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# Effects of Premature Loss of Deciduous Molars

**A statistical exploration of space changes following early loss of deciduous molars, developing a picture of closure from both directions with distict differences between upper and lower arch changes.**

KEY WORDS: Eruption, Extraction, Space loss, Tooth deciduous

Much has been written on the effects of premature loss of deciduous teeth on the dentition. Unfortunately, most reports are based on cross-sectional data, limited sample size and crude methodologies that have sometimes led to misconceptions. Computer-interfaced three-dimensional recording equipment now enables much more precise quantification and evaluation.

This study uses longitudinal data to compare mean spatial changes in the dental arch subsequent to premature loss of deciduous molars with the changes that occur in undisturbed arches.

Numerous aspects must be considered in studying this problem, so the report is divided to examine various questions independently. These include the dimension of space loss (Part I), the direction from which it is lost (Part II), the influence of age on the rate of space loss (Part III), the regaining of space at the time of emergence of the succedaneous teeth (Part IV), the effect on molar relationships as indicated by Angle classification (Part V), and finally, schematic models to describe the combination of changes that take place (Part VI).

Each section includes a literature review, findings and discussion relevant to that aspect.

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## Part I

## Changes in Posterior Arch Dimensions

One of the problems encumbering this subject has been a lack of specific definitions. This starts with an evaluation of the sample and an apt description of what constitutes premature loss.

In a study by MILLER ET AL. (1965), the mean ages at exfoliation and replacement in the transition from the deciduous molars were found to differ by less than 0.4 years.

None of the individuals in the Ann Arbor Elementary School Growth Sample (n=208) who exhibited natural exfoliation was without a tooth in the deciduous molar position for more than one year after exfoliation (MOYERS ET AL. 1976). As the material for the present study was collected on an annual basis, generally within one week of each subject's birthday, a tooth absent at two consecutive annual recordings was judged to be prematurely lost.

Another factor which has impaired consistency in interpretation has been awkward methodology. Differences in measurement technique, especially when applied to constructed arch configurations, can produce inconsistent results. There are many factors causing changes in various parts of the dental arch that might lead to confusion in the interpretation of a constructed measure.

In this report, arch changes are described in terms of the deciduous molar space (D+E space). This measurement provides a segment of arch length that is easily defined and monitored, and limits the number of factors that could influence space change.

D+E space is defined for this application as the distance between the mesial midpoint of the first permanent molar (or in its absence, the distal of the second deciduous molar or second bicuspid) and the distal midpoint of the cuspid (or the mesial midpoint of the first deciduous molar or first bicuspid) (Fig. 1) (NORTHWAY AND WAINRIGHT 1980).

Premature loss of deciduous molars would warrant little concern were it not for the resulting loss of arch space. Numerous authors have reported space losses ranging from 11% to 83% (Table 1).

BRANDHORST (1932) stated that premature loss of deciduous molars is one of the controllable factors in preventing malocclusion, and UNGER (1938) concluded that a history of premature loss was twice as great in those with malocclusion. CLINCH (1951), and CLINCH AND HEALY (1959) went so far as to state that premature loss invariably resulted in malocclusion.

PEDERSEN ET AL. (1978) documented a frequency of 50% of the 723 third-grade school children in Silkeborg, Denmark who had premature extractions that caused changes in sagittal occlusal relations, deepening of the bite, midline displacement, or crossbites. While frequency was greater in the mandible, the most serious consequences occurred in the maxilla.

Numerous authors have estimated arch length loss resulting from the extraction of first or second deciduous molars (LIU 1949, BREAKSPEAR 1951 1961, JARVIS 1952,

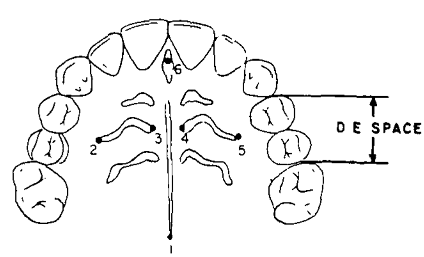


**Fig. 1** Points used for measurement of deciduous molar space

Table 1

Prevalence of Premature Loss of Deciduous Molars

| Author | Age | Percent Premature Loss | Year Reported |
|---|---|---|---|
| Brandhorst | N.A. | 37% | 1932 |
| Charbeneau | 7-8 | 35% | 1950 |
| Foster | 4 | 11% | 1958 |
| | 5 | 20% | |
| | 6 | 30% | |
| | 7 | 34% | |
| Hoffding | grade 1 m | 83% | 1978 |
| | grade 2 | 42% | |
| Pedersen | 8 | 50% | 1978 |
| Pringle | ortho. cases | 70% | 1937 |
| Simons | N.A. | 15% | 1972 |

Table 2

Unilateral Space Loss Due to Premature Extraction

| | Maxilla | | | Mandible | | |
|---|---|---|---|---|---|---|
| | D | E | D+E | D | E | D+E |
| Breakspear (1961) | 0.8 | 2.2 | 2.0 | 0.7 | 1.7 | 1.3 |
| Jarvis (1952) *males* | 0.1 | 4.2 | – | 1.9 | 2.7 | – |
| *females* | – | 2.1 | – | – | 2.9 | – |
| Liu (1949) | 2.3 | 2.5 | 2.3 | 1.4 | 1.4 | 1.3 |

Richardson 1965a, Seward 1965). These studies present the space loss in millimeters of space closure (Table 2).

Most researchers have found that extractions in the maxilla result in significantly more space loss than in the mandible (Unger 1938, Clinch and Healy 1959, Liu 1949, Seward 1965, Cohen 1941, Friel 1945, Hinrichsen 1962, Lundström 1955, and Schachter 1943).

Notable exceptions have been Jarvis (1952) and Olsen (1959). Olsen attributed the greater loss that he reported in the lower to a more mesial axial orientation of the lower first molar, as opposed to the distal inclination of the upper. Friel, using a Bolton plane orientation to evaluate serial change, concluded that the path of emergence for a maxillary molar was parallel to the direction of growth, so that the upper tooth could not lag behind like the lower (Friel 1945 1949 1954).

Linder-Aronson (1960), MacLaughlin et al. (1967), and Richardson (1965a 1965b) found no significant difference between the amount of space loss following the removal of either an upper or a lower tooth. Richardson did find a statistically insignificant tendency for more space to be lost in the upper arch, and similar findings are reported by Seward (1965).

Not only do most researchers find the upper arch to be more vulnerable to space loss than the lower, but they also agree that the loss of the second deciduous molar will result in greater space closure than any other deciduous tooth. This makes the maxillary second deciduous molar the poorest choice in the mouth for premature extraction (Unger 1938, Clinch 1951, Breakspear 1951 1961, Liu 1949, Richardson 1965a 1965b, Cohen 1941, Hinrichsen 1962, Schachter 1943, Brauer 1941, Kopel 1950, Lusterman 1958, and Seipel 1949).

## — Materials and Methods —

One hundred and seven children were selected from the growth sample at the Centre de Recherché sur la Croissance Humaine at the University of Montreal. Data on these individuals were collected annually from age 6, for an average period of observation of 5.9 years. Severe caries was differentiated on the basis of the degree of anatomical destruction observed on the study casts.

Quadrants unaffected by severe caries or premature extraction of deciduous molars for the duration of the study are classified as controls. Those who developed severe caries or lost deciduous molars prematurely are classified according to the maximum degree of destruction. For example, an individual who had severe caries for a portion of the study and ultimately lost the affected tooth was classified with those subjects who lost the tooth. Sexes were pooled for most evaluations (Northway 1977).

Dental cast data was digitized with the Optocom instrument, which is capable of registering numerous coordinates in three dimensions with 0.2mm precision (Northway 1977, van der Linden 1972, and van der Linden and Miller 1974). The computer program accommodated the registration of 348 points from any set of occluded study casts. These demarcated the relative orientation of all upper and lower teeth and palatal rugae. Reference points recorded by this method have been found to be stable enough to allow reliable sequential superimposition of the dental cast data (Moyers et al. 1976, Friel 1945, van der Linden 1974, Lebret 1962, and Peavy and Kendrick 1967).

Annual positional changes were measurable in both magnitude and direction, so the direction of space loss could be identified as mesial or distal relative to palatal rugae. The reproducibility of D+E space among 225 such paired recordings showed a standard deviation of 0.26mm (Northway 1977).

## — Findings —

A two-way cross-tabulation comparing upper and lower quadrants of the 107 individuals in our sample is shown in Table 3. One or more deciduous molars was prematurely exfoliated in 71 (61%) of these children. Deciduous molars were severely decayed in 18 (17%), and only 18 of the others were free of unattended caries or premature extraction.

The amount of destruction in the lower arch (restorations, caries, D loss, E loss, D+E loss) was found to be significantly greater than that in the upper for both sexes at all ages.

Caries-free, restoration, and mild caries groups differed little in D+E space, so these groups were combined into a new group denoted *non-mutilated.* This group was used as the control for the extraction groups. Other findings from the above study were reported in an article on the effects of unattended caries (Northway and Wainright 1980).

### *Space Closure Due to Premature Exfoliation*

Our data has been presented in five groups and plotted in Fig. 2, showing the changes in D+E space as a function of chronological age. For simplicity, one-way analyses of variance among the

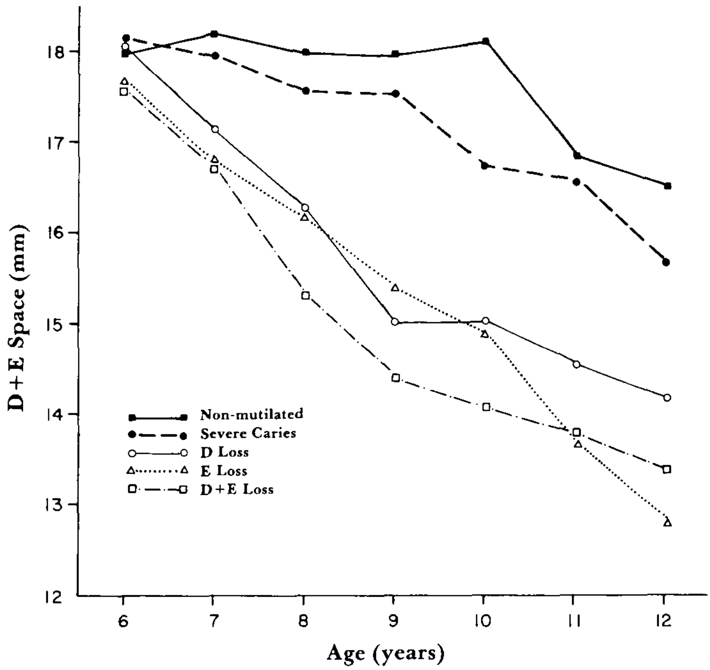


**Fig. 2 Mean changes in Lower D+E Space**

groups were performed for each age. Two way anovas with age and group as factors were not applicable here because of small group size and the disabling effects of missing data. The group effects are, however, so dramatic that the extra power of more exotic statistics was deemed unnecessary.

*Lower Arch*

There was a dramatic difference in space loss for the premature exfoliation groups (D loss, E loss, and D+E loss) compared to the nonmutilated group (Fig. 2). A steady decrease in space with age reflects the continuing space closure in subsequent years.

