.53	1.09	36
		F	+0.55	1.37	36
C	$E_{1/2}$	M	—0.20	0.78	12
		F	—0.10	0.85	14
	E_C	M	—0.10	0.54	11
		F	—0.23	0.58	18

Table 3

Total available space in the mandibular incisor segment.

Tooth	Eruption stage	Sex	Mean (mm)	Standard deviation (mm)	Number of observations
deciduous —		M	+2.1	1.74	287
		F	+1.8	1.68	287
M_1	$E_{1/2}$	M	+2.1	1.80	13
		F	+1.8	1.69	16
I_1	$E_{1/2}$	M	—0.2	2.15	49
		F	—1.0	2.50	66
	E_C	M	—1.7	2.28	40
		F	—1.5	1.78	57
I_2	$E_{1/2}$	M	—1.6	2.14	43
		F	—1.8	2.26	45
	E_C	M	—0.5	1.70	37
		F	—0.8	1.45	40
C	$E_{1/2}$	M	—0.1	0.79	10
		F	—0.6	1.93	22
	E_C	M	—0.3	0.96	10
		F	—0.5	1.16	15

Table 4

Increment in available space in the mandibular incisor segment.

Tooth	Eruption stage	Sex	Mean (mm)	Standard deviation (mm)	Number of observations
deciduous —		M	+0.01	0.64	194
		F	—0.05	0.62	187
M_1	$E_{1/2}$	M	—0.26	1.08	12
		F	—0.27	0.88	13
I_1	$E_{1/2}$	M	—1.76	1.52	49
		F	—1.39	1.40	63
	E_C	M	—0.61	1.66	40
		F	—0.70	1.59	57
I_2	$E_{1/2}$	M	—0.88	1.66	40
		F	—0.90	1.29	43
	E_C	M	+0.68	1.35	37
		F	+0.65	1.27	39
C	$E_{1/2}$	M	—0.09	1.06	10
		F	+0.21	0.96	22
	E_C	M	—0.29	0.49	10
		F	—0.01	0.42	16

AVAILABLE SPACE - INCISOR SEGMENT

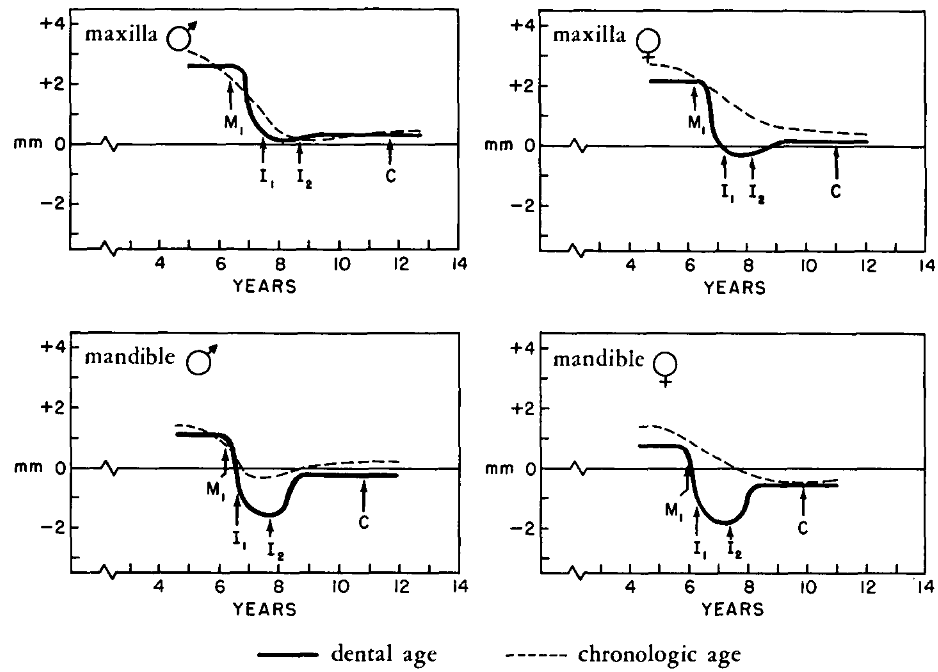

Fig. 4 Average amounts of available space obtained when sampling observations on chronologic age as compared with dental age (tooth eruption) in the maxillary and mandibular dentitions of both sexes.

