PRIMARY MOLAR SPACE CHANGES IN A MINIMAL TREATMENT PROGRAMME: A FOUR YEAR STUDY

K.R. POWELL, MDS, FRACDS

A Thesis submitted in partial requirement
for the degree of

MASTER OF DENTAL SCIENCE

Department of Preventive Dentistry
Faculty of Dentistry
University of Sydney
1985

ACKNOWLEDGEMENTS

The author would like to express his gratitude to:

Professor N.D. Martin, Head of the Department of Preventive Dentistry, for permission to conduct this work in his Department.

Associate Professor Graham G. Craig, a good friend and colleague, who initiated the minimal treatment programme, inspired this study and gave valuable advice on a number of occasions.

Associate Professor Keith Godfrey who supported my participation in the Orthodontics course and supervised the preparation of this thesis.

Associate Professor Peter D. Barnard for his assistance with the statistical aspects of this thesis.

Mr. R. Johnson and Mr. R. Van Luyn of the Audio-Visual Department, United Dental Hospital of Sydney, for the preparation of the photographic material in this thesis.

Mrs. Joan Thwaite, Mrs. Kaye Daniels and Mrs. Janet Jeffreys, Faculty librarians, for their assistance with the library research for this thesis.

Mrs. Barbara Lapsley and Mrs. Carole Beacher for their valuable assistance with typing of this thesis.

My dear wife, Helen, who gave me moral support throughout the Orthodontics course and helped with many burdens.

My children, Sebastian, Emily and Gareth, who make all these labours worthwhile.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION

In November, 1978, a minimal treatment programme for the treatment of dental caries was commenced in a group of 94 schoolchildren resident in Bourke in western New South Wales, where the water supply contains less than 0.2 parts per million fluoride.[11] Participants in the programme were Australian aboriginal and Caucasian schoolchildren from a low socio-economic background who were awaiting treatment by the School Dental Service.

Previous attempts to provide conventional dental treatment for school children in this community has been hampered by four factors: (1) a high incidence of dental disease; (2) a large backlog of unmet treatment needs; (3) limited patient co-operation during dental procedures and (4) limited availability of dental manpower. To help overcome these problems, a minimal treatment programme was initiated under the direction of Associate Professor Graham Craig of the Department of Preventive Dentistry, University of Sydney.

In the devised programme, emphasis was placed on the prevention of new carious lesions and the inhibition of growth of existing ones. Furthermore, by reducing reparative procedures to a minimum it was felt that acclimatisation of children to dental procedures would be facilitated. Such an approach would have to be developed if a systematic and gradual reduction in the treatment backlog was to be made within the capacity of the dental manpower available. Access to dental manpower was limited to periodic visits to the township by a dental therapist or a dentist. When these dental personnel were not available, dental treatment could be sought at Nyngan, a town situated more than 200 kilometres from Bourke.

Initially, all existing carious lesions were treated solely by a 2-stage topical application of metal fluoride salts (AgF followed by SnF_2). The children were examined at 6-monthly recall visits throughout the period of the study. The initial topical metal fluoride treatments were supplemented, in some cases, by restoration of lesions with glass ionomer cement. In keeping with the minimal treatment approach, restorations were only placed in cases where food impaction was a problem or where pulp involvement existed or was likely to occur. Pulp therapy was instituted where required and consisted of direct pulp capping with a mixture of a corticosteroid paste ¶ and an iodoform paste † in vital cases and a simplified pulpotomy procedure with those medicaments where the pulp had undergone necrosis. All restorative procedures were carried out using ultra-slow speed cutting techniques without local anaesthetic and

---

¶ *Ledermix*[R] Paste, Lederle Pharmaceuticals, Wolfratshausen, West Germany

† *Kri 1* Paste, Pharmachemie AG, Zurich, Switzerland

without the use of a high speed air rotor. At no stage during the period in which the minimal treatment approach has been in effect, were conventional treatments involving injections, extractions or amalgam restorations carried out by the clinicians involved with the study.

Indeed, grossly carious deciduous teeth and retained roots were all maintained in situ after minimal treatment without recourse to extractions.

It is commonly accepted [18,44] that the premature loss of deciduous teeth may lead to space loss which may jeopardize the eruption pattern of the permanent succedaneous teeth. Premature loss of deciduous teeth may directly contribute to arch length discrepancy problems or be responsible for the loss of valuable anchorage space required in the treatment of a pre-existing orthodontic problem.[7-10,12-14,19,21-22,25,28-34,43,50-57,60-63]

Hence, by avoiding extraction of deciduous teeth despite gross dental caries involvement, the approach adopted in the minimal treatment programme seems to have considerable merit from an orthodontic standpoint.

However, some degree of space loss may occur when teeth are affected by dental caries such that there is breakdown of contacting marginal ridges. There appears to be very little published data which indicate the extent of space loss that occurs under these circumstances and it is difficult to determine from the literature exactly what contribution dental caries in the deciduous dentition makes to the prevalence of malocclusions.[26,46] Certainly, however, it appears that loss of approximating tooth structure may sacrifice some anchorage space [13] which may be critical in some cases, whilst cases in which "leeway" space [*] may be utilised to correct minor crowding by space supervision procedures [38,40] might also be detrimentally affected.

The purposes of this study were (1) to determine the range of space loss that occurred in the primary molar region when dental caries in the primary molars led to marginal ridge breakdown and (2) to determine the extent of space changes in the primary molar region over a 4-year period in a minimal treatment programme.

It has been observed that the primary molar region of the arch perimeter is affected least by the dimensional changes that occur as the deciduous dentition is progressively replaced by the permanent tooth successors.[42] For this reason the primary molar space was used to assess changes pertinent to this study.

Data for this study were collected from study casts and photographic records obtained 6-monthly beginning November, 1978, and extending for the first 4 years in which the minimal treatment programme was in progress in the township of Bourke.

---

* The "leeway" space refers to the difference between the combined mesio-distal widths of the deciduous canine and molars and the combined widths of the permanent canine and premolars (Nance).[40]

REVIEW OF LITERATURE

One of the virtues of treating dental caries in the primary dentition by the minimal treatment approach is that deciduous teeth are not extracted prematurely. According to the literature, a number of consequences can arise from the premature loss of deciduous teeth, particularly deciduous molars. Generally, space closure may result in permanent arch length decrease,[13,18,21,22,44] increased overbite,[44] increased crowding and/or tooth malposition,[13,21,61-63] impactions [25,44] and arch asymmetries [44] depending on the circumstances that prevail in the oral environment.

CONSEQUENCES OF PREMATURE LOSS OF DECIDUOUS MOLARS

In 1971, Owen [44] carried out an extensive review of the literature on the outcomes of premature loss of deciduous molar teeth.

In summarising the literature, Owen's general findings were:

1. The incidence of space closure is related to the length of time the extraction space is present. Where extraction spaces were present for one year or more in reported cases, at least 96 percent showed some closure.

2. The space closure rate is higher for the maxillary arch than for the mandibular arch. Generally, the reports agreed that the rate

of maxillary space closure slowed after the initial 6-12 months period. Mandibular space closure rates were found to be more varied. Owen cited the work of Breakspear [8,9] who found that the maxillary second deciduous molar spaces had greater average rates of closure than other deciduous tooth extraction spaces.

3. The amounts of deciduous molar space closure varied with the site of tooth loss. Owen found cases reported to have lost 6-8 millimetres of space in the upper second deciduous molar region when spaces were present 3 years or more. In a given period of time, maxillary second deciduous molar spaces show the greatest closure, followed by lower second deciduous molar spaces, while upper and lower first deciduous molar spaces show almost equal amounts of closure. The longer the time available for closure, the greater the total closure of molar extraction space, particularly if deciduous molars are extracted prior to the eruption of first permanent molars.

4. There appears to be a difference between the predominant closure direction for maxillary and mandibular spaces. Early maxillary extraction spaces close predominantly by mesial movement of teeth posterior to the extraction space. Mandibular spaces often close by distal movement of teeth anterior to the extraction space. Such tooth movements in the mandible may significantly contribute to an increase in overbite and overjet and the effects can be exacerbated in the presence of abnormal muscle activity.

5. Opening of premature extraction spaces was extremely unlikely but occasionally occurs with very late extractions in association with imminently erupting permanent successors.

More recently, Høffding and Kisling [21,22,29-31] studied premature loss of primary teeth and evaluated the effects on the permanent dentition using records obtained from 231 children who had suffered early loss of primary teeth. For purposes of comparison, a group of 182 children without early loss of deciduous teeth were used as a control group. Data were compiled from serial treatment records obtained from the Danish public school dental service over a 7-year period. The study participants were 13-14 years old and only children who had not lost permanent teeth were included in the study. The findings of that recent study are significant in that, in the main, they are supportive of the findings of other earlier workers.

In general, Høffding and Kisling found that premature loss of primary molars was capable of causing permanent changes in the amount of space available and changes in sagittal molar relationships in the permanent dentition. Overall, the prevalence of malocclusion was significantly higher in the groups who had suffered premature loss of deciduous teeth. The dental aspects of a malocclusion, particularly crowding, tended to be accentuated by premature loss of primary molars. This finding is in accord with the findings of others.[10,52,60,62,63]

Crowding in at least one of 6 segments assessed was significantly higher in the premature loss of subjects and that was true for both maxillary and mandibular arches.

Høffding and Kisling also found that mesioclusion of molars was significantly more prevalent in the premature-loss group of subjects. Although, not statistically significant, there was a tendency for distoclusion of the molars to occur more commonly in the premature-loss group of subjects. However, these results might have been influenced by the particular pattern of tooth loss in the participants of the study. It should be noted, that, in that study, mandibular primary molars were extracted three times more frequently than maxillary primary molars and this might have some bearing on the prevalence pattern reported for the sagittal molar relationships with mesioclusion being more commonplace than distoclusion.

There was also a tendency for more midline deviations to occur in the group of subjects with premature loss of deciduous teeth. This effect was more likely to occur in the mandible.

Interestingly, there was no significant increase in the frequency of extreme overjet in premature-loss subjects despite there being a large number of subjects with premature loss of mandibular primary molars.[22] Nor was there a difference in the vertical incisor relationship for control and premature-loss subjects. These findings were contrary to the conclusions reached by Owen.[44] The prevalence of tooth rotations also appeared unaffected by premature loss of primary molars for the groups studied.

The loss of upper second deciduous molars more severely affected the sagittal relationship of permanent molars than the loss of upper first deciduous molars, producing an increased likelihood of a mesioocclusion relationship. Crowding in the buccal segments was also more likely when upper second deciduous molars rather than upper first deciduous molars were prematurely lost.

The loss of the lower second deciduous molars had more influence on the sagittal relationship of the permanent molars than when first deciduous molars were lost. However, the loss of the lower first deciduous molars appeared to have greater influence on crowding than did the loss of second primary molars. When both lower deciduous molars were lost, crowding and a tendency to a distoclusion of permanent molars were the likely result.[22]

The drifting patterns of teeth observed by Kisling and Høffding [29] are also of interest and may explain some of the effects on the occlusion previously described. Kisling and Høffding [29] studied the drifting patterns of teeth adjacent to extraction spaces of first primary molars in 55 subjects who had the extractions performed prior to the eruption of the first permanent molars. The mean observation time for these subjects was 3 years. In these cases, it was found that in the maxilla, most space loss occurred due to mesial drifting of the upper second deciduous molars prior to the eruption of the first permanent molars. Up to 5 millimetres of space loss were reported. In the mandible, space loss usually occurred due to the distal drifting of the lower deciduous canines prior to eruption of the first permanent molars. Up to 6 millimetres of space loss were reported for the lower arches studied.

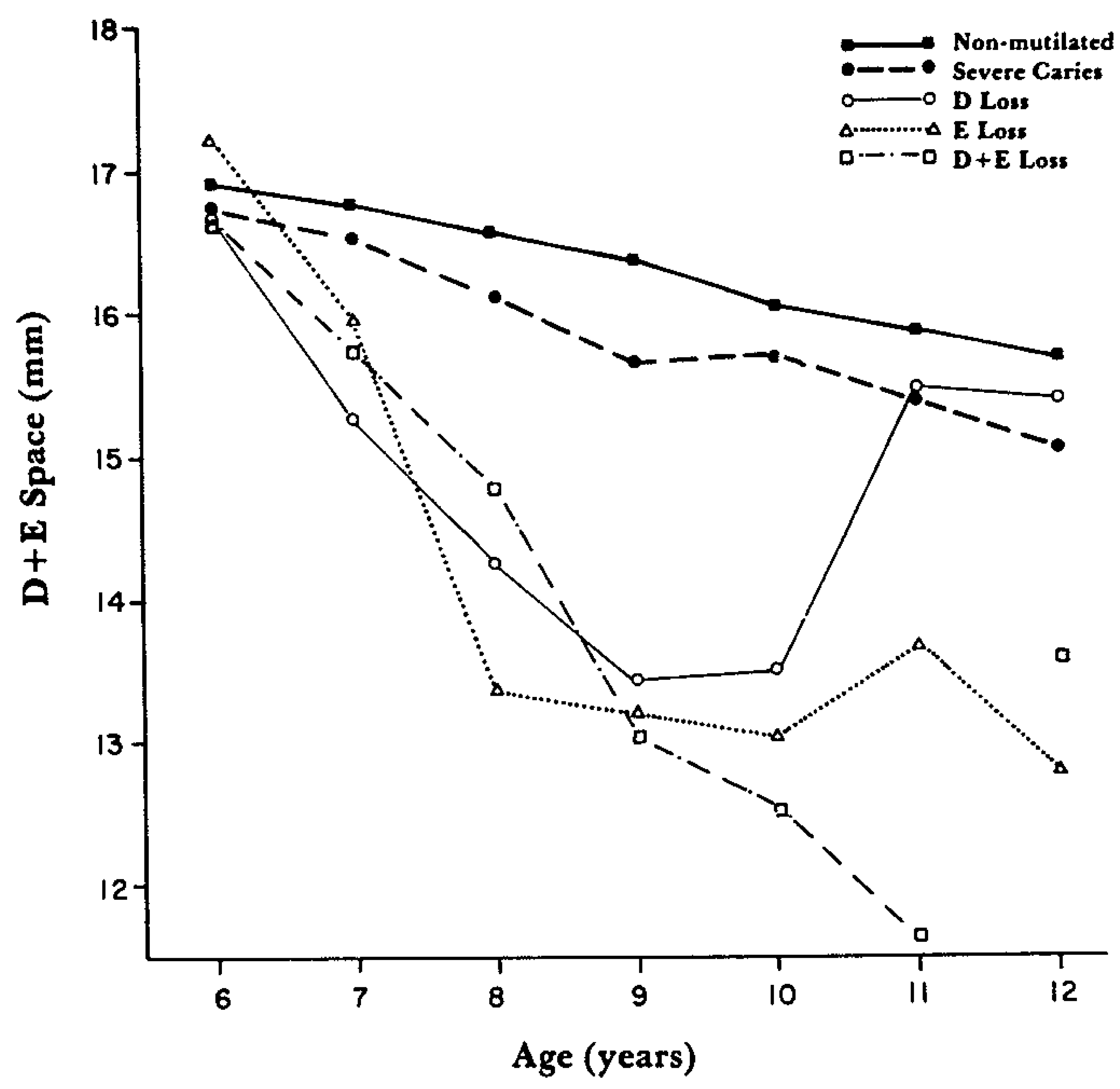
Those authors also reported their general observations on drifting patterns of teeth where primary molars were lost prematurely. They commented that both upper and lower first permanent molars tended to drift mesially but upper first permanent molars tended to remain upright and may rotate around their palatal root. By comparison, lower first permanent molars tended to drift and tip mesially and travel less distance than their upper counterparts. These patterns of drift for first permanent molars tended to be similar for second deciduous molars. Kisling and Høffding [29] feel that deciduous canines tend to drift distally with that tendency being greater for lower deciduous canines. Similarly, the lower arch, more so than the upper arch, tended to be affected more by midline deviations and distal drifting of premolars. Kisling and Høffding [29] also felt that primary molar extraction spaces may reopen under the influence of erupting premolars, giving support to the findings of Owen.[44]

Kisling and Høffding, however, generally felt that the amount of drifting varies from individual to individual with many factors being involved. The most decisive factor, they felt, was the type of tooth lost with other important factors being the dental age at the time of extraction, the space conditions present, the eruption times and paths of succedaneous teeth and the degree of intercuspation of buccal teeth.[29]

Other considerations offered were the effects of the musculature, and individual skeletal and bony and periodontal characteristics. Kisling and Høffding [29] also supported the view of other authors [10,12,14] who suggest that extraction of primary molars prior to the eruption of the first permanent molars produced more serious effects on the permanent dentition.