It can be seen that the severe caries group behaved very much like the nonmutilated group, but did tend to lose almost 1mm more throughout the series. The only year in which the two groups differed significantly in the lower arch was at age ten. Upon inspection, it was found that the affected teeth were exfoliated an average of one year earlier than in the controls.

Specific findings for the extraction groups were —

- A significant difference in lower D+E space at all ages after 6 years ($F=7.5$ at age 7). The mean D+E space for all extraction groups at all ages was significantly shorter than in the controls ($t=2.2$ for D loss, 4.2 for E loss, and 3.5 for D+E loss at age 7).
- For all extraction groups, the mean space loss in the first year was 0.9mm. For the first two years it was 1.9mm. The mean space loss was uniform for all years. In the E loss and D+E loss groups, the ranges for space closure were between 0.3mm and 1.6mm per

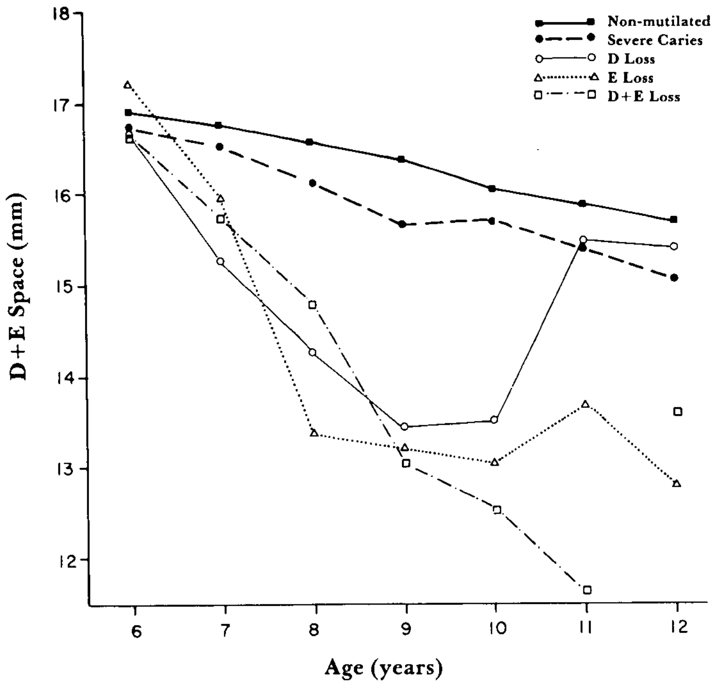


**Fig. 3 Mean Changes in Upper D+E Space**

year, with averages of 0.9mm and 0.7mm per year, respectively. The D loss group showed an increase in D+E space for one year; otherwise, there was a 0.3mmto 1.0mm annual loss, with an average of 0.5mm.

- The maximum difference from the control group was 4.0mm, found in the D+E loss group at age ten.
- The greatest divergence from the controls at the end of the series was in the E loss group, where the space was 3.7mm shorter.
- No mandibular group tended to return toward the control level.

## *Upper arch*

For upper D+E space, as viewed longitudinally by chronological age,the observations are shown in Fig. 3 and summarized below —

- Again, by age 7, space in the D loss group was significantly smaller than in the controls. By age 8 through 10 all extraction groups were significantly shorter than the controls. By age 11 the D loss group space began to again approach that of the controls, and by age 12 only the E loss group remained significantly shorter than the controls.

- The space lost initially was more dramatic for the maxillary extraction groups; in the first two years the mean loss in these groups was 2.8mm. However, by age 8 and 9 the E loss and D loss groups began to level off in annual D+E space decrements. Maxillary space loss ceased to be as dramatic as that in the mandible. Average rates of space loss were 0.3mm for the D loss, 0.7mm for the E loss, and 0.9mm for the D+E loss.

- The greatest variation from the controls was again in the D+E loss group, which was 4.3mm shorter at age 11. This was also the group and interval most divergent at the end of the series.
- Most strikingly different from the mandibular data was the behavior of the D loss group, which demonstrated an increase in the D+E space and reestablished a length similar to that of the controls. It should be noted that this increase in D+E space coincided with the replacement of the missing deciduous molar by the bicuspid, and was typically attained at the expense of lateral displacement of the cuspid.

## — Discussion —

Most surveys dealing with the changes pursuant to premature loss of deciduous teeth have utilized constructed measurements, usually involving the incisors (arch depth), but as STRAMRUD (1964) and others have demonstrated, these are of limited usefulness.

Changes in incisor position can account for tremendous variation in arch depth, especially during incisor emergence. In order to minimize any such incisor influence, we have restricted our observations to the boundaries of the deciduous molar sites (D+E space), as used by SEIPEL (1949).

With the advantage that the Optocom could consistently register serial data for the same individual in a pattern related to the palatal rugae, we have been able to dissect D+E space, and discern changes in rate and direction occurring at either the anterior or posterior limits. Especially impressive is the precision that this machine has afforded us in being able to demonstrate even the smaller divergences from the norm. In some cases, these have accumulated to provide information heretofore undetected. In Ronnerman's paper, for example, cases were not shown to differ from the norm until they fell into a group 0.5mm–3.5mm shorter than the controls (RONNERMAN 1977, AND RONNERMAN AND THILANDER 1977 AND 1978). Such categorization would understandably influence results.

Due to the influences of the duration factors, dental age does not lend itself to a serial survey of morphological changes. (NORTHWAY 1977, MOORREES ET AL. 1963A AND 1963B, MOORREES 1964, 1965, MOORREES AND CHADHA 1965, MOORREES AND REED 1965, AND MOORREES 1977). Therefore, chronological age was used in examining most of the areas germane to this article.

In certain sections of this report, developmental ages based on age at exfoliation and age at emergence have also been used, for reasons which will be discussed with those findings.

Using D+E space to examine the effect of premature extractions of deciduous teeth, significant closures have been revealed for each extraction group in both arches. Nevertheless, teeth in the maxilla and mandible behaved differently in many respects. Initial rate of space loss in the maxilla was greater than that in the mandible, but after the second year of absence, the annual maxillary loss tended to level off. The mandibular extraction groups, on the other hand, continued to lose space at a rather constant rate.

The total amount of D+E space closure, relative to the controls, was 2.0mm to 3.5mm for all mandibular extraction groups. The maxillary D+E space loss also reached this level, but at age 10 the single-extraction groups, D loss only and E loss only, began to gain space.

The majority of previous investigators have reported far greater sagittal alteration in the maxilla than in the mandible following exfoliation (UNGER 1938, CLINCH 1951, CLINCH AND HEALY 1959, BREAKSPEAR 1951, 1961; RONNERMAN 1977, RONNERMAN AND THILANDER 1977 AND 1978, AND HOFFDING AND KISLING 1979). Perhaps the uprighting of the maxillary central incisor so influenced any constructed measurement of arch depth that the maxilla seemed to be losing more space.

While none of the mandibular groups in our data showed an increase in D+E space, the maxillary D loss group actually returned to the control group level. Until age 11, there were no significant differences in D+E space among any extraction groups in either arch. Thereafter, D loss in the maxilla diverged from the other two extraction groups toward the normal. This return to the normal level probably accounts for the benign reputation that this insult has gained. Space reopening has been observed by other authors, and their findings will be discussed in Part IV of this series (HOFFDING AND KISLING 1979).

In terms of loss of D+E space, the most deleterious act is clearly the removal of a second deciduous molar with or without other extractions. This would agree with earlier reports (UNGER 1938, CLINCH 1951, CLINCH AND HEALY 1959, BREAKSPEAR 1951 1961, LIU 1949, COHEN 1941, HINRICHSEN 1962, LUNDSTRÖM 1955, SCHACHTER 1943, RICHARDSON 1965B, BRAUER 1941, KOPEL 1950, SEIPEL 1949, AND RONNERMAN 1977).

There are, however, subtle changes in the aftermath of a first deciduous molar extraction that make it difficult to downplay the gravity of its premature removal.

One of our most interesting findings was also one of the most frightening. Little loss of arch length has been historically attributed to the removal of a maxillary first deciduous molar, and even in our data the D+E space, which initially closed, conveniently returned to the control level. In an effort to better understand this graphic change, updated longitudinal study casts were reexamined three years after the original data were digitized. Also, panagraphic material was consulted in an effort to confirm our findings.

Of 11 cases where the D loss phenomenon was active, the only 2 that did not result in malalignment of the maxillary cuspid (blocked out to the labial), were one case of microdontia, and one with a palatally impacted cuspid. The mechanism exposed here is the exclusion of the maxillary cuspid from the arch when the maxillary first deciduous molar is lost prematurely (note the definition of premature loss). To our knowledge, this has not been previously reported in the literature (The sequence is shown in part VI).

In both arches, severe caries resulted in increased space loss. This was significant for one year only, the year the affected tooth was exfoliated. This usually occurred one year earlier than exfoliation in the nonmutilated group. It is felt that unrestored caries caused these teeth to be lost early, resulting in significant reduction of space. This severe caries was not classified as "early" loss because the succedaneous bicuspid emerged within the year. These findings were previously reported in a paper on the effects of dental caries (NORTHWAY AND WAINRIGHT 1980).

Also apparent is the dramatic difference in space loss which begins to occur immediately after exfoliation. This immediate space loss persisted throughout the study.

## — Part I —
## Summary and Conclusion

Dental casts from 107 children in the Montreal growth sample were digitized on the Optocom. Changes in arch length were explored via D+E space, which was shown to close as a consequence of unattended severe caries or premature exfoliation of a deciduous molar.

The lower D+E space loss during the entire study period was almost 1.7mm for the controls. Mean excess space loss above that value varied from 0.9mm in the severe caries group to 3.7mm in the E loss group. While space closure subsequent to premature exfoliation was significantly divergent from the nonmutilated group in every subsequent year, the only year that unattended caries in this group resulted in significant loss in the lower arch was at age 10.

In the maxilla, the control D+E space closure was 1.2mm during the survey. Again, the effect of unattended severe caries tended to be nearly 1mm of additional space loss, with the divergence among groups being significant only at age 8, when it was 0.7mm. All three of the extraction groups behaved similarly through age 10, losing 3mm to 4mm more than the controls.

The maxillary D loss group experienced a later increase in D+E space averaging 2.3mm. This was subsequently revealed to be related to the blocking out of the maxillary cuspid.

The group experiencing the greatest loss of D+E space was the maxillary D+E loss group, which averaged 4.3mm shorter than the controls at age 11.

# Part II

## Source of Space Change

Among the features unique to the Optocom method of collecting data on dental casts (discussed in Part I) is the opportunity to sequentially orient data for subsequent years in a reproducible and highly accurate way. Not only does this afford one the ability to make meaningful conclusions about the amount of space change, but directional relationships can be followed as well.

In this segment, we explore what happens as space is lost when different combinations of deciduous teeth are lost prematurely — are the more mesial teeth moving distally, or are the teeth distal to the extraction site moving mesially? (van der Linden 1973 and 1974)

### — Literature —

Students of dentistry are taught that mesial migration (mesial drift) of the permanent molars takes up most of the leeway between the crown diameters of the deciduous posterior teeth and their permanent successors in the development of the dentition.

This phenomenon, yet to be sufficiently explained, has been credited with many dimensional changes in the dental arch.

Lusterman (1958) spoke of a growth center distal to the permanent molars that acted as a wedging force as the second molar erupts.