spanned a considerable range in this group of children (Tables 1-4). It may be recalled that, in the sample studied, tooth alignment at 16-18 years was satisfactory. The incomplete series, augmenting the "normal" series, was included only when crowding was close to average until the last stages of the incisor transition. The additional observations, therefore, did not accentuate the variance in available space during the critical phase of development when the permanent incisors emerge.

A graphic depiction of dental development was drawn to scale (1:1) for all average dimensions of males including mesiodistal crown diameters of the deciduous and permanent teeth (Figs. 5-9).

Discussion

Added precision in the description of dental development makes a more rational diagnosis in the mixed dentition possible, particularly with reference to the need for and timing of serial extraction.[9]

Since available space is, to a large extent, dependent on tooth size, it stands to reason that the use of tooth emergence and eruption provides a realistic account of the changes in available space. In fact, the effect of combining early and late maturing children of the same chronologic age has been shown to disguise the actual loss of space during the incisor transition.

The changes in arch length and arch breadth, obtained as part of this inves-

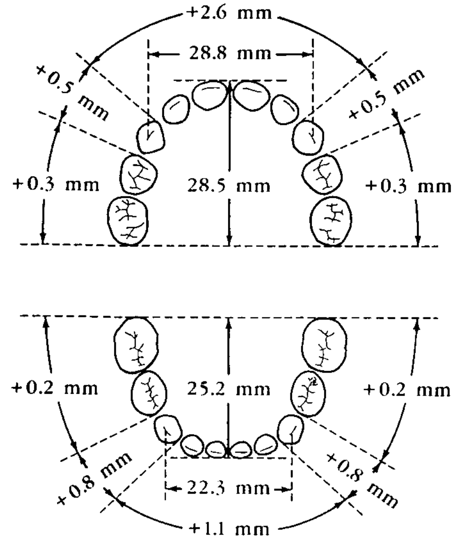

Fig. 5 The deciduous maxillary and mandibular dentitions of the average male child, drawn to scale for all measurements of available space in the incisor, canine and premolar segments; arch lengths, the intercanine distances as well as mesiodistal crown diameters of the teeth.

tigation,[5] are also consistent with the pattern of change in available space for the incisor segment. The proof of this contention is furnished by the data presented, because crowding of the permanent incisors is largely relieved when the crowns of the lateral incisors are fully erupted while the increments in arch size are also completed at that time. Thus, a plateau is reached for the arch dimensions[5] and only a slight increase occurs in the maxillary arch breadth when the permanent canines appear. Moreover, the increase in arch length is confined to the maxillary arch, and it explains why emerging maxillary incisors have nearly sufficient space for their alignment as opposed to mandibular incisors (Fig. 7).

At the end of the incisor transition the spaces between the deciduous canines and molars are closed. Mesial migration of permanent first molars takes up most of the leeway between the crown diameters of these deciduous posterior teeth and their permanent successors[10] as reflected in a shortening of arch length.[5] The partitioning of the leeway actually depends on the sequence of shedding and emergence of the deciduous second molars and second premolars, respectively, on the interdigitation of the cusps of the permanent first molars and on the position of the second premolars in relation to the mesial aspect of the first molars.

It would then appear that generally no great relief of crowding in the incisor segment can be expected after the complete eruption of lateral incisors.