Most recently, Northway, Wainright and Demirjian [43] presented a notable study of space changes associated with premature loss of primary molars. The authors used the palatal rugae as stable reference points from which to determine the relative movements of teeth in and adjacent to the primary molar space. From this, the effects of premature loss of primary molars could be evaluated.

FIGURE 1

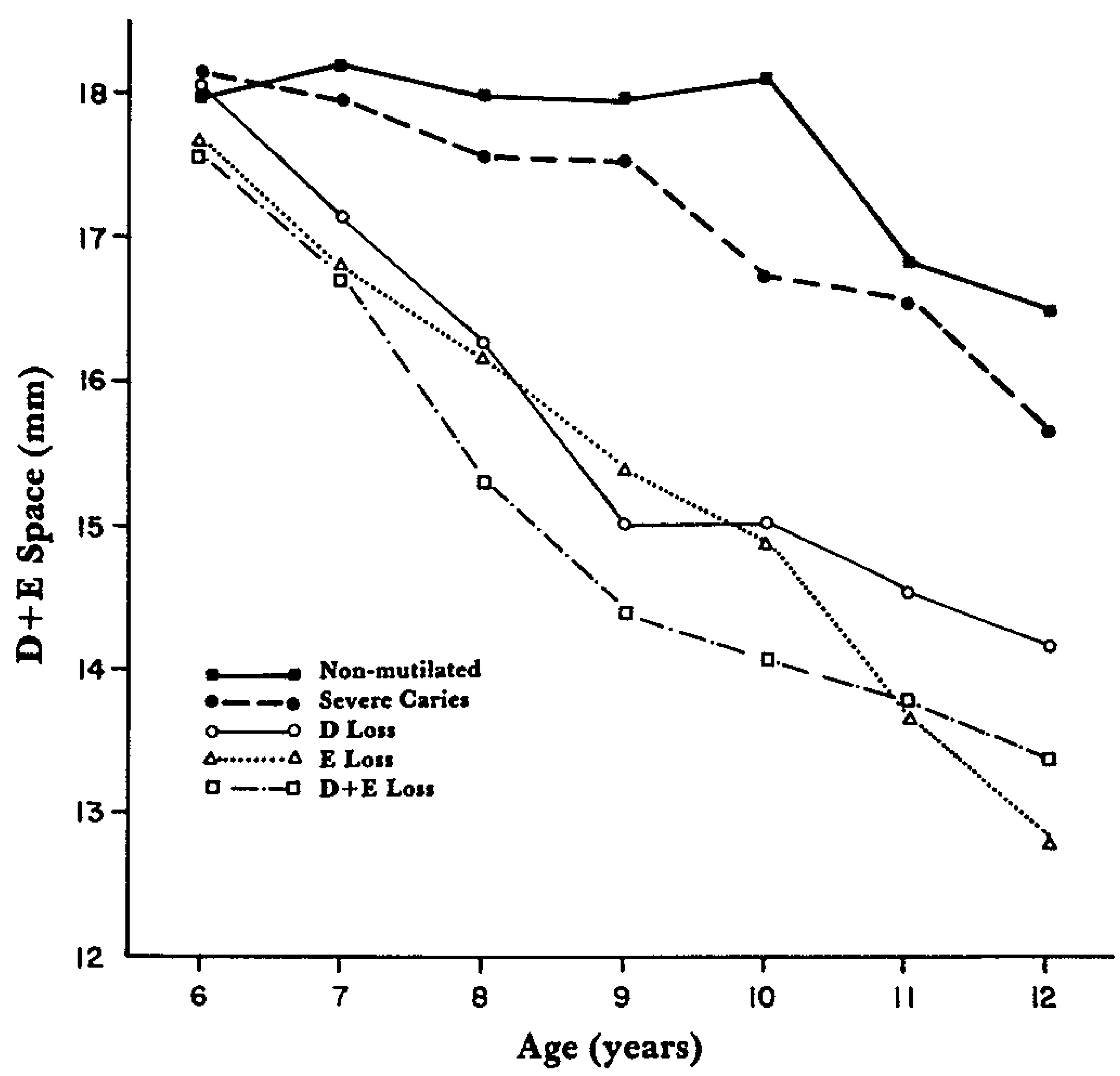


Graph showing primary molar space (D+E space) changes for the maxillary arches from the study by Northway, Wainright and Demirjian.[43]

In that study data were collected annually from 107 children from age 6 years for an average period of 5.9 years. Control quadrants, unaffected by dental caries or premature loss of deciduous molars, were compared with quadrants in which there was premature loss of one or more deciduous molars and quadrants which were severely affected by dental caries.

Those authors findings for the dimensional changes in the primary molar space are shown in Figures 1 and 2. Longitudinal changes that occurred over a 6-year period are shown.

FIGURE 2



Graph showing the primary molar space (D+E space) changes for the mandibular arches from the study by Northway, Wainright and Demirjian.[43]

The findings of that study indicated that if a deciduous molar is lost early then, almost certainly, a loss of primary molar space will occur. Furthermore, the early loss of a second deciduous molar with or without other extractions produced the most damaging effects on primary molar space loss. This agrees with the findings of other authors.[7,12,19,32-34,50,52,60]

Certainly, the premature loss of a second deciduous molar in either arch produced the most damaging effect on the molar relationship. This tended to be worsened if the first primary molar was removed as well. Furthermore, the quadrants which demonstrated the greatest effects on cuspid relationships in either arch were those in which first deciduous molars had been removed. These findings concur with those of other workers.[28,29,44] However, a noteworthy finding of Northway, Wainright and Demirjian was that premature loss of the upper first deciduous molar often resulted in the permanent cuspid being excluded from the arch.

Northway, Wainright and Demirjian also assessed the influence that age had on space loss. Concerning this, the findings were that, for the upper arch, the age at which premature loss of a tooth occurred significantly affected the amount of space lost during the first year. Thus, younger children lost significantly more space in the first year following extraction than 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.

By contrast, in the lower arch, the rate of space loss appeared to be steady with no apparent tendency for younger children to lose more space than older children. In the first 4 years following extraction of a primary molar or molars average losses from 2.6mm to 3.2mm occurred.

SPACE LOSS AND DENTAL CARIES

In contrast to the large number of published studies assessing the consequences of premature loss of primary molars there is a paucity of published reports dealing with space loss that may result from the presence of caries in approximal surfaces of primary molars.

Several authors [13,18,41] have suggested that arch length can be lost due to caries in the approximal surfaces of deciduous molars, but there are few definitive reports which quantify and clarify the dimensional and spatial changes that occur in the dental arches due to the presence of dental caries in the primary molars.

Breakspear,[8,9] in his studies on the effects of premature loss of deciduous molars, deduced that the amount of space lost due to dental caries affecting the approximal surfaces was an average of approximately one millimetre in the buccal segments. However, this figure was an assumption which was felt to be subject to age variation [8] and, in Breakspear's own view, that figure is an estimate.[9]

Jarvis [27] is cited in Noonan [41] and Northway and Wainright [42] as suggesting that the loss of space due to the presence of deep interproximal caries in primary molars jeopardised arch length to the same extent as the premature loss of a primary molar.

However, the results of the study by Northway and Wainright [42] did not substantiate the view held by Jarvis. Indeed, their study offers the most definitive data to date on the space changes that occur in the presence of untreated caries in primary molars.

Those authors measured the dimensional changes in the primary molar region in 107 subjects for an average of 5.9 years starting at age six. Data on the subjects were collected annually and longitudinally. Palatal rugae landmarks were used as stable reference points to assess dimensional changes.

Northway and Wainright chose the primary molar region of the arch perimeter for assessment since that portion of the arch perimeter was affected least by the dynamic changes which occur during the normal development and eruption of the permanent dentition. The purpose of that study was to gauge the degree of space changes that could be ascribed to the presence of "unattended" carious lesions. Dimensional changes can occur as the deciduous dentition is replaced by the permanent tooth successors. Arch length and arch perimeter measurements will change, for example, when permanent incisors erupt and where primate spaces exist and later close.[5,6,36,37] Changes in these areas during the course of a longitudinal study could be superimposed on space changes which may occur as a result of tooth structure loss due to dental caries.

In the study by Northway and Wainright,[42] primary molar space dimensions for "Caries-Free" control quadrants were compared to similar segments in quadrants categorised as "Restored" quadrants, "Mild-Caries" quadrants and "Severe-Caries" quadrants. These categories were not clearly defined in the study but the authors apparently differentiated the "Severe-Caries" group from the "Mild-Caries" group according to the degree of tooth structure loss observed on the study casts.

The results of that study showed that only quadrants in which primary molars were severely affected by dental caries differed markedly from the "Caries-Free" control group quadrants in terms of dimensional changes in the primary molar space. The "Caries-Free", "Restored" and "Mild-Caries" groups differed little in primary molar space dimensional changes. For both upper and lower arches, the "Severe-Caries" group of quadrants maintained a primary molar space 0.5 - 1.0mm shorter than the "Caries-Free" group of quadrants for the duration of the study. This finding lends support to the deduction by Breakspear [8,9] that an average space loss of one millimetre occurs due to dental caries in approximal surfaces of primary molars.

In a later report Northway, Wainright and Demirjian [43] showed that although primary molar segments affected severely by caries lost about 1 millimetre more space than control primary molar segments, the space changes were generally far less than those that occurred when primary molars were prematurely extracted (Figures 1 and 2).

SPACE LOSS AFTER MINIMAL TREATMENT

As far as can be ascertained from the literature, little data are available indicating the primary molar space changes that might occur when caries in deciduous teeth are treated in an unconventional or minimal fashion.

However, Ingers, Cromvik, Gleerup and Ronnerman [24] have described an operative procedure which involves slicing the approximal surfaces of deciduous molars to treat caries rather than placing a conventional two-surface amalgam which restores the marginal ridge. Those authors have reported the effects on space conditions of grinding the carious approximal surfaces of primary molars.

The aim of that study was to assess whether the spaces in quadrants treated by "modified caries therapy" using a slice technique differed from the spaces in the contralateral quadrants in which caries was treated by conventional restorations.

After a 6-year period, 19 children were available to compare the two operative techniques for their effects on space conditions. The space conditions were assessed within the canine-premolar segments of quadrants. The 19 subjects yielded 52 quadrants that could be measured before and 6-years-after treatment.

The results indicated that clinically significant amounts of space loss did not occur as a result of grinding carious approximal surfaces of primary molars rather than restoring them with amalgam.

For the upper jaw, the mean difference in the canine-premolar space change was 0.51 millimetres for the sliced experimental side and 0.45 millimetres for the restored control side. For the lower jaw, the space change was 2.06 millimetres on the sliced experimental side compared to 1.87 millimetres on the restored control side.

MATERIALS AND METHODS

SUBJECTS

The data for this study were obtained from subjects who had participated in a minimal treatment programme for the treatment of dental caries for periods up to 4 years. The subjects were residents of Bourke, a small, isolated community in western New South Wales where the water supply contains less than 0.2 parts/10^6 fluoride. The subjects were Aboriginal and Caucasian schoolchildren from a low socio-economic background and had received little or no previous dental care.

A total of 94 children commenced the minimal treatment programme in November, 1978. Of these, 72 subjects were eligible for inclusion in the present study to assess primary molar space changes after minimal treatment. That is, they had both primary molars present in at least one quadrant for periods ranging from 6 months to 4 years.

Within this group of subjects, 28 children had at least one contralateral pair of control and caries-affected primary molar regions which could be used to assess the range of space loss that occurred when caries in primary molars led to marginal ridge breakdown.

Neither Associate Professor Craig, who initiated the minimal treatment programme, nor this author (K.P.) were involved in the selection of subjects. The screening was carried out by employees of the School Dental Service on the basis of their experience of the population they were treating. A characteristic of the subjects was a high caries prevalence and apprehension about conventional dental procedures.

OUTLINE OF THE MINIMAL TREATMENT PROGRAMME

In the minimal treatment programme, an approach was adopted which placed emphasis on prevention of new carious lesions and the inhibition of growth of existing ones.

All existing lesions without clinical evidence of pulp involvement were treated initially with a 2-stage topical fluoride treatment regimen.

Teeth with lesions to be treated were isolated with cotton rolls. A solution of 40% silver fluoride solution * was applied to the treatment sites on a small pellet of cotton wool and the sites were kept wet with the solution for 60 seconds. A thin layer of 10% stannous fluoride paste ¶ was then flowed over the treatment sites and sealed in place with a small piece of adhesive wafer.† Following

---

* *AGF* Creighton Pharmaceuticals Pty. Ltd., Sydney, Australia.

¶ *Floran*[R] *Spot Application Paste* Creighton Pharmaceuticals Pty. Ltd., Sydney, Australia.

† *Stomahesive Wafer*,[R] E.R. Squibb and Sons, New York.

wafer adaptation, the patients were permitted to rinse out and asked not to eat for 1 hour. The wafers were allowed to dissolve in the oral fluids.