Hinrichsen (1962) stated that when the permanent molar loses its support, as in the early extraction of deciduous teeth, it tips forward and drifts bodily.

Liu (1949) also noted a mesial tipping of lower first molars, a movement accompanied by lingual rotation when it occurred in the maxilla.

Not all authors have observed mesial movement of adjoining teeth to be the sole contributor to space loss. Liu, in the above mentioned study, found that space closure may have come from the emergence of incisors pushing other teeth to the distal when the extraction occurred prior to their emergence. While Clinch (1951 and 1959) felt that maxillary space closure occurred primarily due to mesial migration, it was nevertheless felt that mandibular teeth anterior to an extraction also showed a lack of forward movement.

Hoffding and Kisling (1979) followed 55 preschool children for three years to study the sagittal changes subsequent to removal of the first deciduous molars. This was done by observing occlusal relationships in the deciduous cuspid and second deciduous molar regions. From this view it appeared obvious that space in the mandible was lost by both mesial migration of posterior teeth and distal movement of anterior teeth.

Some researchers found a lack of predictability in the direction of space closure. Love and Adams (1971) found a small percentage of cases closing as a result of distal movement, but a greater percentage closed by mesial migration. Salzmann (1938) reported that 13.6% of the cases he observed closed from the distal, 5.8% from the mesial and 67.6% showed movement in both directions.

Sowden Hills (1941), observing his own cases, found distal drift of cuspids and laterals following mandibular first deciduous molar extractions and even some second deciduous molar extractions, yet he felt that the impaction of the second bicuspid was caused by the mesial shift of the permanent molar.

On the other extreme, Conner (1892), Davenport (1887) and Flint (1907) all conjectured that teeth move distally. Brandt (1963) claimed that the uprighting of anterior teeth, rather than mesial movement, closed extraction sites. Turner (1941) had discussed distal force of the muscles, but later (1947) measured distal movement clinically and conjectured that the distal inclination of developing tooth buds in their crypts might explain the distal movement.

Registration lies at the heart of describing the direction of closure. A clearly defined and appropriate reference point is essential to any geometric discussion.

Friel (1945 and 1954), orienting cephalographs on the Bolton plane, concluded that teeth could only move forward. He explained the distal migration seen in certain teeth as a function of an applied muscular force.

Using a stereograph for evaluating the study casts of 41 children with unilateral extractions, Linder-Aronson (1960) was unable to show a midline shift. It is worthy of note, however, that the mean first permanent molar location was 1.0mm more anterior on the extraction side than on the nonaffected side. No difference was found between upper and lower arches.

Seward (1965) studied the effects of the extraction of deciduous teeth using study casts, cephalographs and clinical examination at three-month intervals. He found mesial movement of the distal tooth in all but one of the 12 cases involving maxillary deciduous molars. In the mandible, distal movement outweighed mesial movement in 17 of 24 cases, and accounted for half or more of the closures that exceeded 2.0mm.

Ng (1971) and Davey (1966) used 45° oblique cephalographs to study migration.

Ng concluded that the mesial drift theory cannot be applied totally in man, because the predominant directions of tooth migration during the development of the dentition are distal in every mandibular tooth except the permanent molars — overwhelmingly so between the ages of six and nine. Between 9 and 16 years of age, it was felt that mandibular buccal teeth were moving both mesially and distally.

Davey's article dealt with the effect of premature loss of second deciduous molars in the maxilla, and showed that space was lost in both directions. In these individuals, the mean space loss attributable to mesial drift of the maxillary first permanent molar was 1.7mm, while 1.6mm was ascribed to distal movement of the first deciduous molar or first bicuspid in uncrowded arches. These values were 2.6mm and 1.6mm respectively in arches judged to have a negative leeway space.

Three experiments on space closure in monkeys have been reported. Richardson

(1965A) placed implants and performed unilateral extraction on four juvenile rhesus monkeys. It was concluded that teeth distal to an extraction site could move mesially, teeth mesial could move distally, and both could occur simultaneously. Distal bodily movement definitely occurred.

Moss and Picton (1967 and 1970) implanted six adult *Macaca* iris monkeys and reduced dental width by abrasion of interproximal contacts. Serial cephalographs and casts were used, supplemented by histologic observations. It was found that molars moved mesially and bicuspids moved distally, leading to the conclusion that there was no universal occlusal component of force to cause mesial drift in these animals.

Pietrokovski (1970) extracted 45 teeth from five adult rhesus monkeys. These teeth were extracted in pairs to eliminate occlusal antagonists. Histologic observations were performed as the animals were sacrificed at intervals ranging from one week to four months. Pietrokovski found only mesial drift of all teeth; even the teeth mesial to the extraction sites were found to be moving forward.

Obviously, histology is not a viable reference medium for human observation. Brash (1926) demonstrated that the bony rugae of the palate of the pig were moving forward during its downward and forward growth, so that the teeth must be moving forward through the bone at an even greater rate than the rugae.

Friel (1945) updated this finding when he compared development of human rugae with the skeletal changes seen by serially orienting cephalometric tracings on the Bolton plane. From both registrations, a forward and downward migration of the dentition was observed.

Lebret (1962 and 1964) asserted that the relative stability of the rugae as examined by the symmetrograph qualified the palatal vault as a reference point. In 1964 she used this reference pattern to examine the physiologic migration of maxillary teeth. The molars were found to drift mesially an average 4.0mm, compared to 3.1mm of mesial movement at the cuspid. This occurred mainly during the emergence of the posterior teeth, but continued even after the emergence of the second molar. These findings compare closely with the grouped plots in the atlas of the Ann Arbor Optocom study (Moyers et al. 1976).

Peavy (1967) studied orthodontically treated cases to observe differences in morphology of the rugae, and found little effect on the rugae as a result of dental movement. In some cases, teeth and the lateral aspects of the rugae were traveling in opposite directions. It was felt that these soft tissue landmarks might be of value in orientation, especially if the more medial points were used.

van der Linden (1974) also found negligible changes in the patterns of rugae points, and used them as a reference. He showed that the mesial upper molar movement averaged 0.3mm per year, while the lowers moved mesially 0.5mm relative to rugae points. This mesial shift, stronger in the mandible, was attributed to forward growth.

## — Methods and Materials —

The sample and technique for recording our information have been discussed in Part I.

The reference point for directional changes recorded in this survey was derived from a constructed plane consistently determined by orienting on the palatal rugae, so all directional changes are reported relative to the rugae. The mandibular dentition was oriented to the occlusal registration with the maxilla, and thus indirectly to palatal rugae.

For any given subset, the mean value for the distance that a landmark lay from the palatal rugae was predicated on which pair of rugae was selected for registration,

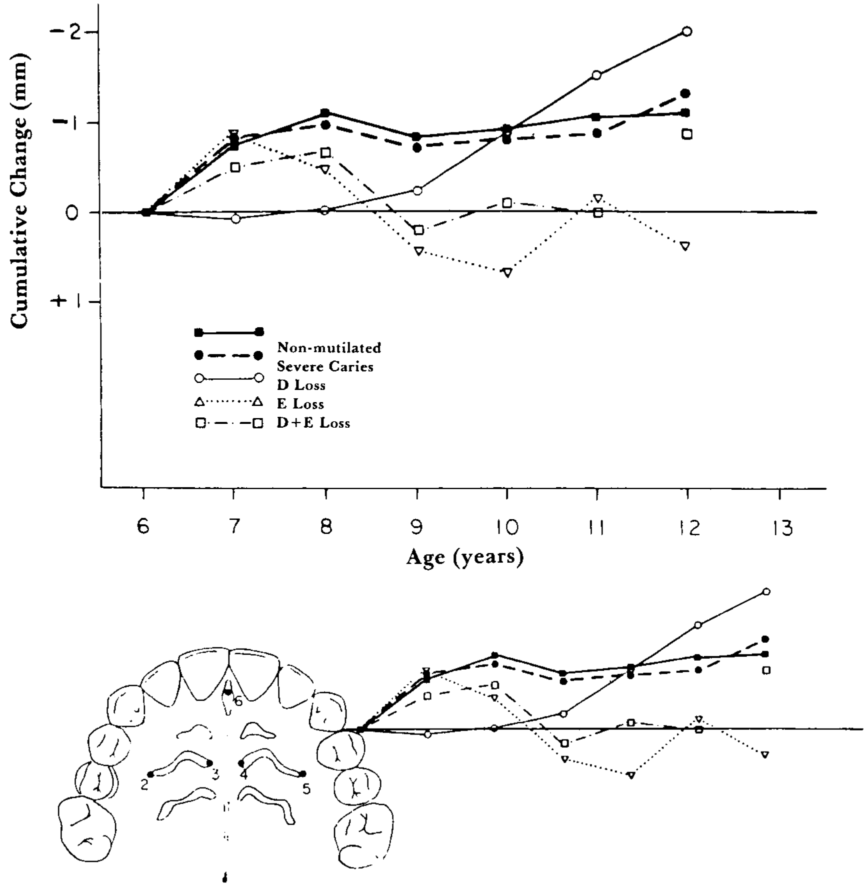


**Fig. 4** **Cumulative Annual Increments of Upper Cuspid Change (Δ)**

and the location of that pair within the arch. Consequently, little meaning could be gleaned directly from measured values, except for their intended purpose of serving as a means for determining annual incremental changes.

## — Findings —

### *Upper cuspid*

Anterior-posterior positional changes of the upper cuspid relative to the palatal rugae were calculated, and individual values pooled according to the various categories of destruction. Annual mean differences (Δ) are presented graphically in Fig. 4. Behavior of each group is plotted relative to its original position relative to the palatal rugae points.

As expected, the control group values show more mesial movement than the rugae. A schematic representation of the changes being monitored is portrayed in Fig. 5. The horizontal axis is the starting point held constant. The influence of a particular insult (caries or extraction) can be seen as divergence from the controls.

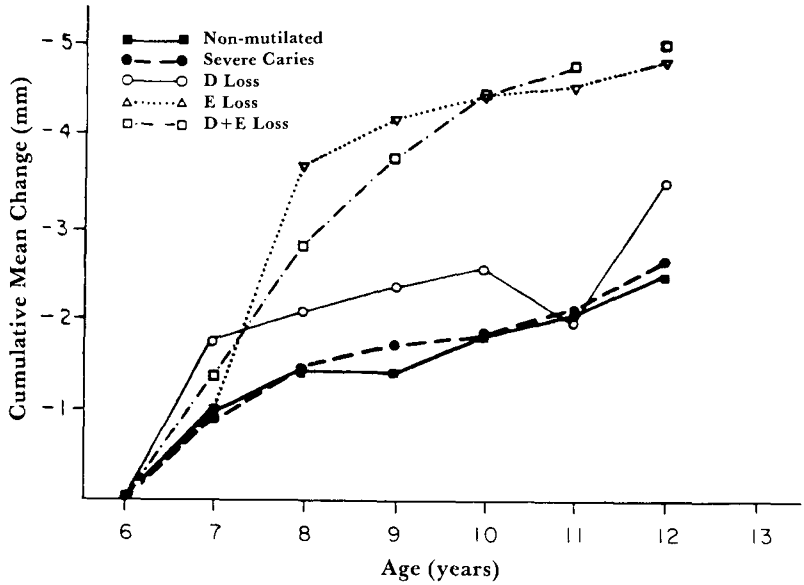


**Fig. 5** Cumulative Mean Annual Increments of Upper Molar Change (Δ)

The most statistically significant difference (F=2.66*) among the groups occurred between ages 8 and 9, when the D loss group experienced a mean mesial shift of the cuspid at a time when all other groups showed distal movement of this tooth. This group was significantly different from the controls (t=2.54*), the severe caries (t=2.41*), and the E loss group (t=2.89**). No other groups differed significantly from one another.