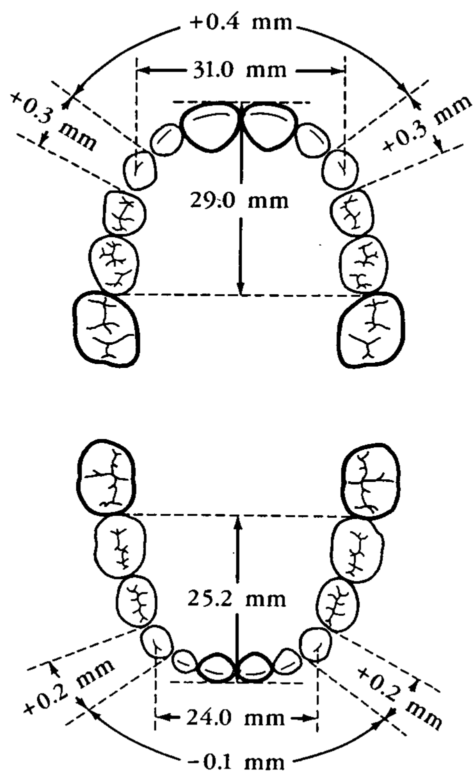

Fig. 6 The transitional dentition of the average male child after eruption of the permanent maxillary and mandibular central incisors and first molars (Note: closing of spaces between deciduous molars).

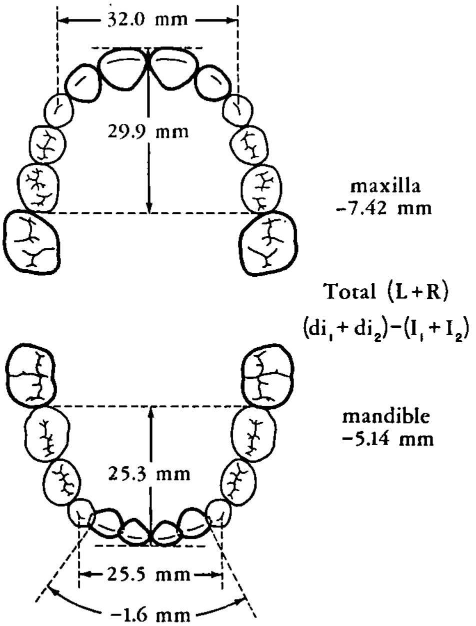

Fig. 7 The transitional dentition of the average male child after eruption of all permanent incisors (Note: differences in size of permanent and deciduous incisors, crowding of mandibular incisors, increments in the maxillary and mandibular intercanine distances, and increase only in the maxillary arch length).

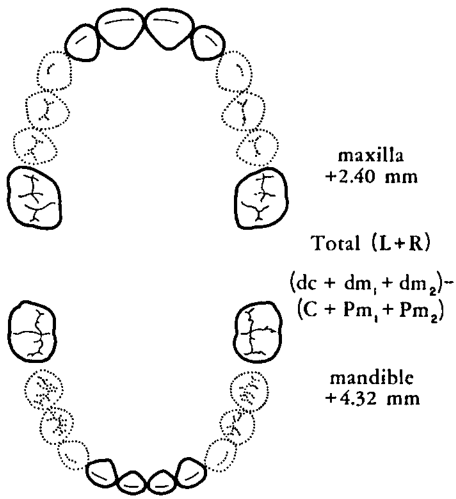

Fig. 8 The transitional dentition of the average male child at an imaginary phase where all deciduous posterior teeth (*dc*, dm_1, dm_2,) are shed, just prior to the emergence of their permanent successors (Note: so-called leeway space).

One can, however, prevent mesial migration of permanent first molars and thereby make provisions for the utilization of the leeway space by the anterior teeth (Fig. 8).

The foregoing discussion pertains to development in terms of mean findings. The individual child should be expected to differ from the average child because of greater or lesser amounts of spacing between deciduous teeth, differences in the size of permanent and deciduous incisors and growth of the alveolar processes. The net result will be greater or lesser amounts of crowding during the eruption of permanent incisors than in the average child.