All treated teeth were examined clinically and radiographically at 6-monthly intervals. Photographic records and impressions were also taken as at baseline. At recall visits, a restoration was placed if a lesion appeared to be progressing rapidly or if an open lesion was causing food impaction between teeth. Pulp therapy was instituted if there was any indication of pulpal involvement in the teeth under observation.

Pulpally involved teeth were treated with a combination of iodoform paste [#] and a corticosteroid paste [¶] sealed into the tooth with an appropriately designed restoration.

The restorative material used in all instances was glass ionomer cement.[§] This material has been used for restoration of deciduous molar teeth.[15,48,59] Glass ionomer cement was preferred to amalgam since this cement has demonstrated slow release of trace amounts of

---

\# *Kri 1* Paste, Pharmachemie AG, Zurich, Switzerland.

¶ *Ledermix*[R] Paste, Lederle Pharmaceuticals, Wolfratshausen, West Germany.

§ *ASPA*, De Trey, Amalgamated Dental, London, England until 1980 then *Fuji Ionomer Type II*, G-C Dental Industrial Corp., Tokyo, Japan.

fluoride ion over lengthy periods of time.[35,58] This property conformed to the overall preventive approach adopted in the minimal treatment programme. Furthermore, glass ionomer cement has the ability to chemically adhere to sound tooth structure,[64] and it was felt that this property may minimise the extent of cavity preparations where restorations were required.

Another objective of the minimal treatment programme was to make all treatments as atraumatic as possible. To this end, use of handpieces for cavity preparation was kept to a minimum and injections and extractions were avoided since these treatment procedures are known sources of fear and anxiety in child patients.[4,49] Where handpiece usage was required, only "ultra-slow" speed cutting handpieces † equipped with an 8:1 reduction head were used.

Grossly carious deciduous teeth and retained roots were all maintained *in situ* after minimal treatment without recourse to extraction. Extractions were only performed in the later years of the study if a deciduous molar or root was over-retained and causing the permanent successor to adopt an ectopic position in the dental arch.

---

† *W & H,* Dentalwerk, Buermoos, Austria.

IMPRESSIONS AND STUDY MODELS

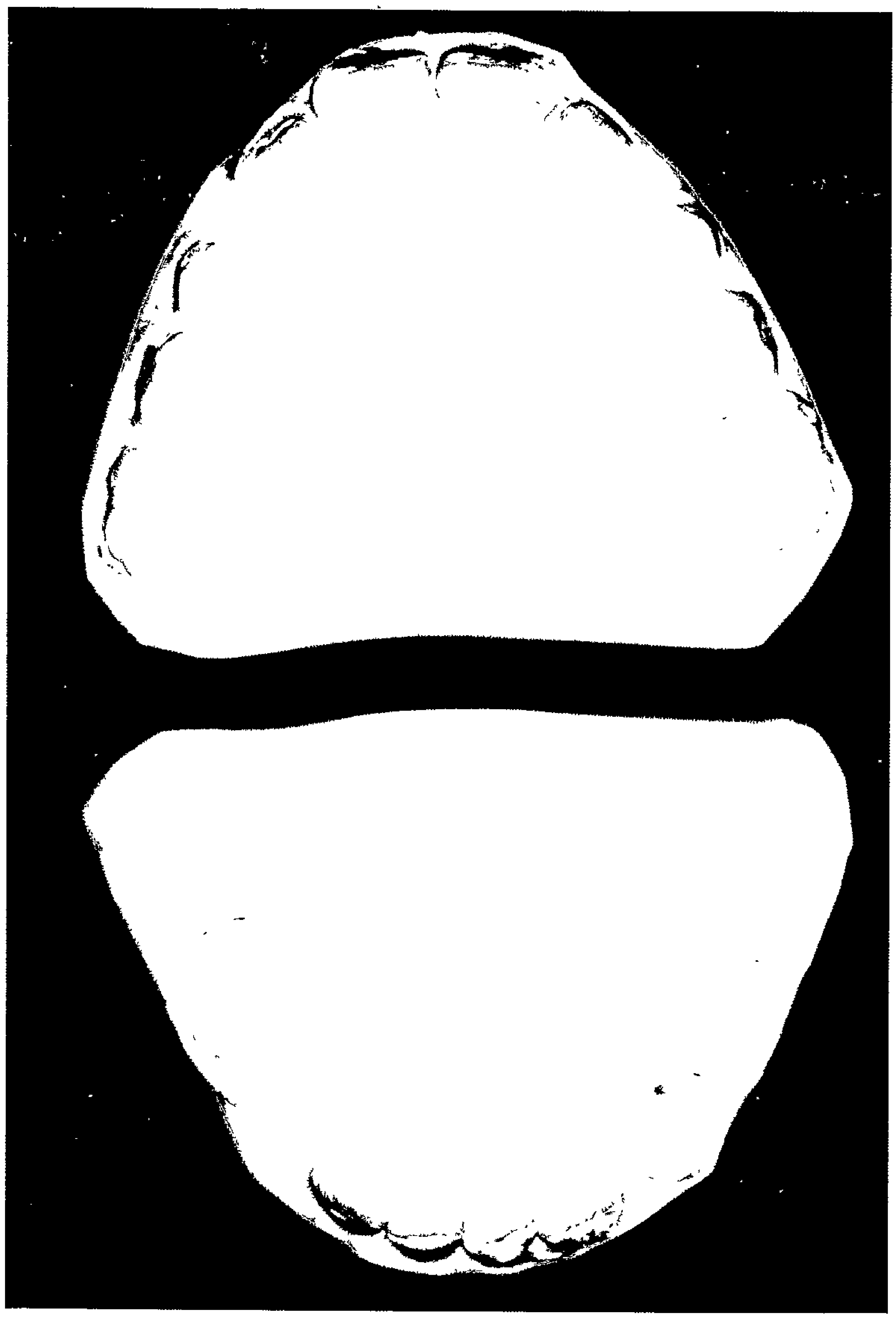
At baseline and at 6-monthly recall visits, clinical examination was performed and photographic records and wax-bite impressions were taken of the dental arches of each subject. Plaster study models were prepared from these impressions. Examples of study models obtained from wax-bite impressions are shown in Figure 3. Wax-bite impressions were preferred to conventional alginate impressions because the impressions could be taken quickly and required minimal patient co-operation. The wax-bite material consisted of a copper impregnated wax-bite wafer * placed between two trimmed sheets of soft dental bite and boxing wax § (Figure 4). The wax-bite material was softened in hot water prior to the impression taking. Using this method, the entire impression procedure for upper and lower arches took approximately 30-40 seconds. An example of a wax-bite impression is shown in Figure 5. To assess the accuracy of measurements from the study casts obtained by the wax-bite impression method, study casts were also made from alginate impressions of 10 of the subjects and these were measured for comparison and the differences tested for statistical significance using the Student's 't' test.

---

* *Coprwax*, Surgident, Ohio, U.S.A.

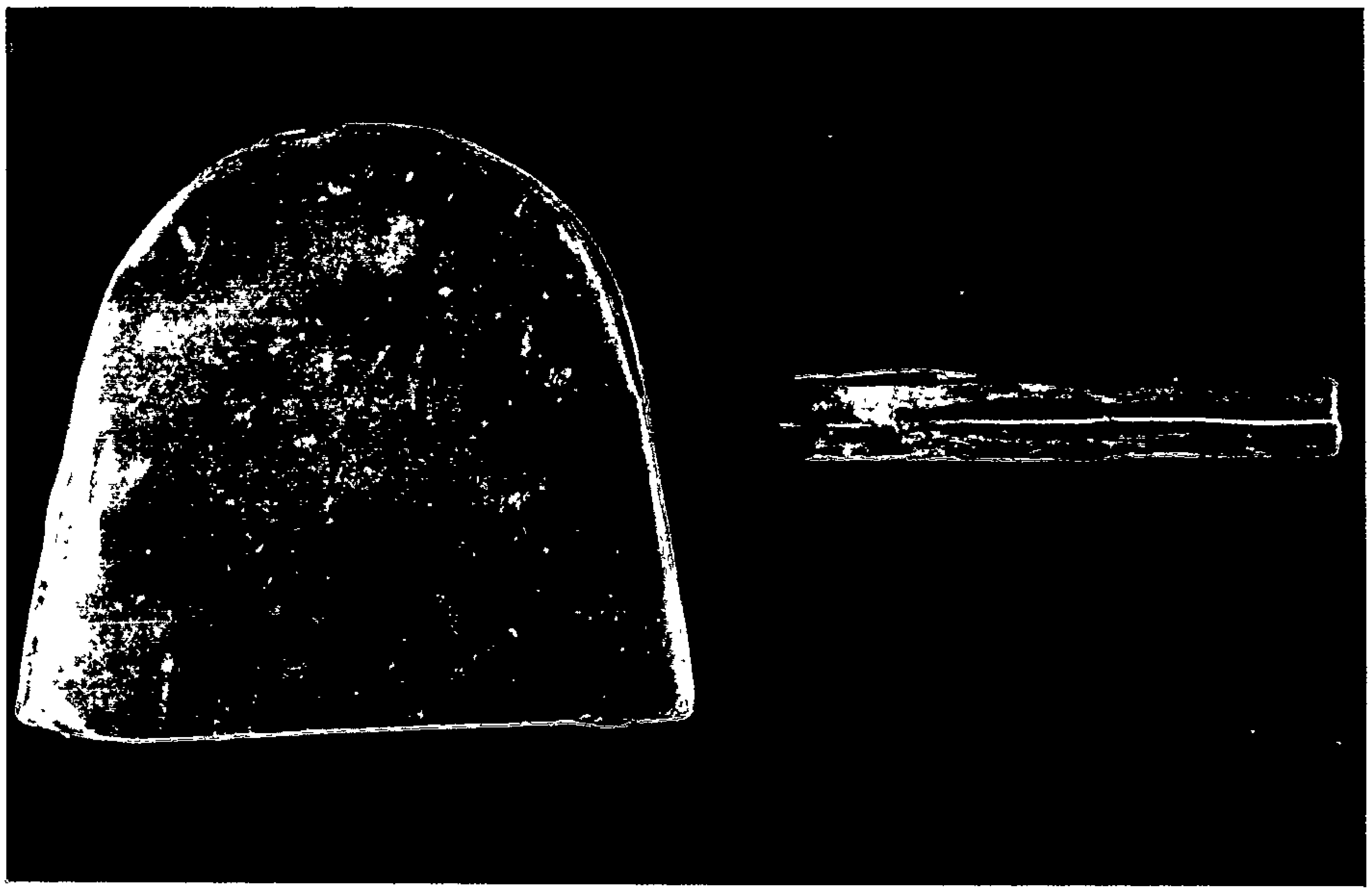
§ Investo Manufacturing Co., Sydney, Australia.

FIGURE 3



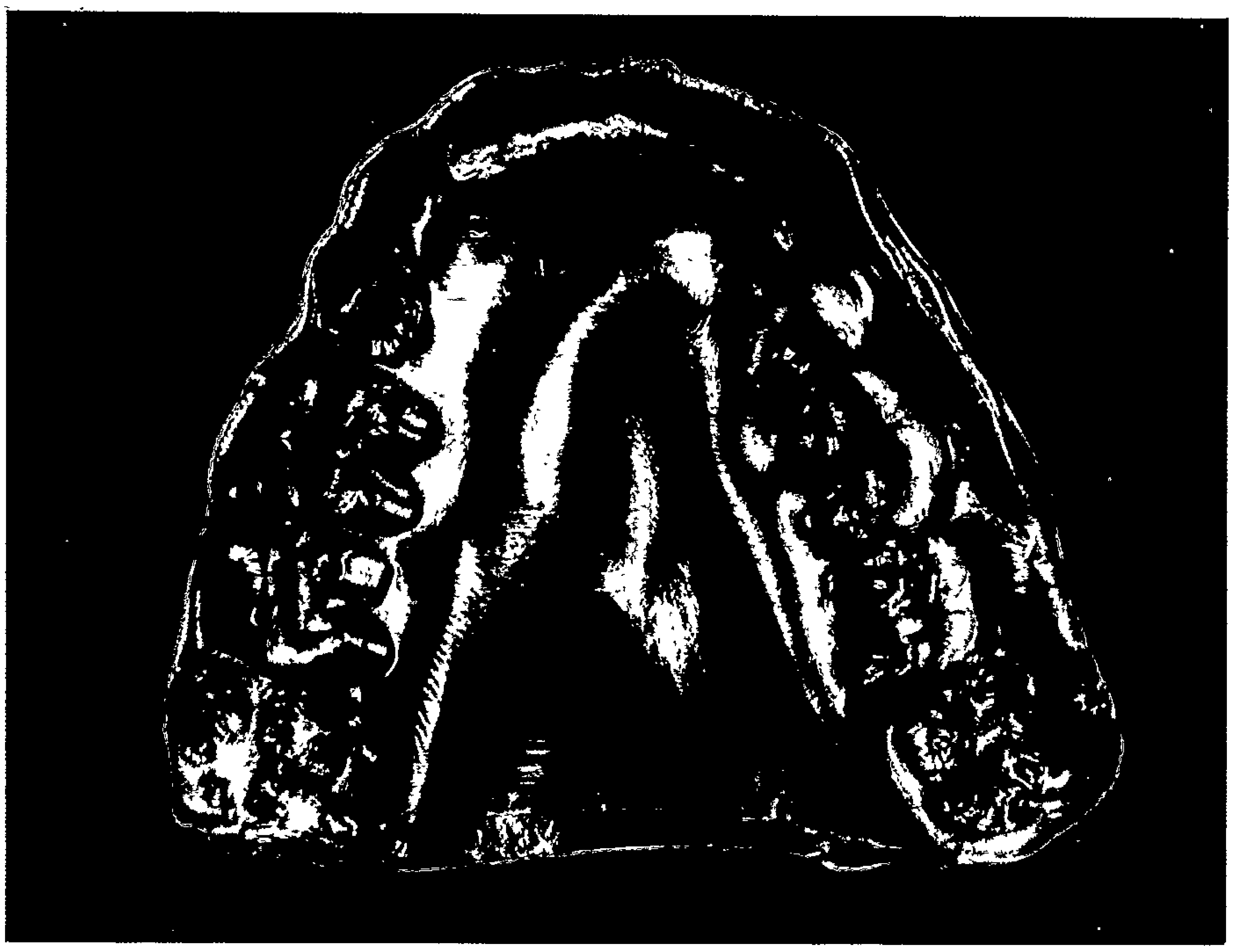
Examples of plaster study models obtained from the wax-bite impressions taken in this study.

FIGURE 4



A top view (left) and lateral view (right) of the wax-bite material used for taking the impressions in this study. A copper impregnated wax-bite wafer (brown central portion on right of picture) is placed between two trimmed sheets of soft dental bite and boxing wax (red portions).

FIGURE 5



An example of a wax-bite impression.