Cumulative values for the direction of change at this anterior determinant of D+E Space showed a tendency for the cuspid in the E loss and D+E loss groups to drift distally (Fig. 4). No annual intervals were significantly different from the nonmutilated group.

On the other hand, the mesial cuspid shift that occurred in the D loss group at age 9 marked the first in a series of four consecutive anterior movements in mean cuspid position relative to the controls. This was the only group that behaved in this fashion.

### *Upper Molar*

In Fig. 5, the Upper molar to anterior-posterior Δ values have been plotted in a cumulative fashion to demonstrate directional changes at the first permanent molar. Plotted changes in annual mean differences again show movements mesial from the rugae, ascending on the graph. A significant difference was disclosed at age 8 (F=6.46***). Student's **t** test demonstrated the differences in the E loss (t=2.28*) and the D+E loss (t=2.38*) groups from the controls. No other significant differences were found among groups at this age, nor in the succeeding years.

The statistics in the table in Fig. 6 do not apply to the cumulative values for a given year, but to simple incremental values; nonetheless, it is safe to make certain assumptions regarding the data —

- Between 7 and 8 years of age, the first permanent molar in the E loss and

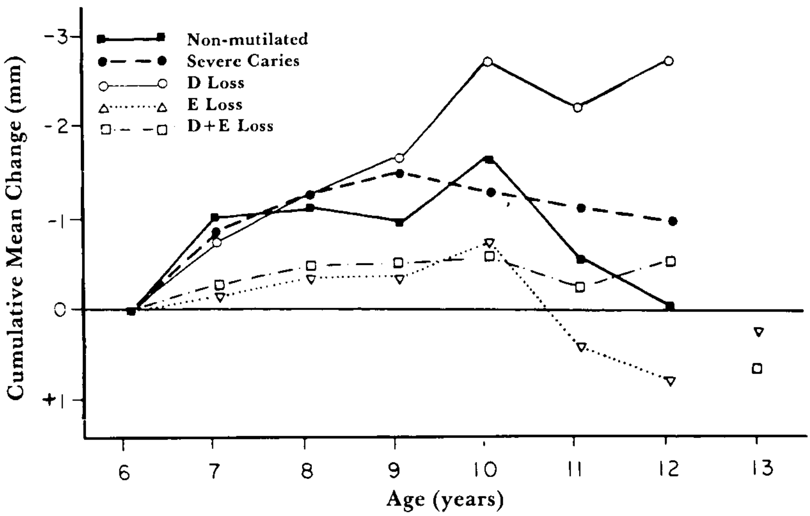


**Fig. 6** Cumulative Mean Annual Increments of Lower Cuspid Change (Δ)

D+E loss groups moved significantly more mesially than in the control group.

- In subsequent years, although the rates of forward movement in the D+E loss and E loss groups did not differ significantly from control values, the initial deviation was more than maintained.
- As there were no significant subsequent movements toward the control level, it might be assumed that the cumulative values for E loss and D+E loss were significant. These groups experienced a mean mesial migration 2.5mm greater than the control group.
- While the D loss group tended to show a greater molar shift than the controls in the first year, the mean value returned to that of the controls at age 11, when the first bicuspid emerged.

### *Lower cuspid*

Two trends for the Lower cuspid that appear on Fig. 6 are similar to the findings for the cuspid in the maxillary data. The E loss and D+E loss groups again experienced a distal shift of the cuspid relative to the controls. In the D loss group, the tendency was toward more relative forward migration than in the control group.

Using one-way analyses of variance at each year for comparing directional differences in movement of the cuspid, significant differences occurred at ages ten (F=3.80**) and eleven (F=3.44**). At age ten, the mean cuspid drift in the severe caries group was distal, while the tendency in all other groups was mesial, resulting in especially marked discrepancies from the controls (t=3.42***) and the D loss (t=3.78***) groups. The D loss group, where the cuspid was moving most rapidly forward at this age, was also significantly divergent from the D+E loss group.

In the eleventh year, the cuspids in all groups shifted distally, but most rapidly in the control and E loss groups.

### *Lower Molar*

In the lower arch, the permanent molar in all destruction groups tended toward a strong mesial movement between ages 7

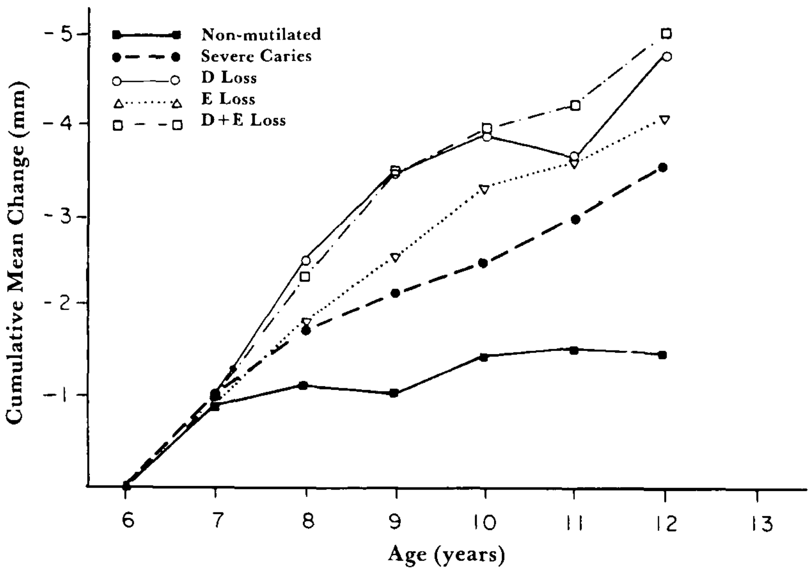


**Fig. 7** Cumulative Mean Annual Increments of Lower Molar Change (Δ)

and 8 (F=3.08*), and again between  and 9 (F=4.32***). Only the D loss group showed a tendency to return toward the control level, and this was temporary.

The resulting cumulative picture was one in which the severe caries group averaged 2.1mm more forward movement than the controls, the E loss 2.6mm, the D loss 3.3mm, and the D+E loss 3.6mm (Fig. 7). Specific findings and interpretations are —

- At 8 years of age, the lower molars in all groups moved mesially. The affected groups moved more than the controls. The **t** values were - D+E loss t=1.98, severe caries t=2.30*, D loss t=3.31**, E loss t=2.69*.
- At age 9, all groups differed significantly from the controls - severe caries, t=2.25*; D loss, t=3.18**; E loss, t=2.53*; and D+E, t=3.29**.
- As no group made a significant movement toward the control level, and most continued to move forward more rapidly than the controls, it can be stated that the cumulative mesial movement of the lower molar was greater for all groups than for the controls.
- In no one year was there a significant difference among any of the extraction groups in terms of mesial movement of the molar.

## *Confirmation of Findings by Multiple-year Deltas*

Differences were measured between values for molar or cuspid at age 6 and all other ages in the survey (6-7, 6-8, 6-9, etc.). While these multiple-year Δs obviously do not reflect exactly the same sampling, they do provide a method of confirming the cumulative data described above.

Just as with the cumulative findings, a significant difference among the upper molar values first occurs at age 8 (analysis of variance yields and F− statistics=5.43***). However, the groups that vary significantly are the D loss (t=2.65*) and E loss (t=3.28**), not the D+E loss.

In the following year, and in most of the remaining years of the survey, the D+E loss group joins the other extraction groups in differing significantly from the controls. At age 11, the average molar in the D loss group returns to the control level. The mean value for the highly variable E loss group also fails to show a significant difference.

For the upper cuspids, analyses of variance comparing multiple-year Δs again show significant differences only at age 9. Contrary to the mesial shift shown by the one-year interval data displayed above, the 3-year difference data show the average cuspid in both groups that lost a first deciduous molar to still display a mean net movement toward the distal at age 9.

However, for the next comparison and each successive comparison thereafter, the cuspid — most notably in the D loss group — showed movement in a mesial direction. The **t** value for comparison of the D loss group with the controls at age 9 is 4.24***. The D+E loss group, whose cuspids appear to be slightly more mesial than at age 6, has a **t** score of 2.64* for the Δ between these ages.

The lower molar multiple-year Δs again corroborate the above incremental findings, but significant differences do not appear until age 9 (F=4.02**). All groups differed significantly from the controls. Furthermore, all groups continued to give values divergent from the controls for all ages in the survey until 12, when the numbers fell dramatically. The only exception is the E loss group, whose 6-10-year Δ is not significantly different statistically from the controls, probably due to a large variance.

Once again, the multiple-year Δ values for those groups who lost a second deciduous molar differed significantly from the controls when comparing the relative positions of the lower cuspid. In both the E loss and the D+E loss groups, this anterior determinant of D+E Space failed to move as far to the mesial as it did in the controls. The differences are significant from age 8 until 11.

The mesial shift of the lower cuspid in the D loss group, which appeared to be rather dramatic in the one-year Δ data does not differ significantly from the controls, but at age 11 the difference from the E loss group shows t=2.62*.

## — Discussion —

While the sample sizes fail to correspond exactly from year to year, the cumulated one-year Δs tend to give findings which agree very nicely with those of the multiple-year Δs. Either approach provides the same general findings regarding the direction in which space is lost.

For both arches, the greatest amount of space loss occurs as a result of the molar moving mesially. The only situation where the ultimate space loss attributable to the molar is not significantly greater than in the controls is in the maxillary D loss group. Here, as was the case for the mandibular D loss group, the cuspid is farther mesial than in the controls at the end of the series. Again, it should be borne in mind that all references to direction are relative to the palatal rugae.

Numerous earlier authors have tended to arrive at the general conclusions that maxillary extraction sites close primarily due to mesial movement of posterior teeth and mandibular extraction sites by distal migration of anterior teeth (Sowden Hills 1941, Clinch and Healy 1959, Seward 1965).

Hoffding and Kisling (1979) stated that their schematic representation of closure was based on observations made on serial casts and on reports in the literature. This concept is supported by Kronfeld's theory of neutral areas located between the bicuspids in the maxilla and just mesial to the first molar in the mandible. Teeth anterior to the neutral area are expected to erupt to the distal, while distal teeth migrate forward.

The developmental profiles shown in *Standards of Occlusal Development* (Moyers 1976) do not substantiate any such tendencies. While we have found differences in the behavior of the maxilla and the mandible, our findings do not support the concept that there is such an opposite behavior pattern in the direction of space closure.

The mean molar movement in all extractions was more mesial than in the controls. With the exception of the maxillary D loss group, whose molar made a strong mesial shift in the first year but not in subsequent years, the molars in all extraction groups in both arches experience sufficient mesial shifts to make them significantly different from the controls for all ages after eight.

The maxillary E loss group showed 1.5mm more mesial advancement than the mandibular at age 8, but this difference diminished to 0.5mm by age 11. The upper and lower D+E loss groups behaved very similar to one another.