The lower limit of the range of individual variation poses an intriguing problem for clinical prognosis inasmuch as the deciduous teeth are crowded or lack interdental spaces. In this sample the outcome of dental development is favorable in such instances in spite of an unfavorable beginning, because normal tooth alignment was the selective criterion. Yet, unlike the group from which the data were derived, not every child will have a normal occlusion at 18 years of age simply because the available space is within normal limits (± 2 S.D.) at an earlier phase.[4]

The symptom of crowding has little meaning unless it is related to its determining factors. For instance, a large surplus of space in the deciduous dentition may occur in a large dental arch with teeth of average crown diameters. But in a large dental arch, crowding of the deciduous teeth may occur if the teeth are very broad. On the other hand, crowding and spacing are seen in dental arches with smaller than average dimensions.[11]

Baume[12] cites a figure of 57 per cent

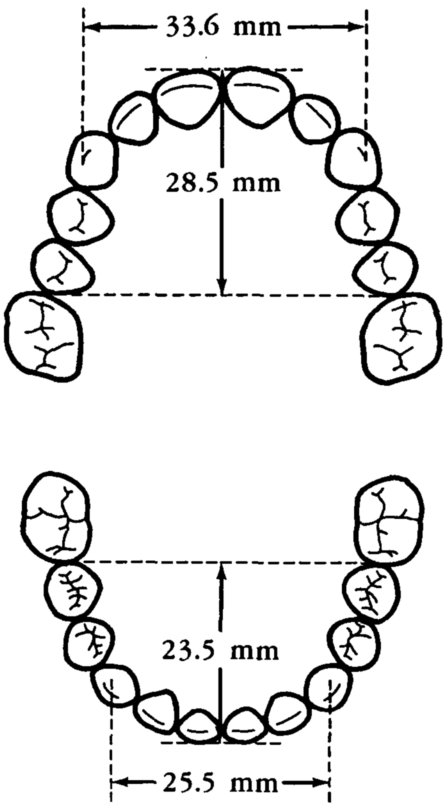

Fig. 9 The permanent dentition of the average male child (Note: lack of increment in the mandibular intercanine distance after the eruption of the permanent incisors, as well as shortening of arch lengths in both maxilla and mandible).

(9 out of 16) for satisfactory outcome of dental development from a deciduous dentition lacking interdental spaces. In eleven individuals in this study with lack of spacing or with crowding of deciduous incisors and unmutilated permanent dentitions, only one showed crowding (4 mm) in the mandible, but not in the maxilla at 18 years of age. The others achieved either normal alignment or crowding of less than 2 mm. The small numbers of children with crowded deciduous incisors studied by Baume and the authors preclude conclusions other than emphasizing the hazards of predicting the occlusion of the permanent teeth.

The sampling on dental age did not materially decrease the variances for available space except during the emergence of central incisors.[13] The factors listed above for differences between individuals also identify the sources of variance in available space for the incisor segment, namely: arch size and growth of the alveolar processes, as well as the mesiodistal crown diameters of deciduous and permanent incisors.

Individual development will bear similarity to the average curve, but the descent may differ in severity and the ascent in magnitude and slope. The descent is a direct function of tooth size, and the remainder of the curve is affected by the rate of alveolar growth. A detailed analysis of individual development cannot be made, because an annual frequency of observations is not sufficient for this purpose.

Nonetheless, findings of the present study reinforce conclusions from earlier work[9] that the level of dental maturation, *i.e.*, tooth formation and emergence, gives decisive clues for diagnosis and treatment planning since it defines the timetable of individual development. A chronology based on calendric age sacrifices the characteristic features that distinguish one child from the next.

Summary

A graphic depiction of the changes in available space for the incisors has been obtained with reference to dental age, as determined from tooth eruption status.

These data differ from findings scaled on chronologic age and they are believed to be representative of the changes occurring in the average child, inasmuch as the eruption of teeth

triggers successive stages of dental development.

The range of individual variation was not reduced significantly by the grouping of observations on similar stages of tooth eruption instead of chronologic age.

The sources of variance for available space of the incisors are tooth size and growth of the alveolar processes.

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