DE SPACE MEASUREMENTS

The area measured on the study models was the primary molar space or DE space. The DE space is the distance between the mesial mid-point of the first permanent molar (or, if absent, the distal mid-point of the second primary molar) and the mesial mid-point of the first primary molar (Figure 6). The DE spaces were measured with a vernier calliper * with a vernier scale which allowed readings to 0.02 millimetres. To improve the precision of measurements, each jaw of the calliper was sharpened to a fine point (Figure 7). To assess the reproducibility of the measuring technique, replicate measurements of the DE spaces were made on 21 sets of study models. Eighty four replicate measurements were made at least 1 year after the initial measurements. The differences between the first set of measurements and the replicate measurements were tested for statistical significance using the Student's 't' test.

CONTROL AND TREATMENT GROUPS

At baseline and at each 6-monthly recall visit, the DE spaces were assigned to either a control group or a treatment group after assessing the status of the primary molars from the photographic

---

* Mitutayo Mfg. Co. Ltd., Japan.

records and the plaster casts. The "Control" group consisted of DE spaces in which both primary molars were present with all marginal ridges intact. The "Treatment" group consisted of DE spaces in which both primary molars were present but in which one or both primary molars had been treated by minimal treatment procedures and had marginal ridge breakdown. Examples of primary molars in a treatment group are shown in Figures 8 and 9. Measurements of the DE spaces were made on the longitudinal series of study models until one or both of the primary molars was exfoliated.

BASELINE DE SPACE CHANGE ASSESSMENT

The range of space loss that occurred in the primary molar region when dental caries in the primary molar region led to marginal ridge breakdown was assessed from the study casts taken at baseline. Only subjects who had at least one contralateral pair of control and treatment DE spaces were used for this part of the study. That is, one quadrant had both primary molars which did not have marginal ridge breakdown while the contralateral quadrant had one or both primary molars affected by marginal ridge breakdown due to dental caries.

DE SPACE CHANGES AFTER MINIMAL TREATMENT

To determine the DE space changes that occurred when primary molars were treated by procedures outlined in the minimal treatment programme, DE space measurements of control and treatment quadrants were made on study casts obtained at baseline and at 6-monthly recall visits extending over a 4-year period from November, 1978 to November, 1982. Measurements of the DE spaces were made on the longitudinal series of study models until one or both of the primary molars was exfoliated. Space changes for the control and treatment quadrant were determined by comparing the initial DE space measurement obtained from baseline study casts with the DE space measurements made on study casts obtained at 6-monthly intervals up to a maximum of 4 years. The difference between the baseline DE space measurement and the corresponding DE space measurement obtained at a later time represented the DE space change over the intervening time period.

Measuring changes in DE space after various time intervals from baseline is more valid than comparing absolute measurements of DE space as was the approach of Northway and Wainright.[42,43] Measuring the dimensional change is more valid since it overcomes the difficulty of the inherent tooth-size differences between control and treatment quadrants and inherent tooth size differences due to sexual dimorphism [17] and racial polymorphism.[16] This is pertinent to the present study since the population sample from which the data was collected is a mixture of males and females and Caucasians and Australian aboriginals.

If primary molars in a "control" DE space subsequently suffered marginal ridge breakdown, these DE spaces were recategorised as "treatment" DE spaces at and from the time breakdown was first detected.

FIGURE 6

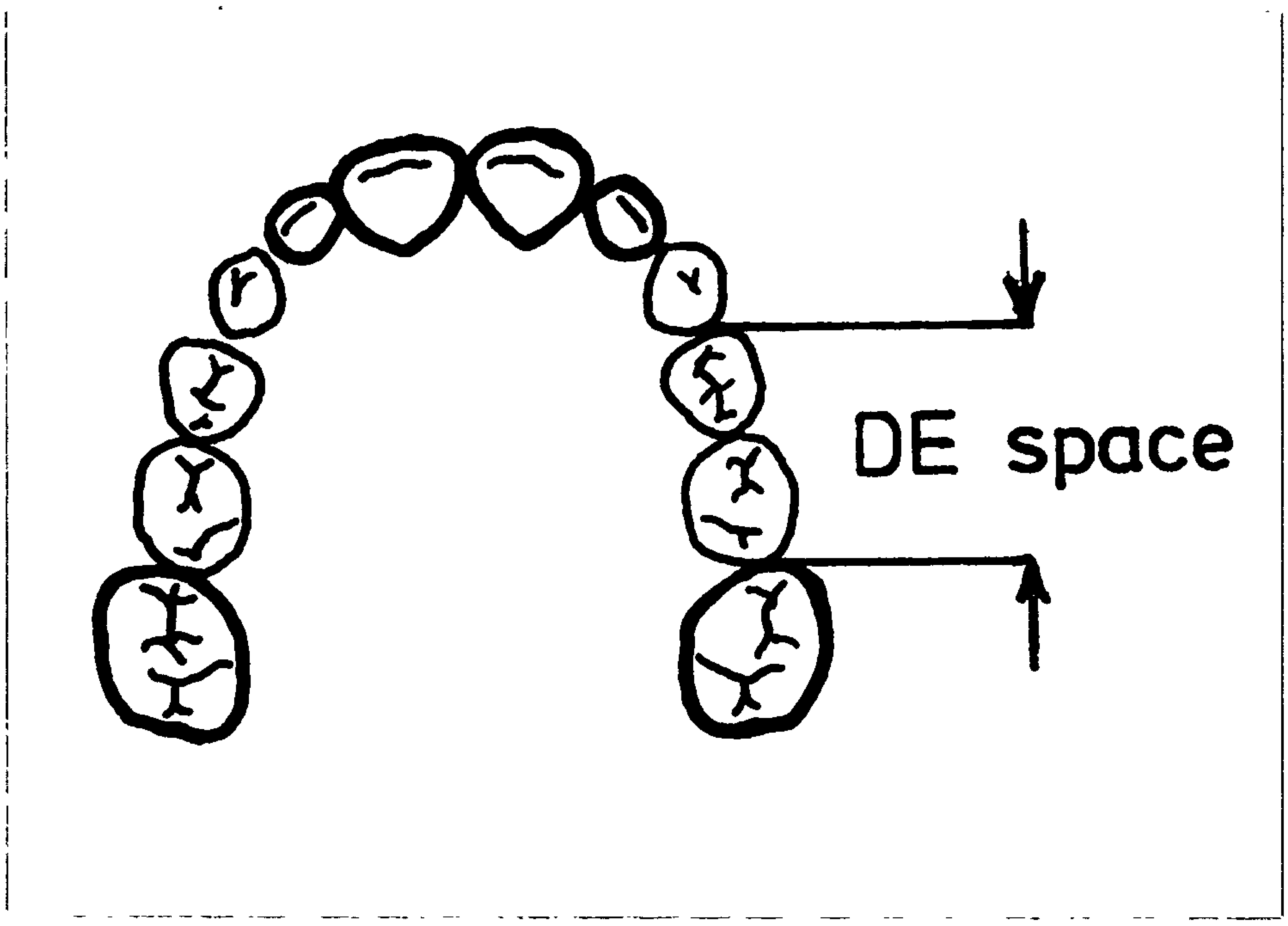
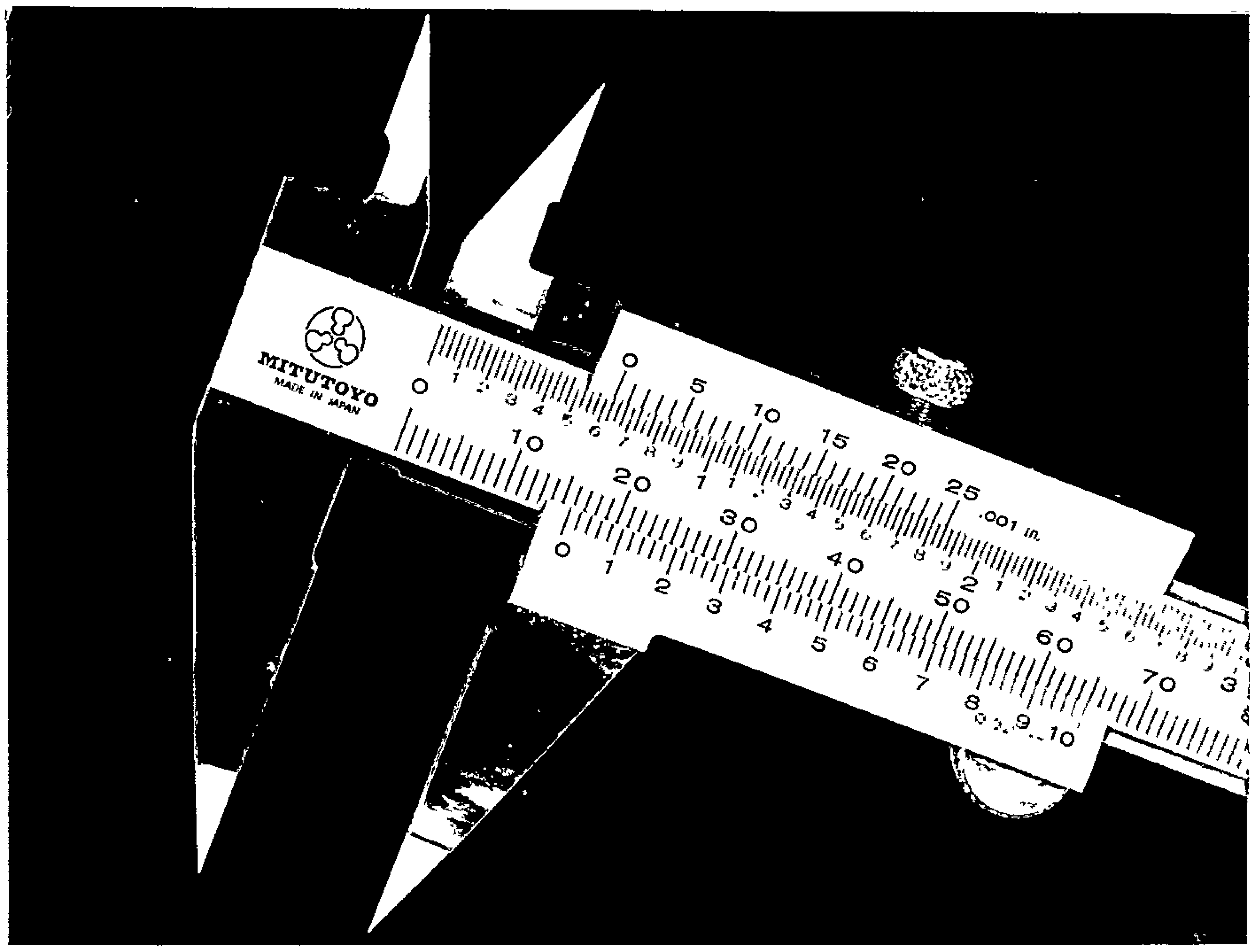


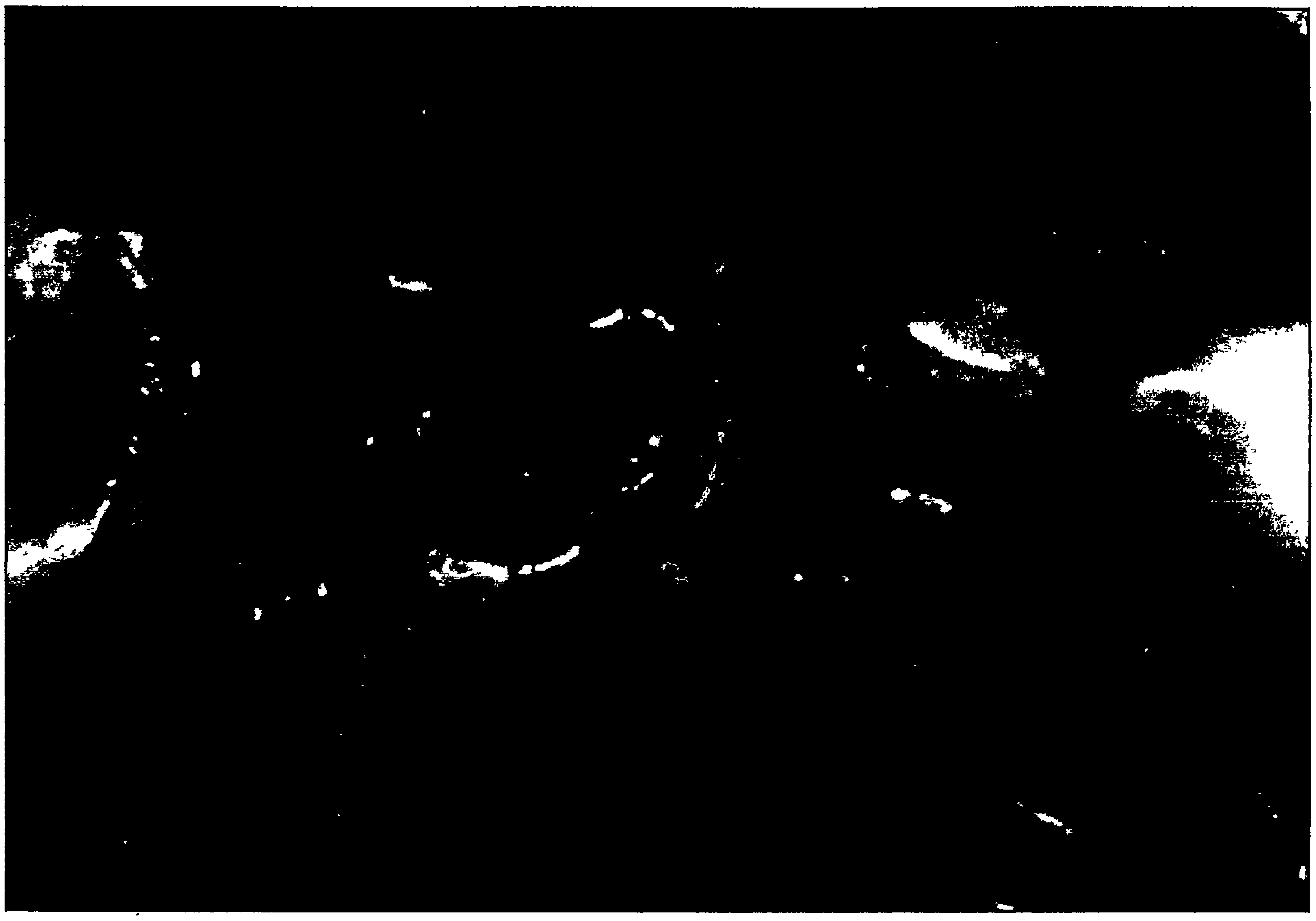
Diagram illustrating the segment of the arch measured as the primary molar space (DE space).

FIGURE 7



This figure shows the vernier calliper used to measure the primary molar spaces. Each jaw of the calliper has been sharpened to a fine point to improve measurement precision.

FIGURE 8



Example of primary molars in a treatment group demonstrating marginal ridge breakdown. The caries has been stained black due to the treatment with metal fluorides.