The greatest difference in the way that the molars behaved was between maxillary and mandibular D loss groups. Contrary to the findings in previous publications, the molars in the lower D loss group moved much farther forward than their upper counterparts. By age 11, the difference from the controls was 2.0mm.

The maxillary and mandibular cuspids responded in very similar fashions for both the E loss and D+E loss groups. In both arches, the cuspids drifted distally 0.5-1.5mm more than the controls.

Again, the notable exception is the D loss group. In the lower, the cuspid in this group behaved like the controls for two years and then began to migrate mesially relative to the controls. In the maxilla we found a delayed mesial migration after it had made a strong distal shift in the first year.

## — Part II —
## Conclusions

- For both arches, the greatest space loss occurred as a result of the molar moving toward the mesial. Only in the maxillary D loss group, where there was a significant mesial shift prior to age 11, did the molar return to a position comparable to the controls. This was not found for any mandibular group.
- The maxillary cuspid contribution to a reduction in available arch length was statistically significant only at age 9, and then only in those groups with second deciduous molar extractions. In the mandible, the groups with most significant space loss as a result of cuspid migration were also those which had lost the second deciduous molar prematurely, with the divergence significant from age 8 to 11.
- While the maximum divergence of cuspid migration from the controls in either arch was 1.0-1.5mm, the average molar deviation was 2.0-3.0mm. Noteworthy exceptions were the D loss groups in either arch, where the cuspid displacement was mesial rather than distal.

## Part III

## Age at Exfoliation and Its Influence on Rate of Space Change

In 1949, Seipel noted in his article on the "Prevention of malocclusion" that the age at which a premature loss occurred was important, because earlier periods of development offered less anatomical resistance to migration. UNGER (1938) had previously put forth the proposition that the earlier a tooth is lost, the greater the initial rate and total loss. Many other authors have supported these views (SEIPEL 1949, KRONFELD 1953, LUSTERMAN 1958, LINDER-ARONSON 1960, HINRICHSEN 1962, KRONFELD 1964, GODT AND GREVE 1965, SEWARD 1965, KRAKOWIAK 1966, SEWARD 1967, AND LOVE AND ADAMS 1971).

There are numerous factors which can affect the rate at which two teeth on opposite sides of an extraction site come together. Many of these will be dealt with separately, but the subject of rate cannot be discussed apart from the way in which factors such as location, timing, and other phenomena act.

In SEWARD'S (1965) sample of twenty subjects, it was observed that there was a continual mean rate of closure of 1.5mm per year in the maxilla, and all individuals demonstrated some space loss. In the mandible, the mean rate of closure was 1.0mm per year, with individuals varying widely in the timing of closure — 5 closed early, 4 closed late, and 9 closed steadily.

BREAKSPEAR'S (1951 AND 1961) studies of 100 showed the spaces closing rather steadily, but with a tendency for greatest loss shortly after the extraction. This was especially true in his older group, where the rate of closure was greater than for individuals who lost their teeth early. He also broke the rates down according to which tooth had been extracted. The loss of first deciduous molars resulted in a mean closure of 0.8mm per year in the upper and 0.9mm in the lower. For second deciduous molars, the mean values were 2.2mm per year in the upper and 1.7mm in the lower. The loss of both deciduous molars produced 2.0mm mean closure in the upper and 1.3mm in the lower.

Not distinguishing between upper and lower, LIU (1949) showed that 57% of the cases in her survey had the greatest loss in the first six months following the extraction. This agreed with RICHARDSON'S (1965B) findings, which also included high positive correlations between the space lost during the first six months and in other similar intervals. Further, it was seen that those cases who lost space rapidly in the early periods of observation tended to continue to do so.

In an experiment where contact points and numerous dental antagonists were removed in a number of monkeys, MOSS AND PICTON (1967 AND 1970) held the soft tissues away from the teeth and concluded that overlying muscles had no significant effect on the rate of closure. It was also observed that those teeth that had no occlusal antagonist migrated faster than the ones that did, supporting the role of occlusion as stabilizer in balancing the dentition.

CLINCH (1951) and CLINCH AND HEALY (1959) stated that extractions performed prior to the emergence of the first permanent molars resulted in permanent loss of space in varying degrees, more in the upper than in the lower. Extractions subsequent to first molar eruption resulted in less permanent disruption.

DAVEY (1966) corroborated this interpretation and went on to say that the period after the emergence of the permanent molar, but before the emergence of the first bicuspid, was the second most deleterious. He indicated that average loss in the maxilla following an extraction before first molar eruption was 6.1mm, while after molar eruption it was 3.7mm. Within the year before the emergence of the second bicuspid it was only 2.3mm.

HUTCHINSON (1884) said that the loss of space following premature extraction was dependent on the eruptive state of the second molar. If this tooth had not emerged at the time, the space loss would be toward the mesial. If it had emerged, the anterior teeth would close the gap by distal migration.

LUSTERMAN (1958) also found great import in the period of emergence of the second molar as he speculated that there was a growth center distal to the first molar which could cause problems for a case with prematurely extracted deciduous molars.

## — Methods and Materials —

In order to examine the rate of D+E space loss due to exfoliation or extraction, the quadrants in which teeth were lost prematurely were listed according to the chronological age of the child when the first tooth in that quadrant was lost. For those who did not lose their deciduous molars prematurely (see earlier definition), indexing began at the age when both deciduous molars were absent.

Results from the mandible and maxilla were treated separately. The mean change in D+E Space during the previous year (D+E Space $\Delta$) was plotted relative to age. In this way, it was possible to examine the effect of the loss of a deciduous molar during the first year of its absence as a function of the age that the exfoliation occurred. Further, as this data was followed longitudinally for each group, the results for subsequent years could also be monitored.

Sample description and measurement technique have been discussed earlier. Because of missing data, the sample sizes under study changed slightly as a function of chronological age. Consequently, it has been necessary to display multiple-year changes graphically as sums of single-year $\Delta$s.

## — Findings —

### *Upper arch* (Fig. 8)

One-way analysis of variance, comparing maxillary D+E Space $\Delta$s for ages 6 through 12 indicates that the age at which a tooth is lost is very significant in determining the amount of space that will be lost during the first year. Younger individuals lose significantly more space in the first year following an extraction than do older individuals (F=4.06***). By comparing the means, it becomes obvious that the space lost subsequent to extractions at ages 6, 7 or 8 was greater than that for teeth removed at ages 9, 10 or 11.

To further validate this observation, the average of the first three ages was compared to the average of the last three. The difference was found to be statistically significant using either a nonsimultaneous **t** statistic ($t_{125}=4.76$***), or a simultaneous Scheffe confidence interval of 95% certainty.

The mean space loss in the first year for all groups was significantly greater than that lost in any subsequent year. The **t** statistics for paired comparisons of the first-year loss with second-, third-, and fourth-year losses were 3.11, 5.50 and 4.87 respectively, implying statistically significant differences.

For this sample, the total amount of space lost in the 4 years following a maxillary extraction appears to be three times

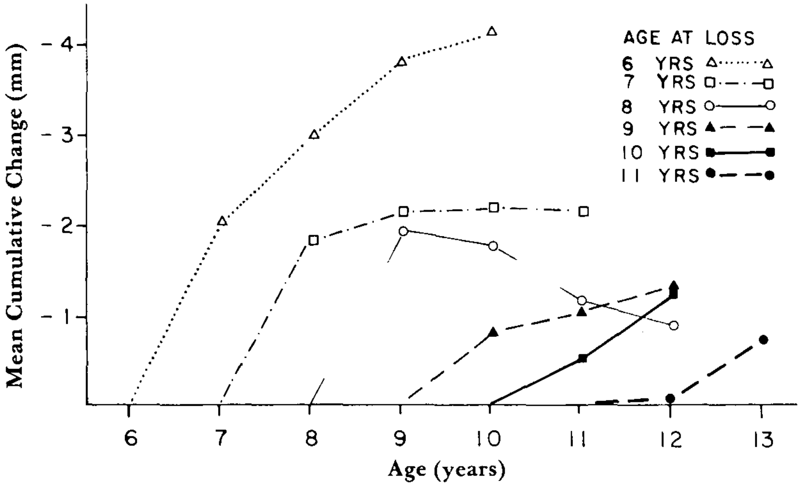


**Fig. 8** Cumulative Mean Upper D+E Space Loss by Age of Tooth Loss

greater for a child whose deciduous molar is removed before he is seven than for one whose tooth is removed after age 8.

The average space loss during the first 4 years following an extraction before the age of 7 was 4.1mm, or about 1mm per year. For 7-year-olds, extractions resulted in an average loss of 2.1mm in the ensuing 4 years, or 0.5mm per year.

Eight-year-olds tended to regain a good part of what they lost in the first year, resulting in a 4-year net change of 0.9mm. While the information becomes sketchy for 9- and 10-year-olds, average losses were below 1.5mm in the 4 years following an extraction.

### *Lower arch* (Fig. 9)

The rate of space loss in the mandible appears to be very steady. Regardless of the age at extraction, the average loss in the first 4 years was between 2.6mm and 3.2mm, an average annual rate of 0.8mm loss.

There was no apparent tendency for younger children to lose more space than older children in the years after a lower extraction. There was also no apparent age-related difference in the average total space loss in the 4 years following a mandibular extraction.

There was a significant difference between the amount of space lost in the first year and the amount lost in the ensuing 3 years. The **t** statistics are 2.55, 4.20 and 4.26 for the second-, third- and fourth-year comparisons respectively.

## — Discussion —

The rate of space loss as portrayed in Part I is confounded by the method of recording the longitudinal data. An individual who lost a tooth later in the series was nevertheless carried with the other subjects in that destruction group. This tends to dampen the statistical impression of the response experienced by those with losses earlier in the series.

While inferences can be drawn from the data in Part I, especially as it applies to any one form of insult, what makes the material in this segment so dynamic is that it deals with rates of space change according to the age at which the extraction took place.

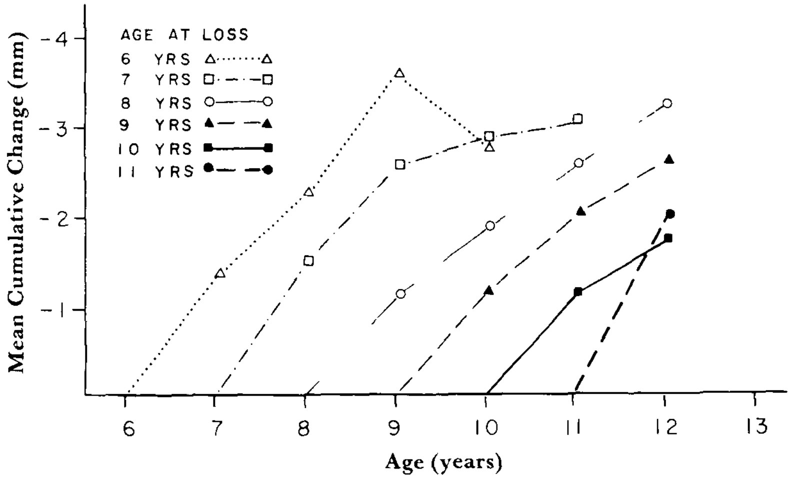


**Fig. 9** Cumulative Mean Lower D+E Space Loss by Age of Tooth Loss

Unger (1938), Seipel (1949), and others have held that the rate of space loss is greatest when extractions are performed when individuals are younger. Our first-year findings agree with this in the maxilla, but not in the mandible. In the maxilla, earlier extractions not only caused more space loss in the first year, but in subsequent years as well.

While age is obviously a factor in the maxilla, the emergence of either of the permanent molars did not appear to effect a turning point for exaggerated space closure as Clinch and others have suggested (Hutchinson 1884, Clinch 1951, Lusterman 1958, Clinch and Healy 1959, Richardson 1965a, Davey 1966, Ronnerman 1977, and Ronnerman and Thilander 1977 1978).

There was no significant difference in mean rate of space loss in the first year in the mandible which could be related to the age at extraction.

The maxilla and mandible did behave similarly in that the rate of space loss in the first year following an extraction was greater than in subsequent years for both arches.

MacLaughlin (1967) reported that there was a "threshold" age for impaction of the permanent successor at 10 years, 4 months in his sample. Most extractions prior to this age tended to result in impaction, while most later extractions had a greater chance for eruption. If there was such a threshold in our sample, it would appear to be at 8 or 9 for the maxillary arch only.

As Fanning (1962) has shown, the very early extractions may cause delayed emergence and increase the period that the replacement tooth will be absent. This will afford more time for space closure. However, the boundary teeth can only move so far before they will encounter the unemerged teeth.

Another consideration would have to be sequence of emergence. When one tooth has erupted much farther than its neighbor, it can pass beyond that tooth and the two occupy the same sagittal space as one. Another possibility, observed by van der Linden (1973 and 1974), is greater mesial movement of the first permanent molar in those cases where the second molar emerges before the transition of the more mesial teeth.

## — Part III — Conclusions

- More space was lost in the first year following an extraction than in successive years.
- The rate of space loss following premature extractions in the maxilla was age-related — extractions on younger children caused more space loss in the first and subsequent years than they did in older children.
- The 4-year space loss in the maxilla was 4.1mm for extractions at age 6, 2.1mm at age 7, and less than 1.5mm for older age groups.
- In the mandible, there was no relation between age at extraction and the amount of space loss.
- Extractions in the mandible at all ages led to average losses from 2.6 to 3.2mm in the ensuing 4 years.

In MacLaughlin's (1967) study, 143 bicuspids appeared to be impacted at age 10. As emergence occurred, 61 of these were found to erupt due to what he described as a "distal shift of the first molar that was measurable." Twenty-four of these were maxillary teeth and thirty-seven were mandibular. A second contributor in the resolution of the impactions was mesial shift of the first bicuspid. Ultimately, one-fifth of the premature extractions resulted in impaction. Of those that remained impacted, two-thirds had undergone deciduous extraction before 8 years of age.

Other authors have compared the status of bicuspid emergence as a means of evaluating the permanence of space lost through extraction of the first or second deciduous molars.

Cohen (1941) found 6% of the first bicuspids and 40% of the second bicuspids blocked from normal emergence.

Unger (1938) reported 37% and 67% respectively.

Schachter's (1943) findings revealed 35% and 41% in the maxilla, and 8% and 50% in the mandible.

Of Brauer's (1941) cases, 36% of the first bicuspids and 62% of the second bicuspids failed to erupt normally. In his combined extraction cases, half of the second bicuspids emerged poorly, as did 20% of the first bicuspids.

# Part IV

## Space Reattainment

The effect of space loss would not be so traumatic if one could anticipate reclaiming the space necessary to accommodate the erupting succedaneous teeth. Seipel (1949) felt that this could occur in a small percentage of cases, calling it a *reverse migration*.

Hinrichsen (1962) stated that this was not really a reopening of lost space, but probably an uprighting of teeth tipped earlier — certainly not the result of an anterior-posterior growth spurt.

Weber (1949) observed this reopening in 6.3% of the cases. In Charbeneau's (1950) sample, one out of 43 experienced a later increase in the space at the extraction site.

Kopel (1950) suggested that this occurred more readily at the site of a first deciduous molar or cuspid extraction than at the second deciduous molar.

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## — Method —

In order to evaluate the possible reopening of a previously closing extraction site at the time of replacement by the succedaneous tooth, all individuals were listed according to their ages when the permanent tooth appeared. This was called the replacement age.

Annual incremental values for changes in position were averaged for each destruction group. A significant difference in the behavior of certain groups at this time, compared with other groups, might indicate a tendency toward relocation of boundary teeth with the emergence of the permanent teeth.

## — Findings —

### *Upper Arch*

There were no significant mean differences for the upper molar position among any of the groups. Not only the year of replacement, but the previous year and the year after failed to show significance via analyses of variance. Further, there were no significant differences for the upper cuspid measurement among groups at any of the three years. It was concluded that no maxillary group showed a significantly consistent shift that would provide more space for the permanent tooth at the time of its emergence (Fig. 10).

### *Lower Arch*

For the year of replacement, a one-way analysis of variance revealed a significant difference for the mandibular data ($F=2.40^\star$). The molar in the D+E loss group moved backward 2.6mm in the year that the second of these teeth was replaced. In all other groups the molar was moving forward.

Differences between D+E loss and all other groups were significant (nonmutilated $t=2.72^\star$, severe caries $t=2.47^\star$, D loss $t=2.36^\star$, and $t=2.26^\star$ for E loss). No other groups differed significantly during this period, and values during previous and subsequent years did not differ significantly (Fig. 11). It is interesting to note, however, that the following year most of the space gained tended to be lost again.

The Lower cuspid position data showed no significant differences among groups for any of the three years.

In summary, the lower molar in the D+E loss group was the only landmark where, subsequent to premature extraction, significant accommodation occurred at the time of emergence.

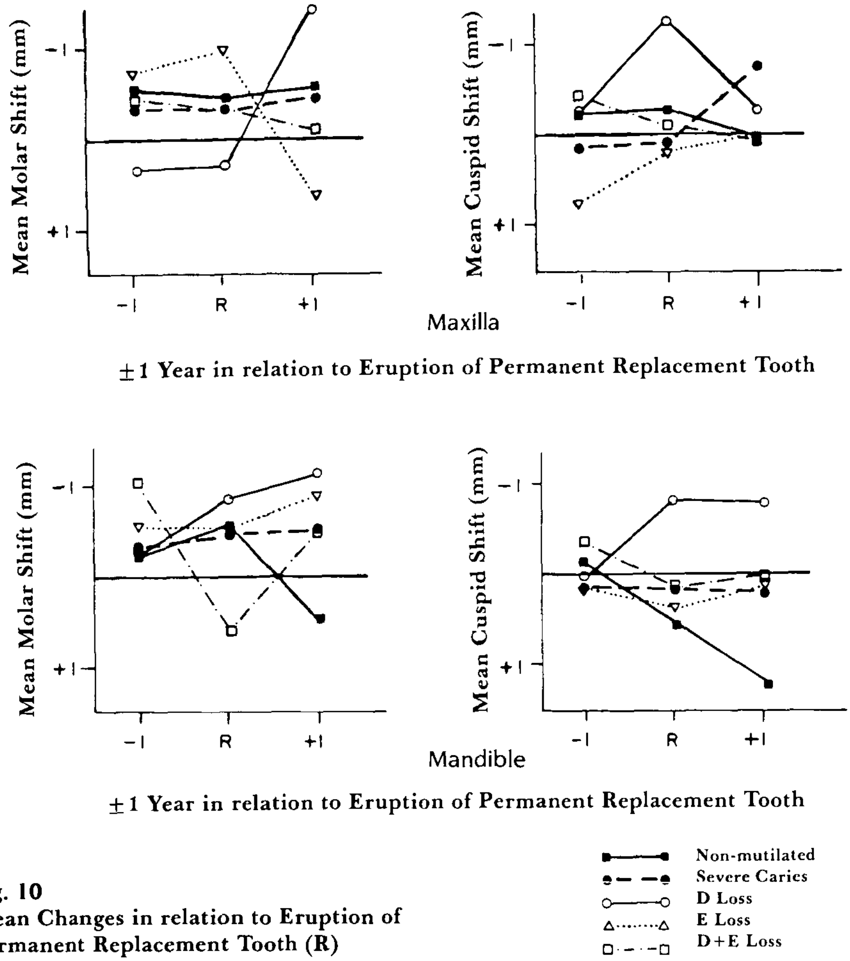


**Fig. 10**
**Mean Changes in relation to Eruption of Permanent Replacement Tooth (R)**

## — Discussion —

In order to examine any change that might occur as a function of replacement, we analyzed the data according to the age of replacement, which is a developmental age. The directional changes of molar and cuspid were studied for all individuals grouped according to this event. Changes one year before and one year after the emergence were also evaluated.

Only the lower D+E loss group showed a statistically significant difference. During the year of replacement, the molar in this group moved distally an average of 1.0mm more than in the controls. This partial uprighting of tipped molars as the second bicuspids erupt is consistent with the findings of MacLaughlin (1967).

Various impactions, especially in the lower arch, expressed themselves in such different ways as to give a wide range of possible findings, especially in the E loss group.

# Part V

## Role of Occlusion in Tooth Migration

The interlocking of occlusion has been theorized to account for stability in an orthodontic result. By the same token, it has been held responsible for affecting the rate at which teeth migrate.

Breakspear (1951 and 1961) spoke of cuspal interlock, and advised that cases with good interdigitation would lose less space after premature extraction. Clinch (1951), Clinch and Healy (1959), Liu (1949), Lundström (1955), and Seipel (1949) have all made similar observations.

Davey (1966) examined the phenomenon in terms of cusp height, and found 2.4mm more drift of the permanent molar (extraction side) for each millimeter decrement in cusp height.

Moss and Picton (1967 and 1970) removed interproximal and occlusal contacts and found the least migration in those cases where occlusal contacts remained. In this way, they eliminated any possible mesial force component from the forces of occlusion.

Moorrees (1965) stated that interdigitation had played a role in the extent and direction from which migration would fill a leeway space. Similarly, he conjectured that space would be lost more slowly in neutrocclusion than in edge-to-edge relationships.

The concept of neutrocclusion evolving from a developmental status of edge-to-edge was explored by Baume (1975). Cases that first lost a lower deciduous molar shifted into an Angle Class I molar relationship, and those losing an upper deciduous molar first ran the risk of becoming locked into distocclusion or Class II.

This fear was also voiced by Higley and Marks (1967) as an especially alarming feature in maxillary premature extraction cases. They felt that this might lead to permanent fixation in Class II.

Unger (1938) determined that the type of occlusion played no role in the incidence of abnormal emergence following extractions. Davey (1966) also found no significant correlation between the amount of drift and the occlusal relationship. From an impaction sample, MacLaughlin, et al. (1967) were also unable to demonstrate that the type of occlusion had any influence on the changes affecting ultimate arch form.

### — Method —

Molar occlusal relationships were recorded as the horizontal difference in first molar positions. Cuspid occlusal relationships were recorded in a similar fashion.

Again, analyses of variance were used to compare the means for each group at each year.

### — Findings —

#### *Maxillary Extractions*

*Molar occlusal relationships*

Maxillary extractions first showed a significant effect on molar relationship at age 8 ($F=4.54^{**}$)(Fig. 12). The E loss group showed a significant trend toward distocclusion ($t=2.01^{*}$), and the D+E loss group also showed a small similar shift.