FIGURE 9

Example of primary molars in a treatment group demonstrating extreme breakdown of the marginal ridges of the lower first primary molar. Such roots were retained *in situ* and not extracted.

STATISTICAL ANALYSES

Baseline DE Space Assessment

The DE space lengths for the control and treatment groups at baseline were compared and analysed for statistically significant differences using the Student's 't' test. The data for the maxillary and mandibular arches were analysed separately. The DE space differences for the maxillary arches were compared to the DE space differences in the mandibular arches for statistical significance.

DE Space Changes after Minimal Treatment

The DE space changes for the control and treatment groups were compared and analysed for statistically significant differences at each 6-monthly interval of the study. The Student's 't' test was used for the analyses. The data for the maxillary and mandibular arches were analysed separately.

Differences were regarded as statistically significant at the 5 per cent level (i.e., $p<0.05$).

RESULTS

The data on which all the results were based are given in Appendix I.

BASELINE DE SPACE CHANGE ASSESSMENT

There were 28 subjects who had at least one contralateral pair of control and treatment DE spaces at baseline. That is, the control DE space had both primary molars with intact marginal ridges while the contralateral treatment DE space had at least one primary molar with marginal ridge breakdown due to dental caries. In this sample there were 14 female subjects and 14 male subjects with a mean age of 7.17 years (S.D., 1.28) at baseline. The baseline data from these subjects were used to determine the range of space loss that resulted when marginal ridge breakdown occurred due to the presence of dental caries in the primary molars. The data are shown in Table I.

The 28 subjects yielded 19 maxillary and 17 mandibular pairs of contralateral control and caries-affected DE spaces.

For the maxillary arches, the degree of space change (i.e. "Control" DE space minus "Treatment" DE space) ranged from 0.5 millimetres of space gain to 1.7 millimetres of space loss. There was a mean primary molar space loss of 0.5 millimetres for the upper arch when the caries-affected DE spaces were compared to the control DE spaces.

TABLE 1

DE SPACE MEASUREMENTS FOR SUBJECTS HAVING CONTRALATERAL PAIRS OF CONTROL AND TREATMENT QUADRANTS AT BASELINE

Maxilla				Mandible			
Subject Code (N=19)	DE Space Length(mm.) C*	T**	Difference(mm.) C − T	Subject Code (N=17)	DE Space Length(mm.) C*	T**	Difference(mm.) C − T
C3	15.8	15.7	0.1	C4	17.4	16.5	0.9
C4	16.4	15.3	1.1	I2	17.4	17.4	0.0
C25	15.0	14.7	0.3	I5	19.5	18.9	0.6
I2	16.9	16.2	0.7	I18	17.1	17.3	-0.2
I4	18.3	18.1	0.2	I30	20.5	20.3	0.2
I6	15.6	14.4	1.2	I43	17.9	18.9	-1.0
I29	16.6	16.1	0.5	K4	20.9	20.2	0.7
I30	18.1	18.3	-0.2	K5	18.9	19.2	-0.3
I33	18.2	17.9	0.3	K12	18.0	18.1	-0.1
I34	18.6	18.3	0.3	K13	20.3	20.2	0.1
I43	16.0	16.5	-0.5	K15	18.9	19.4	-0.5
K2	17.6	16.2	1.4	C9	19.2	18.9	0.3
K10	16.9	17.1	-0.2	I32	17.5	17.2	0.3
K15	18.9	17.2	1.7	K11	19.9	19.8	0.1
P52	18.4	17.0	1.4	P15	20.0	19.5	0.5
C10	15.6	15.9	-0.3	P43	18.9	16.8	2.1
C27	17.8	17.0	0.8	P61	17.0	15.1	1.9
I32	16.7	15.9	0.8				
P39	14.6	14.2	0.4				
Means (S.D.)	$\overline{17.0}$(1.3)	$\overline{16.4}$(1.3)	$\overline{0.5}$(0.6)		$\overline{18.8}$(1.3)	$\overline{18.5}$(1.5)	$\overline{0.3}$(0.8)

Maxilla CvT	Mandible CvT	Max. Differences v Mand. Differences
Not significant (t = 1.4226)	Not significant (t = 0.6232)	Not significant (t = 0.8407)

C* = Control DE space in which both primary molars are present with all marginal ridges intact.

T** = Treatment DE space in which both primary molars are present but one or both primary molars has marginal ridge breakdown.

The DE space lengths for the control and treatment groups, however, were not statistically significant (t = 1.4226).

For the mandibular arches, the degree of space change ("Control" DE space minus "Treatment" DE space) ranged from 1.0 millimetre of space gain to 2.1 millimetres of space loss. There was a mean DE space loss of 0.3 millimetres for the lower arch when the caries-affected DE spaces were compared to the control DE spaces. The differences in the DE space lengths for the control and treatment groups in the mandible were not statistically significant (t = 0.6232).

Furthermore, there were no statistically significant differences between the DE space changes (Control v Treatment) that occurred in the maxillary arches when compared to the changes that occurred in the mandibular arches (t = 0.8407).

DE SPACE CHANGES AFTER MINIMAL TREATMENT PROCEDURES

Table 2 shows the age, sex and baseline caries experience of the 72 subjects whose DE space changes were assessed for periods from 6 months to 4 years after minimal treatment procedures. The mean age of the subjects at baseline was 7.5 years (S.D., 1.4) with 39 of the subjects being female and 33 being male. The mean baseline dmfs index of the group of subjects was 12.8 (S.D., 6.2). Twenty-one subjects (29 percent) were Australian aboriginals whilst the remaining 51 subjects (71 percent) were Caucasian.

TABLE 2

AGE, SEX AND PREVIOUS CARIES EXPERIENCE AT BASELINE FOR SUBJECTS WHOSE DE SPACES WERE ASSESSED AFTER MINIMAL TREATMENT

		Age (Yrs.)		dmfs		DMFS	
Sex	No.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
M	33	7.2	1.2	13.21	6.25	1.21	2.27
F	39	7.7	1.5	12.46	6.25	1.41	1.98
M + F	72	7.5	1.4	12.81	6.22	1.32	2.11

Figure 10 shows an ordinate diagram depicting the mean space changes which occurred for the control and treatment of DE spaces in the maxillary arches for 6-monthly periods from baseline to 4 years. Similarly, Figure 11 shows the mean DE space changes that occurred for the mandibular arches.

For the maxillary arches (Figure 10) the mean DE space changes for the control group ranged from less than 0.1 millimetres of DE space reduction at 6 months from baseline to 0.75 millimetres of space reduction at 4 years. By comparison, for the treatment group, the mean DE space change at 6 months after baseline was 0.2 millimetres reduction and approximately 1.2 millimetres of space reduction at 4 years. The loss of space in the treatment group appeared to be greater than in the control group at each 6-monthly examination, but statistically significant differences were shown only at the 6-month, 2-year, 3-year and 3.5-year intervals.

For the mandibular arches (Figure 11), the mean DE space changes for the control group ranged from less than 0.1 millimetres of space loss at 6-months from baseline to approximately 0.4 millimetres of DE space loss after 4 years. By comparison, for the treatment group, the mean DE space change at 6-months after baseline was less than 0.2 millimetres of space loss ranging to approximately 1.2 millimetres of space loss after 4 years. In the mandibular arches, DE space loss for the treatment group appeared to be greater than for control group at each 6-monthly examination, and these differences were statistically significant at each time interval.

ACCURACY OF WAX-BITE IMPRESSIONS

The data for comparing 40 DE space measurements obtained from wax-bite impressions to those measurements obtained from alginate impressions of 10 subjects are shown in Appendix II. There were no statistically significant differences between the measurement values obtained from the wax-bite impressions and those obtained from the alginate impressions ($t = 0.2083$, $p>0.05$). The mean of the differences between the 2 sets of measurement values was 0.06mm with a standard deviation of 0.25mm and a standard error of 0.04mm.

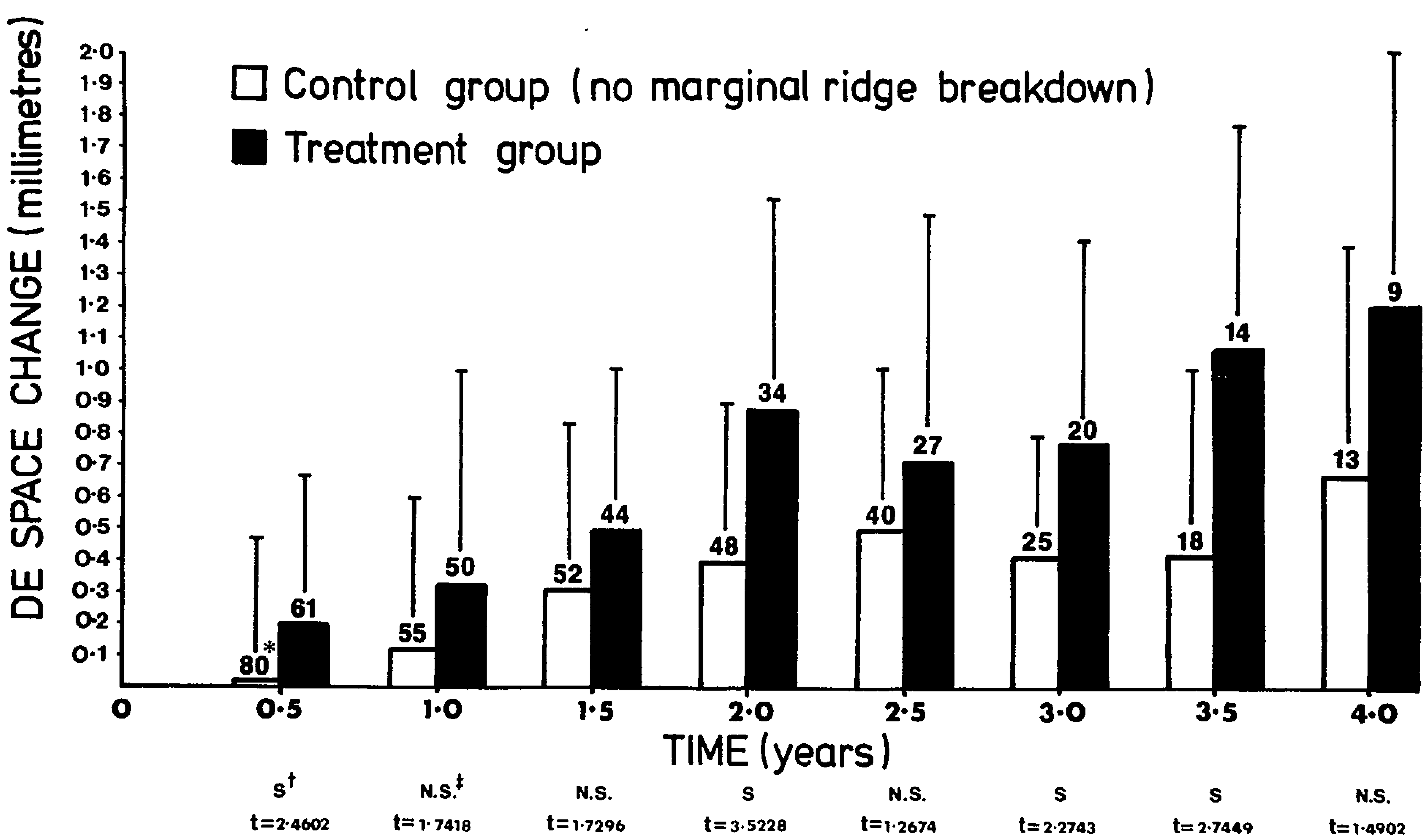
These results show that, for the measurements made in this study, wax-bite impressions were a suitable alternative to alginate impressions for obtaining study models.

MEASUREMENT ERROR

The data for determining the measurement error are shown in Appendix III. The DE space measurement values obtained initially were compared to 84 replicate measurements made from a random sample of 21 sets of study models. There were no statistically significant differences between the first set of measurements and the replicate measurements ($t = 0.0728$, $p>0.05$). The mean of the differences between the first and replicate measurements was 0.02mm with a standard deviation of 0.27mm and a standard error of 0.03mm.

The results show that, in the majority of cases, the actual measurement would be dispersed within a 0.3mm range of the measurement recorded.

FIGURE 10



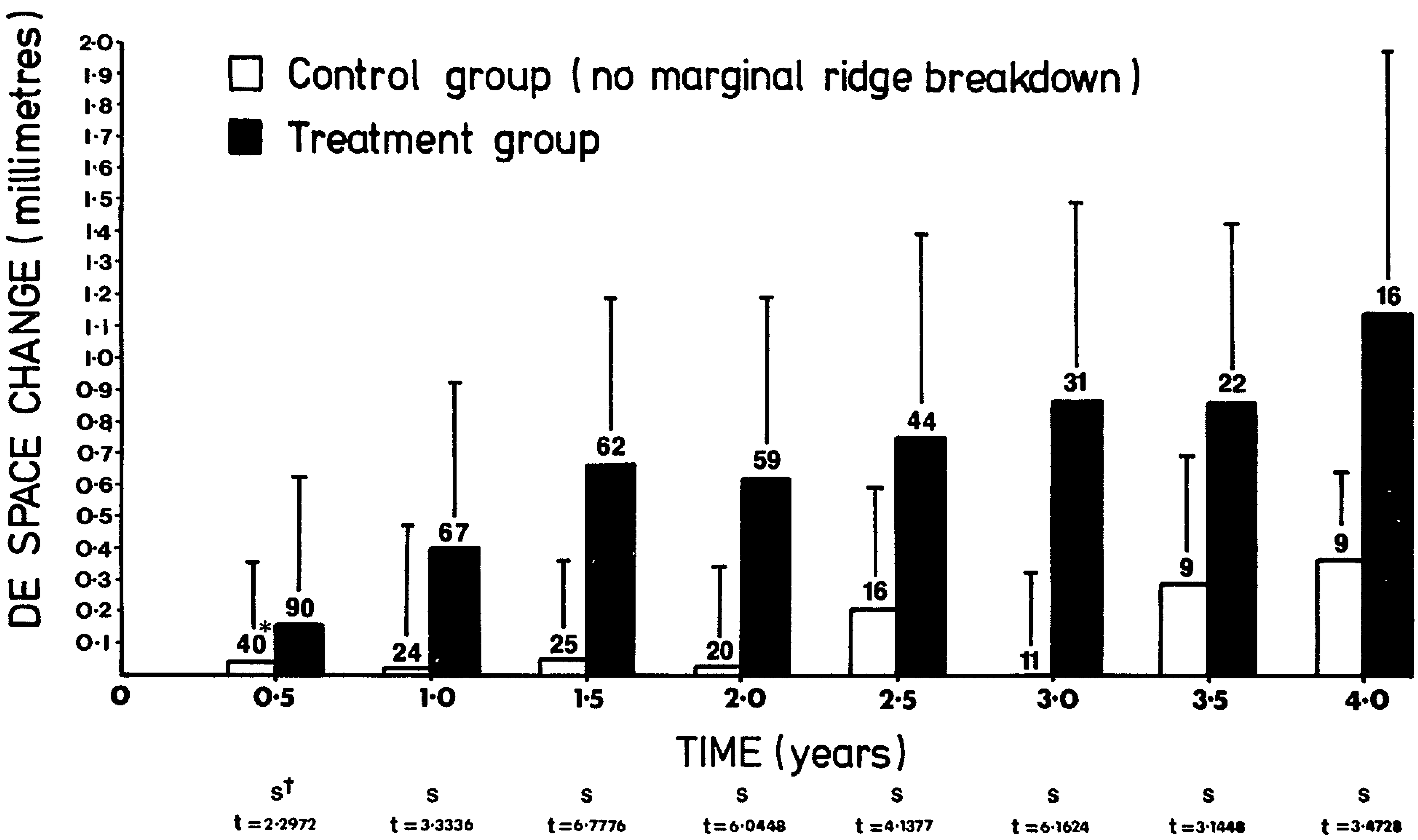
This figure is an ordinate diagram showing the maxillary primary molar space changes for the control and treatment groups at 6-monthly intervals up to 4 years. (The bars represent the standard deviations).