The only other significant mean differences were between E loss and the D loss group ($t=2.81^{*}$), which tended toward mesiocclusion, and between D loss and severe caries groups ($t=2.25^{*}$). It should be borne in mind that while it appeared that the maxillary D loss group was being drawn into mesiocclusions, 69% of all

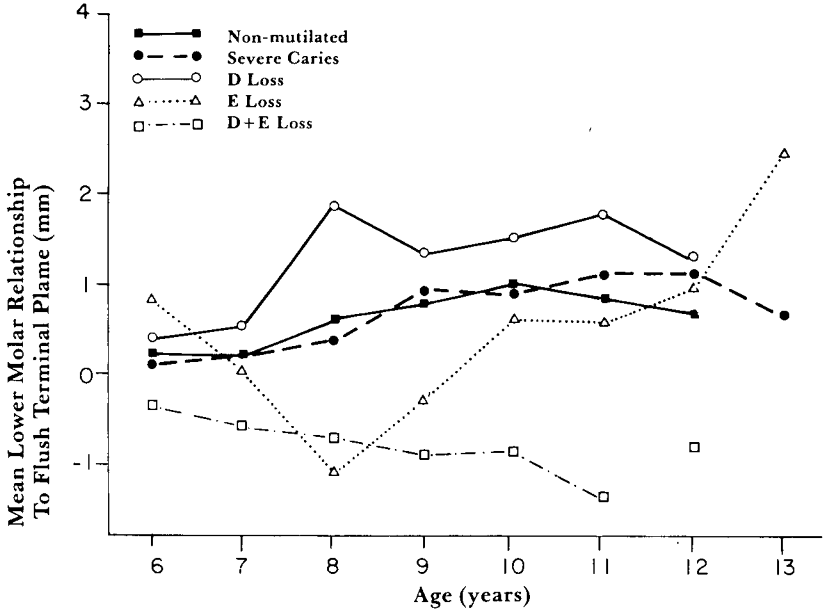


Fig. 11 Mean Molar Relationship Following Upper Deciduous Molar Loss

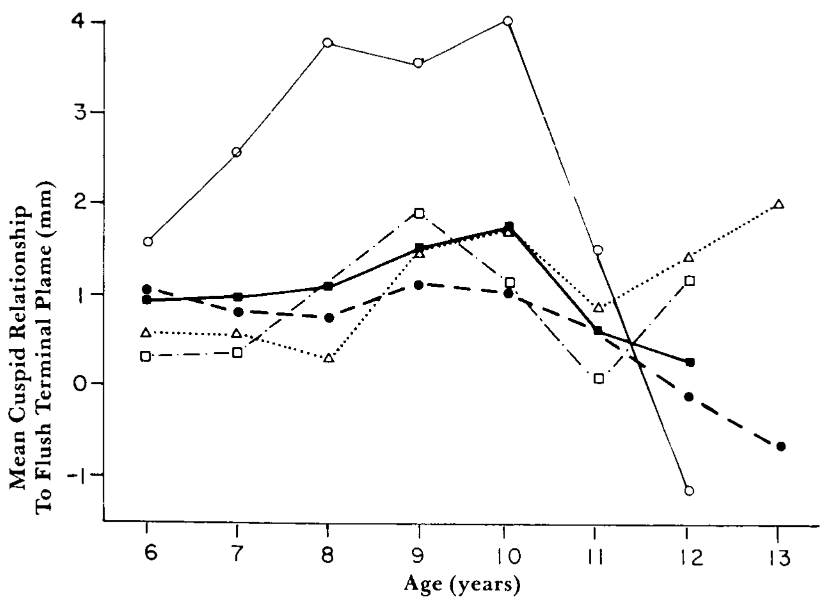


Fig. 12 Mean Cuspid Relationship Following Upper Deciduous Molar Loss

quadrants in which maxillary first deciduous molars had been extracted were opposed by mandibular quadrants in which the D, E, or D+E had also been lost.

At age 9, E loss and D+E loss groups still tended toward distocclusion, but only the D+E differed significantly from the controls (t=2.28*). It also diverged from the severe caries group (t=2.49) and the D loss group (t=2.78*).

At age 10, the only group that differed significantly from the others was the D+E loss (F=2.89*). The **t** score values were — controls t=2.56*, severe caries t=2.43*, and D loss t=3.10**.

At age 11, the same differences were maintained between the D+E loss group and the others (F=3.46**). The **t** scores were 2.60* for the controls, 2.94** for severe cries, and 2.56* for D loss.

Molar relationships were significantly affected by maxillary extractions, especially in the short term. After age 9, the mesial movement following mandibular extractions outdistanced the mesial shifting in maxillary single extractions.

### *Cuspid Occlusal Relationships*

Maxillary extractions affected cuspid occlusal relationship in a significant fashion in only one group.

The D loss population experienced an immediate mean distal shift of the maxillary cuspid, especially when compared to the controls, which typically led to mesiocclusion of the cuspids until age 12 (Fig. 12). The cuspid relationship for this group was significantly different in all groups between ages 7 and 10. The maxillary D loss group was also the only maxillary loss group that was significantly different from the other groups. The **t** score values for comparisons with the controls are t=2.45* at age 7, t=4.09* at age 8, t=2.85** at 9, and t=2.63* at age 10.

By ages 11 and 12, the forward movement of the maxillary cuspid disclosed in Section II on "Source of Space Change" removed the D loss group average from the cuspid mesiocclusion category.

## *Mandibular Extractions*

### *Molar Occlusal Relationships*

It would be expected that destruction in the lower arch would shift the lower molar mesially into a mesiocclusion relationship with the upper molar.

The first significant difference among groups occurred at age 8, when the severe caries group moved toward distocclusion (F=2.44*) (Fig. 13).

The caries group differed significantly from D+E loss, E loss, and the control group (t=2.01*, 2.16*, and 1.73**, respectively). Thereafter, it did not differ significantly from the controls, but it did differ from all three extraction groups for the two ensuing periods.

It was at age 9 that these extraction groups showed significant mean movement away from the controls into mesiocclusion (F=5.30***). E Loss (t=2.83**) and D+E loss groups (t=2.22*) both moved significantly more toward mesiocclusion than the controls.

At age 10, this migration continued. The E loss and D+E loss groups again showed more mesiocclusions than the controls.

At age 11, the D loss group mean shifted to neutrocclusion, very near the level of the severe caries and control groups. These groups all differed significantly from the other two extraction groups (t=3.54** for the controls vs. E loss, and t=2.40* for controls vs. D+E loss ). The F value for the analysis of variance was 5.05***.

On the basis of this data, it can be said that extractions involving the lower second deciduous molar have a significant and lasting effect on molar occlusion. The result can be mesiocclusion.

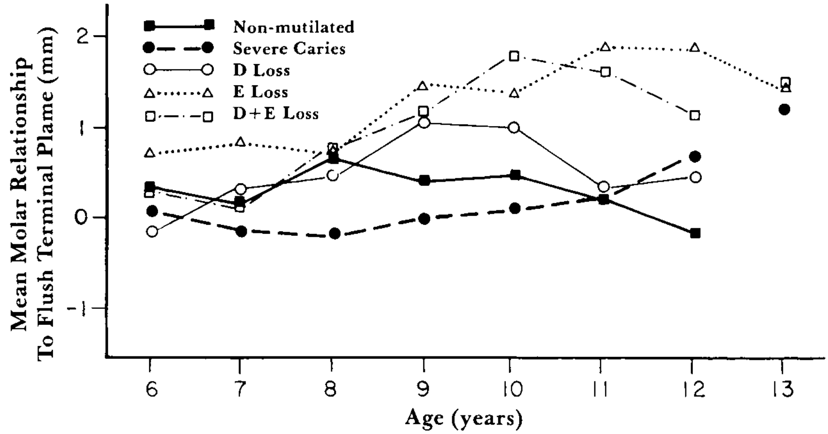


**Fig. 13** Mean Molar Relationship Following Lower Deciduous Molar Loss

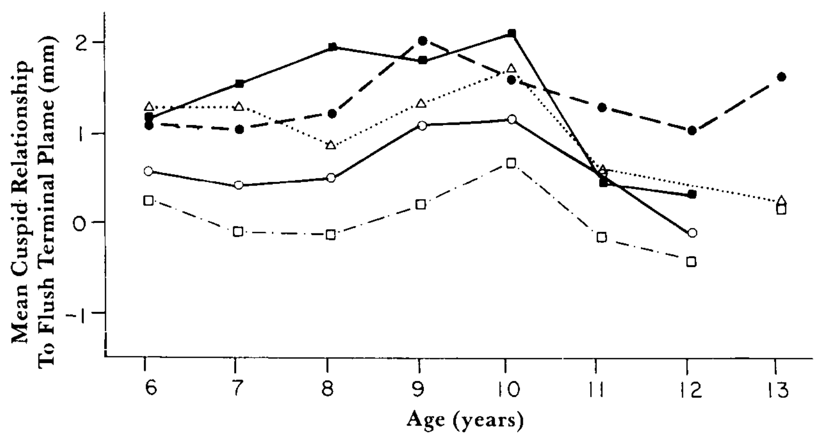


**Fig. 14** Mean Cuspid Relationship Following Lower Deciduous Molar Loss

### *Cuspid Occlusal Relationships*

The mandibular data reveals that the extraction of mandibular first and second deciduous molars effects a significant mean shift of the cuspid toward distocclusion. The D+E loss group maintained a cuspid occlusion significantly different from that of the controls from age 7 until 10(Fig. 14).

At age 8 a one-way analysis of variance yielded an F value of 5.63***. All groups were significantly different from the controls — severe caries t=2.27*, D loss t=2.35*, and E loss t=2.68**. While this was the only year that D loss and E loss groups showed significant differences, all extraction groups tended more toward distocclusion than the control group did.

At age 11, the cuspids in the control group had made a strong distal shift resulting in a mean value near neutrocclusion. The **t** score values contrasting the control and the D+E loss group are — t=2.08* at age 6, t=3.67*** at 7, t=3.76*** at 8, t=3.16** at 9, and t=3.78** at 10 years of age.

## — Discussion —

The loss of a maxillary second deciduous molar resulted in a mean mesial shift of the upper molar to such an extent that the occlusion began to resemble an Angle Class II relationship. This was not the case for the first deciduous molar extractions in the maxilla, but 66% of all such quadrants were opposed by mandibular extractions. In fact, the amount of disruption in the mandible so outweighed the maxillary disruption that after age 8, the E loss group began a shift which returned it to a mean Class I relationship.

Ultimately, the maxillary D+E loss group was the only group with Class II molar relationship resulting from premature extractions.

The lone group in which the cuspid relationship was significantly affected by maxillary extractions was the D loss, where the deciduous cuspid shifted rapidly toward a Class III relationship. As the bicuspid erupted, followed by the permanent cuspid, this group moved dramatically into a Class II relationship.

By age 9, lower extractions involving the second deciduous molar can precipitate a state of mesiocclusion of the molar which is significantly more advanced than the controls. While the D loss group did not differ from the controls, the other two extraction groups maintained their divergence, with a lasting effect on molar relationship.