* The numbers above the columns indicate the number in the sample.

† S = Differences statistically significant ($p<0.05$).

‡ N.S. = Differences not statistically significant ($p>0.05$).

FIGURE 11



This figure is an ordinate diagram showing the mandibular primary molar space changes for the control and treatment groups at 6-monthly intervals up to 4 years. (The bars represent the standard deviations).

* The numbers above the columns indicate the number in the sample.

† S = Differences statistically significant ($p<0.05$).

DISCUSSION

Although, overall, a significant association between marginal ridge breakdown of primary molars and space loss could not be demonstrated when contralateral pairs of primary molars with and without marginal ridge breakdown were compared at baseline, space loss did occur in individual cases (Table 1). Furthermore, during the 4-year treatment period of the study, compared to control DE spaces, more space loss consistently occurred in the treatment DE spaces which contained primary molars with marginal ridge breakdown (Figures 8 and 9). These findings suggest that where marginal ridge breakdown of primary molars occurs, the potential for space loss exists. The fact that space loss is not inevitable in all cases suggests that a number of factors apart from loss of tooth substance may govern whether space loss occurs.

Isolating the factors that govern space loss in the primary molar region is difficult and complicated by the diverse nature of the cases used for study. All the variables implicated with space loss cannot be uniformly present in a limited sample of subjects.

In cases where total loss of a tooth occurs, a number of factors have been suggested as predisposing to losses of arch length. Factors considered to be associated with space loss following premature loss of primary molars include the site of primary molar loss;[7-10,14,19,32,33,43,50,52,57] the timing and duration of tooth loss (particularly relative to the eruption of first permanent molars);[10,12,14,19,29,33, [34,43,50,52,55,56] the inclination,[51] cusp height [12] and degree of interdigitation [29,33,51,53] of first permanent molars; overeruption of a tooth opposing the site of tooth loss;[51,53] and the presence of existing crowding.[12,19,29, 33,34,50,56].

Presumably, similar factors affecting space loss could be considered when primary molar tooth dimension is reduced due to the presence of caries in approximal surfaces. The influence of such factors in promoting or preventing space loss when caries causes marginal ridge breakdown has not been previously investigated, nor was it determined in the present study. Undoubtedly, this aspect warrants further investigation.

Various published studies have indicated that, although the amount of space loss that may occur after premature removal of primary molars is variable and dependent on many factors, space loss may be equivalent to all or part of the tooth crown dimension of the extracted primary molar. For example, Rosenzweig and Klein [54] and De Boer [14] reported space losses between 0.5mm to 8.0mm after extraction of primary molars while there are several reports of mean space loss values in excess of 3-4mm.[12,14,19,43,52,56]

The values of space loss that may occur after total loss of a primary molar would appear to be far in excess of the space loss that may occur due to the presence of caries in primary molars. Accordingly, it would be reasonable to assume that the orthodontic effects would be less severe in the latter case.

Baseline data in this study show that in the presence of marginal ridge breakdown, primary molar space changes ranged between 0.5mm space gain to 1.7mm space loss in the upper arches and between 1.0mm space gain and 2.1mm space loss in the lower arches (Table 1). These findings provide an indication of the variable nature of the space changes that can occur due to caries in the primary molars.

Breakspear [8,9] surmised that space loss of approximately 1mm could be attributed to dental caries in primary molars. Northway and Wainright [42] found a mean space loss between 0.5mm and 1.0mm when primary molars are severely affected by dental caries. The findings of those authors are consistent with the findings of this study.

In contrast, Jarvis is cited [41,42] as suggesting that space loss in the presence of carious primary molars was akin to that occurring when a primary molar is totally lost. The results of this study and the findings of Breakspear [8,9] and of Northway and Wainright [42,43] do not support the latter view. Indeed, as far as can be ascertained from the literature, Jarvis' findings have not been published in a refereed scientific journal.

During the treatment period of this study there were significant differences between primary molar space changes that occurred for the control and treatment primary molars at each 6-monthly interval of the study in the mandibular arches (Figure 11). There was a similar pattern present for the primary molar space changes that occurred in the maxillary arches (Figure 10).

In the upper arches the differences in the primary molar space changes for the control and treatment groups were not statistically significant at all time intervals of the study. However, the trend towards more space loss in the treated groups was always apparent.

The greatest difference between the means for the control and treatment groups over all time intervals was approximately 0.7mm in the upper arches and approximately 0.9mm in the lower arches. The greatest amounts of space loss that occurred for the treatment groups over all the intervals of the study (during the treatment phase) were 3.1mm in the upper arch and 3.0mm in the lower arch. The corresponding values for the control groups where marginal ridges remained intact were 2.3mm of space loss in the upper arches and 0.9mm of space loss for the mandibular arches.

The mean values and range of space loss that occurred when primary molars with marginal ridge breakdown received a minimal treatment procedure, appear to be far less than corresponding values reported when primary molars are extracted prematurely. Many mean space loss values in excess of 3-4mm have been reported when primary molars are removed early.[12,14,19,43,52,56] At the extreme end of the scale, total loss of a primary molar may lead to space loss equivalent to the dimension of the lost tooth's crown.[14,54] Although, concerning this observation, only the most tentative comparisons can be made, none of the mean values of space loss or maximum values of space loss recorded in this study approached those levels.

This finding suggests that minimal treatment of primary molars with marginal ridge breakdown does not jeopardize primary molar space to the same degree as extraction might do. This is an important consideration since in this study there was a wide range in the degree of carious involvement of the primary molars in the treatment group and if treated by conventional techniques, many of these teeth would have been extracted. Since an important feature of the minimal treatment programme was to avoid extractions then it is a reasonable assumption that less severe space loss problems were initiated by adopting this treatment approach.

There are few reports in the literature which have assessed the space changes which ensue following different forms of caries therapy in the primary dentition. However, Northway and Wainright [42] showed that when primary molars were restored (presumably with amalgam) the primary molar space changes that ensued tended to have a pattern of space change comparable to that of caries-free primary molars (Figures 1 and 2). In that study both the "Caries-Free" and "Restored" primary molars tended to show a reduction in primary molar space with increasing age. Those authors found that only when primary molars were severely affected by caries was there a significant effect on the primary molar space. Unfortunately, the degree of caries involvement implied by "severe" was not specified by the authors but the apparently untreated "Severe-Caries" group maintained primary molar spaces 0.5-1.0 millimetres shorter than the "Caries-Free" group throughout the 6-year period of that study.

Ingers et al.[24] found that "modified caries therapy" involving grinding carious approximal surfaces in primary molars did not appreciably affect space conditions in the primary molar region.

Although direct comparisons cannot be made, the findings of these previous workers and the findings of this study suggest that modifying the treatment of caries in primary molars does not necessarily greatly compromise space in the primary molar region.

Interestingly, in this study, there was a trend towards the control group primary molar spaces becoming smaller with time, particularly in the upper arches (Figures 10 and 11). The primary molars in the control DE spaces had all their marginal ridges intact. This pattern of space change in the control group is difficult to explain but the same trend is evident in the results of Northway, Wainright and Demirjian [43] (Figures 1 and 2) and in an earlier paper by Northway and Wainright.[42]

The tendency to a gradual shortening of the primary molar space may be due to a compaction of the arch during arch development or due to attrition of the approximal surfaces of the deciduous teeth with a concomitant reduction in the primary molar spaces. Reduction in arch length related to attrition of the approximal tooth surfaces has certainly been suggested previously.[3,39]

An increase in the incidence of malocclusion has been ascribed to space loss that may result from premature removal of teeth.[1,13,21,22,45,52] The magnitude and nature of the contribution made by space loss from premature tooth extraction is less clear. However, the consequences of space loss originating from tooth removal have been listed variously as increasing the risk of crowding,[21,22,52,61-63] increasing the incisor overbite [44] and overjet [22,52,57] and the loss of anchorage.[13] It seems logical to deduce that the major contribution made by primary molar space loss would be to the dental aspects of a malocclusion particularly in accentuating crowding.[52,60-63]

Whether the same consequences can result, or result to the same degree, when space loss occurs due to carious breakdown of primary molars appears not to have been clearly established. Studies attempting to implicate caries-experience as a primary and important aetiological factor in malocclusion are equivocal.[1,2,26,46] Furthermore, it must be remembered that such studies have included extracted teeth when assessing the caries experience of subjects and so cannot be reliably used to determine relationships between malocclusion and the presence of retained carious teeth.

As mentioned previously, the differences between the mean DE space changes for the control and treatment groups did not exceed 0.7mm for the upper arches (Figure 10) and 0.9mm for the lower arches (Figure 11) at any time period over the 4-year interval of the study. These differences between the control and treatment groups for the mean DE space changes are less than the upper and lower mean "leeway" space values reported by Nance.[40]

Mean "leeway" space values reported by Nance are 0.9mm and 1.7mm for the upper and lower arches respectively. The greatest amount of "leeway" space reported by Nance was 4mm. The highest values in DE space change after minimal treatment in this study were 3.1mm of space loss in the upper arch and 3.0mm of space loss in the lower arch. This suggests that if space loss did occur in the primary molar region after minimal treatment then the space lost would be within the range reported for the magnitude of "leeway" space.

These comparisons help to put the space changes observed in this study in perspective. Although statistically significant differences between control and treatment group DE space changes were demonstrated at many time periods of the 4-year study, it is important to determine the clinical significance that these differences represent. Recently, Horowitz [23] has focussed attention on the importance of establishing the clinical significance of differences which have been demonstrated statistically.

In placing the degree of space change in perspective, it is pertinent to recall the background of the subjects treated in the minimal treatment programme. The subjects were very young and highly anxious patients who had a high caries experience (Table 2) and who had rejected conventional restorative procedures. Under these circumstances there are few options for treating extensive caries in the mixed dentition and, where the options might include extractions, the incidence and magnitude of space loss might only be increased.

If extraction therapy had been adopted for the treatment of some teeth extensively broken down by caries (Figure 9) then, as has been suggested,[13,18] a fabricated space maintainer might need to be placed to maintain the primary molar space. Such a treatment option would not appear desirable for the subjects in this study since fabricated space maintainers require regular inspection particularly in light of the high failure rate reported for these appliances. Hill, Sorenson and Mink [20] evaluated 226 space maintainers of various types and found that 43 percent of these appliances had failed over a 4-year period.

In addition, the risk of initiating further caries may be enhanced by fabricated appliances being placed in uncooperative young patients who already have a high caries experience (Table 2). Certainly, orthodontic treatment in the mixed dentition, even if of a limited nature, would not be realistically contemplated in subjects with the backgrounds described.

The clinical significance of the degree of space loss detected in this study would seem to be important in Angle Class I minimal discrepancy cases and, at the other end of the orthodontic spectrum, in Angle Class II and Angle Class III maximum anchorage cases. Furthermore, the space lost would only be clinically relevant in cases in which some orthodontic treatment might be contemplated in the mixed dentition since the "leeway" space is normally lost when the permanent dentition erupts. Utilisation of such spaces for orthodontic purposes usually requires that the space is held with an appliance. This applies where preventive orthodontic treatment or interceptive orthodontic treatment is contemplated.[38]

In Class I crowded cases, spaces are created and utilised for the alignment of teeth. In Class II and Class III cases, extraction spaces are utilised for the alignment of teeth and the correction of the relationships of teeth in the sagittal plane. Very frequently, in Class I, Class II and Class III cases, spaces are used to offset reciprocal movements of anchor teeth when intermaxillary or intramaxillary elastics are used. In maximum anchorage cases, any loss of space greater than the "leeway" space may modify the treatment approach in view of the anchorage requirements. Where space is deficient or complicated by space loss then anchorage other than intramaxillary or intermaxillary sources may have to be employed or precautions may have to be adopted to bolster existing anchorage. Extra-oral sources of anchorage may provide this.

In minor discrepancy cases, in which interceptive orthodontic procedures might be adopted, the "leeway" space may be used to correct minor imbrications of the teeth where there is a space discrepancy of only a few millimetres. Loss of this space, either totally or in part, may remove interceptive treatment options and require a case to be treated by an approach involving space regaining or extractions. Thus, at the extreme ends of the orthodontic treatment spectrum, space loss may modify the treatment approach to an orthodontic problem.

It would appear that the amounts of primary molar space change that were detected in this study would not complicate or require modification of orthodontic treatment in extreme cases since, in all cases where space loss occurred, it was well within the accepted range of "leeway" space. Certainly, it seems logical to assume that any space loss that did ensue, following minimal treatment procedures, would complicate orthodontic treatment far less than if caries therapy involving extractions had been adopted.

The results of this study form the basis for further possible areas of investigation. Firstly, since space loss does not always eventuate after marginal ridge breakdown of primary molars, further work could be done to attempt to isolate the factors that predispose to space loss - for example, pre-existing crowding. Secondly, in view of the range of treatments involved in the minimal treatment programme, future attempts could be directed towards determining which treatments were most associated with space loss in the primary molar region.

SUMMARY AND CONCLUSIONS

A study was undertaken to assess the primary molar space changes that occurred in a group of highly anxious young patients who had extensive dental caries treated by "minimal treatment procedures". A major feature of the minimal treatment approach was that extractions were not performed even if extensive tooth structure loss had occurred.

A review of the literature showed that while space changes that occur following premature extraction of primary molars are well documented, there is little published work addressing the subject of space change when carious primary molars are retained. Furthermore, there is very little literature dealing with space changes that occur when carious primary molars are treated unconventionally or by a minimal treatment approach.

Data on primary molar space changes were obtained at 6-monthly intervals from study models of subjects who participated in a minimal treatment programme during a 4-year period.

Data on primary molar space changes that followed minimal treatment of caries in primary molars with marginal ridge breakdown were obtained from 72 subjects. These subjects had both primary molars present in at least one quadrant for periods ranging from 6 months to 4 years.

Baseline data from 28 of the 72 subjects were used to assess the primary molar space changes that had occurred due to the presence of untreated caries which had caused marginal ridge breakdown. These 28 subjects had 19 upper and 17 lower contralateral pairs of primary molars where one side had intact marginal ridges and the other side had some marginal ridge breakdown.

The results of this study showed:

1. The primary molar space changes that had occurred at baseline in the presence of marginal ridge breakdown ranged between 0.5mm of space gain to 1.7mm of space loss for the upper arches and between 1.0mm of space gain and 2.1mm of space loss for the lower arches.

   However, statistically significant differences in the space changes for primary molar pairs with intact marginal ridges and those with marginal ridge breakdown were not demonstrated.

2. For the maxillary arches, after minimal treatments were carried out, the mean primary molar space changes for the control primary molars with intact marginal ridges ranged from less than 0.1mm of space loss at 6 months to 0.7mm of space loss at 4 years from baseline. By comparison for the treated primary molars with marginal ridge breakdown, the mean space changes ranged from 0.2mm of space loss at 6 months to approximately 1.2mm of space loss at 4 years. Statistically significant differences between

primary molar changes for the control and treated groups were demonstrated at the 6-month, 2-year, 3-year and 3.5 year intervals.

3. For the mandibular arches, after minimal treatment, the mean primary molar space changes for the control group ranged from less than 0.1mm of space loss at 6 months to approximately 0.4mm of space loss at 4 years. By comparison, for the treated primary molars with marginal ridge breakdown, the mean primary molar space change ranged from less than 0.2mm space loss at 6 months to 1.2mm of space loss at 4 years. Differences between control and treatment primary molar space changes were statistically significant at all the 6-monthly intervals of the study.

In summary, the results of this study suggest that:

1. When marginal ridge breakdown of primary molars occurs, the potential for space loss exists but does not necessarily occur.

2. Where caries in primary molars is treated by minimal treatment procedures any space changes which may ensue are unlikely to complicate any existing orthodontic problem or any future orthodontic treatment. If space loss does occur after minimal treatment, then it would tend to be much less than could occur if primary molars are extracted and it would be within the dimensional range reported for the "leeway" space.

BIBLIOGRAPHY

1. ADLER, P.: The incidence of dental caries in adolescents with different occlusion. *J Dent Res* 35: 344-349, 1956.

2. AST, D.B.; ALLAWAY, N. and DRAKER, H.L.: The prevalence of malocclusion, related to dental caries and lost first permanent molars, in a fluoridated city and a fluoride-deficient city. *Am J Orthod* 48: 106-113, 1962.

3. BEGG, P.R. and KESLING, P.C.: *Begg Orthodontic Theory and Practice* 3rd ed. Philadelphia, W.B. Saunders Co., 1977, pp. 22-23.

4. BERGGREN, U. and MEYNERT, G.: Dental fear and avoidance: causes, symptoms and consequences. *J Am Dent Assoc* 109: 247-251, 1984.

5. BONNAR, E.M.E.: Aspects of the transition from deciduous to permanent dentition. *D Practitioner* 7: 42-54, 1956.

6. BONNAR, E.M.E.: Aspects of the transition from the deciduous to the permanent dentition. Part II. *D Practitioner* 11: 59-75, 1960.

7. BRAUER J.C.: A report of 113 early or premature extractions of primary molars and the incidence of closure of space.
J Dent Child 8: 222-224, (4th Quart.) 1941.

8. BREAKSPEAR, E.K.: Sequelae of early loss of deciduous molars.
D Record 71: 127-134, 1951.

9. BREAKSPEAR, E.K.: Further observations on early loss of deciduous molars.
D Practitioner 11: 233-252, 1961.

10. CLINCH, L.: An analysis of serial models between three and eight years of age.
D Record 71: 61-72, 1951.

11. CRAIG, G.G.; POWELL, K.R. and COOPER, M.H.: Caries progession in primary molars: 24-month results from a minimal treatment programme.
Community Dent Oral Epidemiol 9: 260-265, 1981.

12. DAVEY, K.W.: Effect of premature loss of primary molars on the anteroposterior position of maxillary first permanent molars and other maxillary teeth.
J Dent Child 34: 383-394, 1967.

13. DEARING, S.G.: Space loss and malocclusion
N Z Dent J 77: 62-67, 1981.

14. DE BOER, M.: Early loss of primary molars.
Ned Tijdschr Tandheelkd 89: 8-28, (Suppl. 21) 1982.

15. FUKS, A.B.; SHAPIRA, J. and BIELAK, S.: Clinical evaluation of a glass-ionomer cement used as a class II restorative material in primary molars.
J Pedod 8: 393-399, 1984.

16. GARN, S.M. and LEWIS, A.B.: Tooth-size, body size and "giant" fossil man.
Am J Anthropol 61: 874-880, 1958.

17. GARN, S.M.; LEWIS, A.B. and KEREWSKY, R.S.: X-linked inheritance of tooth size.
J Dent Res 44: 439-441, 1965.

18. GRABER, T.M.: Orthodontics, Principles and Practice. 3rd ed. Philadelphia.
W.B. Saunders Co., 1972.

19. HAAVIKKO, K. and RAHKAMO, A.: Changes in the dental arches induced by premature extractions of deciduous molars.
Proc Finn Dent Soc 73: 14-20, 1977.

20. HILL, C.J.; SORENSON, H.W. and MINK, J.R.: Space maintenance in a child dental care program. *J Am Dent Assoc* 90: 811-815, 1975.

21. HØFFDING, J. and KISLING, E.: Premature loss of primary teeth: Part 1, Its overall effect on occlusion and space in the permanent dentition. *J Dent Child* 45: 279-283, 1978.

22. HØFFDING, J. and KISLING, E.: Premature loss of primary teeth: Part II, The specific effects on occlusion and space in the permanent dentition. *J Dent Child* 45: 284-287, 1978.

23. HOROWITZ, H.S.: Measurement and expression of treatment effects in caries clinical trials. *J Dent Res* 63: 709-712, 1984.

24. INGERS, G.; CROMVIK, U.; GLEERUP, A. and RONNERMAN, A.: The effect on space conditions of unilateral grinding of carious proximal surfaces of primary molars - a longitudinal study. *J Dent Child* 49: 30-34, 1982.

25. INOUE, N.; KUO, C.H.; ITO, G.; SHIONO, K.; KURAGANO, S.; KAMEGAI, T.; SEINO, Y.; YUYAMA, Y.; TAKAGI, O. and TAURA, K.: Influence of tooth-to-denture base discrepancy on space closure following premature loss of deciduous teeth. *Am J Orthod* 83: 428-434, 1983.

26. JAGO, J.D.: The epidemiology of dental occlusion; A critical appraisal.
J Public Health Dent 34: 80-93, (Spring) 1974.

27. JARVIS, A.: The role of dental caries in space closure in the mixed dentition. Thesis. The University of Toronto. 1952. Cited in Noonan [41] and Northway and Wainright [42]

28. JOHNSEN, D.C.: Space observations following loss of the mandibular first primary molars in mixed dentition.
J Dent Child 47: 24-27, 1980.

29. KISLING, E. and HØFFDING, J.: Premature loss of primary teeth. Part III, Drifting patterns for different types of teeth after loss of adjoining teeth.
J Dent Child 46: 34-38, 1979.

30. KISLING, E. and HØFFDING, J.: Premature loss of primary teeth: Part IV, A clinical control of Sannerud's space maintainer, Type 1.
J Dent Child 46: 109-113, 1979.

31. KISLING, E. and HØFFDING, J.: Premature loss of primary teeth: Part V, Treatment planning with due respect to the significance of drifting patterns.
J Dent Child 46: 300-306, 1979.

32. KRONFELD, S.M.: The effects of premature loss of primary teeth and sequence of eruption of permanent teeth on malocclusion.
J Dent Child 20: 2-13, (1st. Quart.) 1953.

33. LUNDSTROM, A.: The significance of early loss of deciduous teeth in the etiology of malocclusion.
Am J Orthod 41: 819-826, 1955.

34. MAGNUSSON, T.E.: The effect of premature loss of deciduous teeth on the spacing of the permanent dentition.
Eur J Orthod 1: 243-249, 1979.

35. MALDONADO, A.; SWARTZ, M.L. and PHILLIPS, R.W.: An in vitro study of certain properties of a glass-ionomer cement.
J Am Dent Assoc 96: 785-791, 1978.

36. MOORREES, C.F.A.; GRØN, A-M.; LEBRET, L.M.L.; YEN, P.K.J. and FROHLICH, F.J.: Growth studies of the dentition: A review.
Am J Orthod 55: 600-616, 1969.

37. MOYERS, R.E.: *Handbook of Orthodontics for The Student and General Practitioner* 3rd ed., Chicago, Year Book Medical Publishers Inc., 1973. pp. 198-200.

38. Ibid. pp. 202-210 and pp. 496-512.

39. MURPHY, T.: Reduction of the dental arch by approximal attrition.
Br Dent J 116: 483-488, 1964.

40. NANCE, H.Y.: The limitations of orthodontic treatment. I. Mixed dentiton diagnosis and treatment.
Am J Orthod 33: 177-223, 1947.

41. NOONAN, R.G.: The role of dental caries in the primary teeth in the development of malocclusion.
J Indiana State Dent Assoc 46: 14-18, 1967.

42. NORTHWAY, W.M. and WAINRIGHT, R.W.: DE Space - A realistic measure of changes in arch morphology: Space loss due to unattended caries.
J Dent Res 59: 1577-1580, 1980.

43. NORTHWAY, W.M.; WAINRIGHT, R.L. and DEMIRJIAN, A.: Effects of premature loss of deciduous molars.
Angle Orthod 54: 295-329, 1984.

44. OWEN, D.G.: The incidence and nature of space closure following the premature extraction of deciduous teeth : A literature survey.
Am J Orthod 59: 37-49, 1971.

45. PEDERSEN, J.; STENSGAARD, K. and MELSEN, B.: Prevalence of malocclusion in relation to premature loss of primary teeth.
Community Dent Oral Epidemiol 6: 204-209, 1978.

46. PEEL, E.J.: Occlusion and fluoridation. MDSc Thesis. University of Sydney, 1973.

47. PELTON, W.J. and ELSASSAR, W.A.: Studies of dentofacial morphology, III. The role of dental caries in the etiology of malocclusion.
J Am Dent Assoc 46: 648-657, 1953.

48. PLANT, C.G.; SHOVELTON, D.E.; VLIETSTRA, J.R. and WARTNABY, J.M.: The use of glass-ionomer cement in deciduous teeth.
Br Dent J 143: 271-274, 1977.

49. RANKIN, J.A. and HARRIS, M.B.: Dental anxiety: the patient's point of view.
J Am Dent Assoc 109: 43-47, 1984.

50. RICHARDSON, M.E.: The relationship between the relative amount of space present in the deciduous dental arch and the rate and degree of space closure subsequent to the extraction of a deciduous molar.
D Practitioner 16: 111-118, 1965.

51. ROCHE, J.R.: The management of the early loss of primary molars and cuspids during the period of the mixed dentition.
J Dent Child 30: 170-179, (3rd. Quart.) 1963.

52. RONNERMAN, A.: Early loss of primary molars. Relation to space conditons, dental development, facial morphology and the need for orthodontic treatment. Thesis. University of Gotebog, Sweden, 1977. 45p.

53. ROSE, J.S.: Early loss of teeth in children.
Br Dent J 120: 275-280, 1966.

54. ROSENZWEIG, K.A. and KLEIN, H.: Loss of space by extraction of primary molars.
J Dent Child 27: 275-276, (4th. Quart.) 1960.

55. SCHACHTER, H.: Incidence and effect of premature extraction and deciduous teeth.
Br Dent J 75: 57-61, 1943.

56. SEIPEL, C.M.: Prevention of malocclusion.
D Record 69: 224-232, 1949.

57. SEWARD, F.S.: Natural closure of deciduous molar extraction spaces.
Angle Orthod 35: 85-94, 1965.

58. SWARTZ, M.L.; PHILLIPS, R.W. and CLARK, H.E.: Long-term F release from glass ionomer cements.
J Dent Res 63: 158-160, 1984.

59. TELFORD, A.B.: Use of glass ionomer cements in children's dentistry.
Dental Outlook 9: 75-77, 1983.

60. UNGAR, A.L.: Incidence and effect of premature loss of deciduous teeth.
Am J Orthod 24: 613-621, 1938.

61. VAN DER LINDEN, F.P.G.M.: Theoretical and practical aspects of crowding in the human dentition.
J Am Dent Assoc 89: 139-153, 1974.

62. WILLETT, R.C.: Premature loss of deciduous teeth.
Angle Orthod 3: 106-111, 1933.

63. WILLETT, R.C.: Preventive orthodontics.
J Am Dent Assoc 23: 2257-2270, 1936.

64. WILSON, A.D. and PROSSER, H.J.: Biocompatibility of the glass ionomer cement.
Tydskr Tandheelkd Ver S Afr 37: 872-879, 1982.