All lower extraction groups tended more toward neutrocclusion of the cuspid than the controls, but the only year that they were all significantly different was at eight years of age. Otherwise, only the D+E loss group was significantly divergent. This difference remained significant from age 7 through 10.

As might be expected, the removal of a second deciduous molar in either arch precipitated the most deleterious effect on molar relationship. This can be worsened if the first deciduous molar is removed as well. Also predictably, the groups showing the greatest effects on cuspid relationships in either arch were those in which first deciduous molars had been removed.

In the lower, the effects in the D+E loss group were worse than D loss alone, but there were twice as many maxillary D loss quadrants opposing mandibular D+E, diminishing the effect.

## — Part V —
## Conclusions

Molar occlusal relationships were shifted toward distocclusion as a result of maxillary E loss or D+E loss. Due to the preponderance of mandibular extractions and resulting lower molar shifts, the maxillary D loss group did not demonstrate this difference in molar relationship, and it was only temporary in the E loss group.

The only groups in the mandible whose molar relationships were significantly affected were those that lost a second deciduous molar prematurely. These demonstrated a shift toward mesiocclusion.

Of the maxillary extractions, only D loss significantly affected cuspid occlusal relationship, and then only before age 11. After 10, the cuspids in this group moved dramatically into distocclusion.

At age 8, all mandibular extraction groups differed significantly from the controls, with all in lesser states of mesiocclusion. However, the lower D+E loss group alone maintained a significant divergence in cuspid occlusal relations for the duration of the survey.

# Part VI

## Models of Space Closure

Directional drifting patterns for the various teeth have been derived from numerous works on the subject of premature loss (Kronfeld 1953, Clinch and Healy 1959, Brandt 1963, Davey 1966, Krakowiak 1966, Seward 1967, and Hoffding and Kisling 1979). Few of these works used an orientation reference.

Using implants to study the variations in growth pattern in the mandible, Björk (1963) has shown greatly divergent directions of development for the mandibular dentition.

Notwithstanding that the ultimate biological significance is borne by the mechanics of dental interface, the opposite arch — be it upper or lower — really should not be the reference. Both are in a constant state of migration, and while one may be greatly influenced by changes in the opposite arch (the loss of the antagonist, a change in cusp height of an antagonist, movement of an antagonist by orthodontics or otherwise), there are also intrinsic factors that are capable of influencing the position of a tooth.

It cannot be overlooked that these teeth are embedded in different bones that might not be moving in harmony with each other.

It is convenient to say that there is a pattern of drift — that the principal direction of movement in the lower jaw is distal and in the upper is mesial. But individuals differ, circumstances differ, and the ways that we use to evaluate movement differ. Bearing in mind that our reference point is the palatal rugae, we would propose the following model of the sequelae to premature exfoliation of deciduous molars.

### — Space Loss Following Premature Extraction —

If a deciduous molar is lost prematurely, there is a near certainty that a loss of D+E Space will follow. This, more often than not, results in an inability to accommodate all of a normal permanent dentition.

The severity of the pending malemergence appears to depend more on the duration of the absence than on any other single factor. The location of the malemergence depends on which tooth or teeth are removed and in which sequence.

#### *Maxillary D Loss*

Historically, not much arch length loss has been attributed to the removal of a maxillary first deciduous molar, and even in our data the measurement of D+E space shows an initial reduction followed by a restoration to the control level.

But a mechanism that is active here is the almost certain exclusion of the permanent cuspid from proper arch alignment. Of 11 cases of D loss, the only 2 that did not leave the cuspid blocked out to the labial were one case of microdontia and one of a palatally impacted cuspid.

The classic sequelae to the premature extraction of a maxillary first deciduous molar are —

- The deciduous cuspid shifts distally in the first year only, if at all.
- The first permanent molar and second deciduous molar shift mesially, with the amount depending on the duration of absence and age at loss.
- An erupting first bicuspid is guided along the mesial surface of the mesially-migrating second deciduous molar, eventually lying close to the lateral incisor.
- As the cuspid has no place to erupt, its descent from a mesiolabial inclination on the labial is impeded, and it is excluded from the arch.

### *Maxillary E Loss*

If the maxillary second deciduous molar is lost early, the second bicuspid is generally impacted, as follows —

- The molar shifts mesially.
- The cuspid and first deciduous molar shift distally.
- As the first bicuspid generally has an eruption timing advantage over the second bicuspid, will erupt earlier into the site maintained by the first deciduous molar, often with distal drift.
- The resultant lack of space between the permanent molar and first bicuspid causes impaction of the second bicuspid.
- The cuspid can also be affected, but the impaction tendency is less than for the second bicuspid.

### *Maxillary D+E Loss*

There are too many variables involved in multiple maxillary extractions to be able to predict where impaction will occur.

The age at emergence for permanent cuspids and second bicuspids is so close, especially in females, that other factors can easily bias the directional shift of the first bicuspid.

The close timing of emergences can lead to malemergence anywhere between the molar and lateral incisor. Of ten quadrants observed after bicuspid emergence, two were normal, two showed cuspid malemergence, two had impacted second bicuspids, and four showed multiple irregularities.

### *Mandibular Tooth Loss*

The effect of mandibular extractions tends to be similar for all three situations — D loss, E loss, and D+E loss.

- Timing differentials between the cuspid, first bicuspid, and second bicuspid in the mandible appear to account most for the similarity among groups. The advantage shared by cuspid and first bicuspid usually allows their occupation of available space.
- The permanent molar tips forward. In the D loss situation the second deciduous molar may tip forward as well, sometimes enough to be exfoliated by the emergence of the first bicuspid..
- Eruption sequence can be affected by extraction of deciduous precursors.
- An important variable is the developmental orientation of bicuspid tooth buds. While the second bicuspid varied from the controls most often, on certain occasions of E loss the first bicuspid would emerge distal to the first deciduous molar, totally obstructing the path of emergence of the second bicuspid.
- Arch length shortage resulting from premature loss almost always leads to impaction of the second bicuspid. Ample available arch length, sometimes augmented by poor emergence of the cuspid or a favorable leeway differential, may be sufficient for second bicuspid emergence in some cases.

## Summary

Changes in arch morphology are explored via mean D+E space, which is shown to close as a consequence of unattended severe caries or premature extraction of any deciduous molar.

With severe caries, a mean D+E space loss of 0.5mm–1.3mm more than the controls was usually accompanied by early exfoliation and replacement of the affected deciduous molar.

The rate of D+E space closure in the maxilla is found to be related to age at extraction, but this relationship is not found in the mandible.

Maxillary D loss led to blocked-out cuspids. Maxillary E loss tended to cause second bicuspid impaction. Due to emergence sequence and other differences, premature lower deciduous molar exfoliations tended to result in malemergence of the second bicuspids.

The emergence of succedaneous teeth did not increase mean overall D+E space, even though some temporary increases were seen with partial uprighting of tipped first molars.

Schematic representations of the mean changes in D+E space are seen in Figs. 15 and 16, which are constructed by charting all groups according to their divergence from the controls. The control D+E space is represented as a fixed length, with one-year annual incremental values plotted in a cumulative fashion assuming that all groups are identical at the beginning of the survey (normalizing the data). These figures clearly demonstrate the mean changes in space, and where they occur. A/O

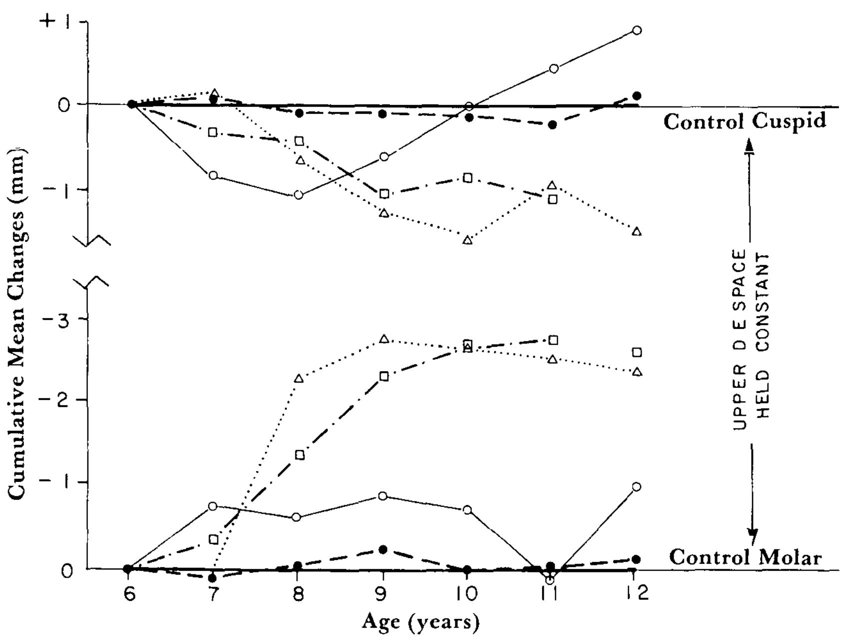


**Fig. 15** Mean Divergence of Upper Cuspids and Molars

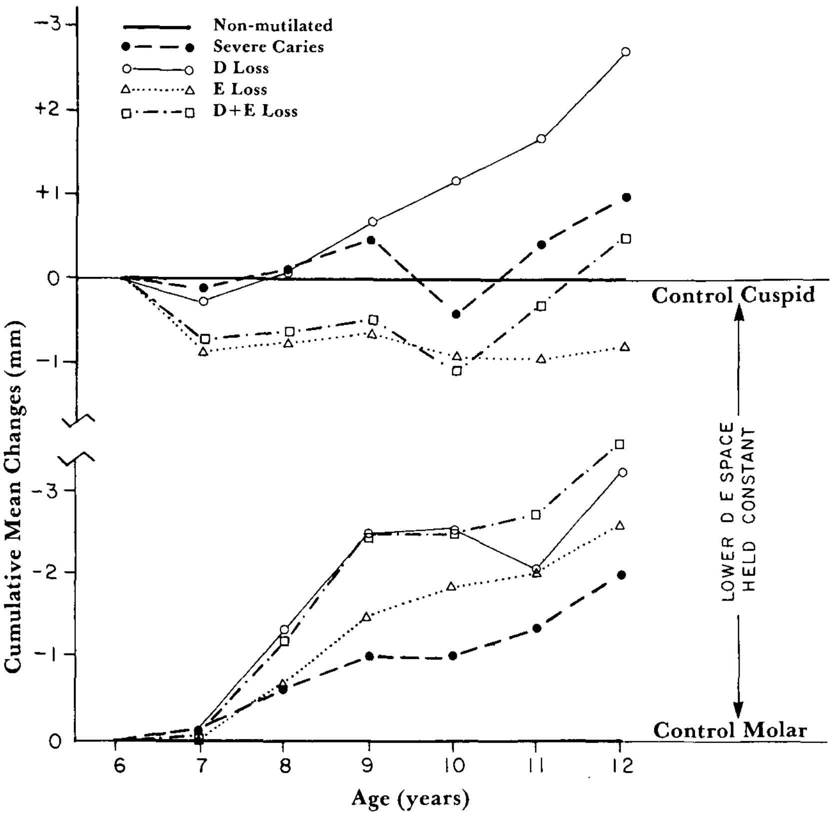


**Fig. 16** Mean Divergence of Lower Cuspids and Molars

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