APPENDIX I

DE SPACE MEASUREMENTS FOR ALL SUBJECTS OVER 4-YEAR PERIOD OF STUDY

SUBJECT CODE	AGE (YRS)	SEX	NOV 78 UR*	NOV 78 UL	NOV 78 LR	NOV 78 LL	APR 79 UR	APR 79 UL	APR 79 LR	APR 79 LL	NOV 79 UR	NOV 79 UL	NOV 79 LR	NOV 79 LL
C 3	6.67	F	15.8 C	15.7 T	17.0 T	16.7 T	15.9 C	15.9 T	16.7 T	16.2 T	15.6 T	16.1 T	16.1 T	15.1 T
C 4	8.42	F	16.4 C	15.3 T	16.5 T	17.4 C	16.8 C	15.2 T	16.5 T	17.5 C	16.3 C	15.7 T	15.4 T	17.0 C
C 18	6.75	M	16.0 T	16.0 T	17.6 C	18.0 C	16.4 T	16.8 T	17.1 C	17.4 C	15.9 T	16.1 T	17.6 C	17.3 T
C 24	6.0	F	17.5 T	17.3 T	17.6 T	18.2 T	17.2 T	17.1 T	17.7 T	18.0 T				
C 25	7.00	F	14.7 T	15.0 C	16.8 T	15.7 T	14.7 T	18.1 C	17.1 T	15.7 T	14.1 T	14.9 T	16.9 T	15.5 T
I 1	7.00	F	16.6 T	17.2 T	20.1 T	19.8 T	16.9 T	16.4 T	20.2 T	19.9 T	18.4 T	15.7 T	20.4 T	19.6 T
I 2	5.92	F	16.9 C	16.2 T	17.4 T	17.4 C	16.4 C	16.1 T	17.2 T	17.7 C	17.7 C		18.5 T	17.3 C
I 3	7.25	M	16.3 C	16.3 C	18.5 C	18.1 C	16.7 C	16.9 C	18.8 C	18.4 C	16.2 C	16.5 C	18.6 C	18.3 C
I 4	6.00	F	18.3 C	18.1 T		18.7 C	18.4 C	17.8 T		18.8 C	18.3 C	17.0 T		18.4 C
I 5	6.00	F	17.7 C	17.7 C	18.9 T	19.5 C	18.0 C	18.3 C	18.5 T	19.5 C	18.1 C	18.0 C	18.7 T	19.3 T
I 6	7.08	M	14.4 T	15.6 C	16.3 T	15.8 T		15.3 C	17.3 T	16.0 T		15.1 C	16.7 T	15.5 T
I 7	6.92	M	16.2 C	16.5 C	17.0 T	18.1 T	16.5 C	16.0 C		17.3 T				
I 12	6.75	F	16.4 C	17.0 C	17.8 C	18.1 C	16.2 C	16.2 C	18.0 C	18.0 C	16.2 C	16.5 C	17.5 T	17.7 T
I 13	7.25	F	16.0 C	15.7 C	15.7 T	15.8 T	15.8 C	15.6 T		16.0 T				
I 14	6.33	F	15.7 T	15.3 T	17.0 C	17.4 C	15.1 T	15.0 T	17.3 T	17.3 C	15.1 T	14.2 T	16.6 T	17.5 C
I 18	7.50	M	16.3 C	16.4 C	17.1 C	17.3 T								
I 24	7.25	F					16.1 T	16.9 T	17.2 T	15.8 T	16.0 T	16.5 T	16.4 T	15.1 T
I 29	7.67	M	16.6 C	16.1 T	17.9 T	17.7 T	16.6 C	16.3 T	17.7 T	17.8 T	16.5 C	16.0 T	17.5 T	17.8 T

SUBJECT CODE	AGE (YRS)	SEX	MAY 80 UR	MAY 80 UL	MAY 80 LR	MAY 80 LL	NOV 80 UR	NOV 80 UL	NOV 80 LR	NOV 80 LL	MAY 81 UR	MAY 81 UL	MAY 81 LR	MAY 81 LL
C 3	6.67	F	15.6 T	15.6 T	16.2 T	15.6 T	15.7 T	15.3 T	15.8 T	15.7 T	15.7 T		16.2 T	16.9 T
C 4	8.42	F	16.3 C	14.4 T	15.3 T	17.2 C	16.7 C	13.5 T	16.4 T	17.4 C	16.3 C	13.3 T	15.7 T	
C 18	6.75	M	15.4 T	15.4 T	17.4 C	17.2 T	15.3 T	15.4 T	17.6 C	17.5 T	15.6 T	15.3 T	17.5 C	17.1 T
C 24	6.0	F	17.3 T	16.2 T	17.5 T	16.9 T	16.8 T	16.6 T	17.2 T	17.2 T	16.8 T	16.6 T	17.4 T	16.8 T
C 25	7.00	F	14.5 T	14.5 T	16.4 T	15.5 T	14.2 T	14.2 T	16.8 T					
I 1	7.00	F		16.2 T		18.2 T				19.4 T				
I 2	5.92	F	16.6 C		17.6 T	17.5 C	16.8 C		17.6 T	17.3 C	16.8 T		17.4 T	17.7 C
I 3	7.25	M	16.1 C	17.5 C	17.7 C	18.6 C	16.1 C	16.2 C	17.5 T	18.4 C	16.4 C	16.4 C	17.2 T	18.1 C
I 4	6.00	F	18.3 C	17.2 T		18.6 C	17.2 C	17.5 T				17.5 T		
I 5	6.00	F	18.1 C	17.9 C	18.6 T	19.1 T	18.2 C	18.0 C	18.3 T	19.0 T	17.8 C	17.8 C	18.1 T	18.9 T
I 6	7.08	M		14.9 C	16.6 T	16.1 T		14.8 C	16.6 T			14.9 C		
I 7	6.92	M	16.0 C	15.5 C		17.0 T		15.6 C		17.2 T				
I 12	6.75	F	16.2 C	16.2 C	17.4 T	17.4 T	15.8 C	16.2 C	17.1 T	17.4 T	15.6 C	15.8 C	17.2 T	16.9 T
I 13	7.25	F	15.8 C	15.0 T			15.9 C	15.3 T			16.0 C	15.0 T		
I 14	6.33	F	14.5 T	14.8 T	17.1 T	17.4 C	14.1 T	13.5 T	16.9 T	17.2 C	15.2 T	13.5 T	17.0 T	17.1 C
I 18	7.50	M	16.6 T	16.1 T	16.9 C	16.7 T	15.6 T	15.2 T	16.9 C	16.7 T	15.2 T	14.9 T	16.6 C	16.5 T
I 24	7.25	F	15.7 T	15.5 T	15.8 T	15.0 T	15.9 T	14.9 T	15.3 T	14.9 T	15.5 T	14.9 T	15.2 T	14.9 T
I 29	7.67	M	16.7 C	15.5 T	17.3 T	17.3 T	16.4 C	15.4 T	17.2 T	17.2 T	16.6 C	15.8 T	16.9 T	17.2 T

SUBJECT CODE	AGE (YRS)	SEX	NOV 81 UR	NOV 81 UL	NOV 81 LR	NOV 81 LL	APR 82 UR	APR 82 UL	APR 82 LR	APR 82 LL	NOV 82 UR	NOV 82 UL	NOV 82 LR	NOV 82 LL
C 3	6.67	F												
C 4	8.42	F												
C 18	6.75	M	15.6 T	15.5 T	17.8 C	17.4 T	16.0 T	15.2 T	17.6 C	17.5 T		15.6 T	17.7 C	17.1 T
C 24	6.0	F	16.9 T	16.6 T	17.7 T	16.9 T	16.5 T	16.3 T	17.3 T	17.3 T				
C 25	7.00	F												
I 1	7.00	F												
I 2	5.92	F	17.2 T			17.5 C								
I 3	7.25	M	15.8 C	15.8 C	17.4 T	18.6 C	15.9 C	16.2 C	17.1 T	18.5 C	16.2 C	16.5 C	16.5 T	17.8 C
I 4	6.00	F												
I 5	6.00	F	17.9 C	17.7 C	18.3 T	19.2 T	17.4 C	17.4 C	18.3 T	19.2 T	17.1 C		18.6 T	19.0 T
I 6	7.08	M												
I 7	6.92	M												
I 12	6.75	F			17.6 T	17.3 T								
I 13	7.25	F												
I 14	6.33	F		13.2 T	17.0 T	16.9 C		12.9 T	16.6 T	17.1 T		12.5 T		
I 18	7.50	M	15.3 T	15.1 T	16.8 C	16.8 T	15.2 T	15.2 T	16.6 C	16.5 T			16.5 C	15.9 T
I 24	7.25	F	15.6 T	14.7 T	14.8 T	15.1 T	15.5 T	15.5 T	14.7 T					
I 29	7.67	M	16.2 C	15.7 T	17.1 T	16.9 T	16.6 C	14.8 T	17.1 T	17.3 T				17.2 T

APPENDIX I (Contd.)

SUBJECT CODE	AGE (YRS)	SEX	NOV 78				APR 79				NOV 79				MAY 80				NOV 80				MAY 81				NOV 81				APR 82				NOV 82			
			UR*	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL	UR	UL	LR	LL
K 7	6.16	M	18.4 C	17.6 C	19.4 T	19.1 T	18.7 C	17.5 C	19.7 T	19.4 T	18.7 C	17.3 C	18.3 T	18.6 T	17.9 C	17.9 C	18.1 T	18.2 T	17.9 C	18.4 C	19.5 T	19.4 T	17.6 C	16.8 C														
K 8	5.92	M					16.7 T	15.6 T	17.3 T	17.4 T	16.4 T	16.5 T	16.8 T	16.9 T	16.1 T	16.4 T	16.3 T	16.8 T	15.8 T	16.0 T	15.8 T	16.7 T	16.0 T	16.0 T	15.8 T	16.3 T	15.5 T	16.4 T		17.5 T	15.7 T	16.3 T			15.7 T			
K 9	5.67	M	18.0 C	17.6 C	19.9 C	20.2 C	17.4 C	17.7 C	19.8 C	20.2 C					17.5 C	17.5 C	19.8 C	19.9 C	17.3 C	17.4 C	19.4 C	19.8 C	17.5 C	17.2 C	19.8 C	19.8 C	17.2 C	17.2 C	19.8 C	20.0 C	17.3 C	17.3 C	19.3 C	19.8 C	16.7 C	17.2 C	19.5 C	19.5 C
K 10	6.33	M	17.1 T	16.9 C	18.7 T	18.5 T	17.1 T	16.7 C	18.6 T	18.5 T	17.1 T	17.0 C	18.0 T	18.0 T	17.0 T	16.8 T	17.9 T	18.1 T	16.7 T	16.5 T	18.0 T	17.5 T	16.7 T	16.0 T	17.9 T	16.7 T	16.4 T	16.0 T	18.0 T	16.5 T	16.1 T	15.6 T	17.1 T	16.1 T	16.7 T	15.6 T	17.0 T	15.7 T
K 12	5.33	F	16.1 C	16.4 C	18.1 T	18.0 C	16.0 T	16.1 C	17.9 T	18.5 C					15.8 T	15.8 C	16.9 T	17.9 C	15.9 T	15.9 C	17.2 T	18.4 C	15.4 T	15.6 C	16.8 T	17.6 C					15.0 T	15.7 C		17.7 C	14.9 T	15.6 C		17.6 C
K 13	5.67	M	17.5 C	17.8 C	20.2 T	20.3 C	18.2 C	18.5 C	19.7 T	20.0 T	17.9 C	17.5 C	19.3 T	19.7 T	17.4 C	17.8 C	19.4 T	20.1 T	17.6 C	17.5 C	19.5 T	19.5 T	16.8 C	16.8 C	19.4 T	19.4 T	16.9 C	16.9 C	19.3 T	19.9 T	16.4 C	16.7 C	19.1 T	19.2 T	16.0 C	16.9 C	18.9 T	18.9 T
K 15	6.25	M	17.2 T	18.9 C	18.9 C	19.4 T	17.2 T	17.5 C	18.6 C	18.3 T					15.5 T	17.1 C	18.3 C	17.6 T	15.4 T	16.9 C	18.2 C	17.9 T	15.3 T	17.1 C	18.3 C	18.0 T					14.8 T	16.6 C	18.0 C		15.0 T	16.5 C	18.3 C	
K 17	6.16	F					18.8 C	18.9 C	19.7 C	19.9 C	18.7 C	18.2 C	19.7 C	19.3 C	18.3 C	18.0 C	19.6 C	19.6 T					17.9 T	17.9 T	19.8 C	19.3 T	17.8 T	17.8 T	20.0 C	19.2 T	18.8 T	18.0 T	20.0 C		17.6 T	18.4 T		
P 13	8.92	M	16.8 C	16.8 C	19.0 T	19.3 T	16.8 C	16.7 C	18.9 T	18.6 T					16.4 C	16.4 C			16.7 C	16.3 C			16.9 C	16.3 C														
P 25	8.33	F	16.7 C	16.8 C	18.5 C	18.9 C	16.8 C	17.0 C	18.7 C	18.7 C	17.0 C	17.0 C	18.2 C	18.4 C	16.6 C	17.2 C	18.6 C	18.9 C	16.7 C	16.7 C	18.6 C	19.3 C	16.4 C	16.6 C	18.8 C		16.4 C	16.4 C										
P 29	8.50	F	16.6 C	16.3 C	17.2 C	17.3 C	16.2 C	16.0 C	17.2 C	17.2 C	16.4 C	16.0 C	17.1 C	17.1 C	16.2 C	16.0 C	17.4 C	17.1 C	16.2 C	15.9 C	17.6 C	17.3 C	16.6 C	15.9 C	17.6 C	18.1 C												
P 33	8.42	F	17.0 C	16.5 C	18.0 T	17.7 T	16.8 C	15.7 C	18.0 T	17.5 T	16.9 C	14.9 C	17.7 T	17.5 T	17.1 C	15.3 C	17.5 T	17.5 T	16.9 C	14.9 C	17.5 T	17.8 T	17.5 C	14.5 C	18.0 T	17.7 T	17.0 C	16.0 C		17.7 T	17.5 C							
P 52	9.00	M	18.4 C	17.0 T	16.6 T	19.2 T	18.3 C	16.3 T	16.4 T	19.0 T	18.7 C		16.8 T	19.2 T	18.3 C		16.8 T	18.3 T				19.5 T																
P 69	8.75	M	16.5 T	15.5 T	16.5 T	17.8 T	16.9 T		16.4 T	17.4 T	16.6 T			16.9 T	16.4 T			16.7 T	16.2 T																			
P 73	8.33	M	15.6 T	15.8 T	17.9 T	17.6 T	16.1 T	15.6 T	18.1 T	17.6 T	15.7 T	15.6 T	17.6 T	17.1 T					15.4 T	15.3 T	17.4 T	17.0 T	15.6 T	15.6 T		16.9 T												
C 9	9.08	M	18.2 C	17.5 C	18.9 T	19.2 C	17.8 C	17.6 C	18.7 T	19.7 C	17.9 C	17.7 C	19.0 T	19.2 C																								
C 10	8.00	M	15.9 T	15.6 C	18.6 C	18.3 C	16.3 T	16.0 C	18.3 C	18.2 C																												

APPENDIX I (Contd.)

SUBJECT CODE AGE (YRS)	SEX	NOV 78 UR*	NOV 78 UL	NOV 78 LR	NOV 78 LL	APR 79 UR	APR 79 UL	APR 79 LR	APR 79 LL	NOV 79 UR	NOV 79 UL	NOV 79 LR	NOV 79 LL
I 30 8.16	M	18.1 C	18.3 T	20.3 T	20.5 C	18.0 C	17.4 T	20.1 T	20.2 C				
I 31 8.08	M	16.6 T		17.6 T	18.4 T								
I 33 7.58	F	18.2 C	17.9 T		19.7 C	18.6 C	17.2 T		19.8 C				
I 34 7.42	F	18.6 C	18.3 T	19.2 T	19.6 T	18.0 C	18.0 T	19.5 T	19.6 T	17.7 C	18.0 T	19.0 T	19.7 T
I 35 7.33	F	16.4 C	16.9 C	16.9 T	16.9 T	16.8 C	16.3 C	17.4 T	17.3 T	16.6 C	15.9 C		
I 37 7.33	F					15.6 C	16.0 C	16.1 T	17.6 C	15.8 C	15.8 C	15.8 T	16.7 T
I 41 7.83	M	16.6 T	16.8 T	18.2 T	18.7 T	16.1 T	15.6 T	17.2 T	18.1 T	16.0 T	16.5 T	17.1 T	18.0 T
I 43 6.00	F	16.5 T	16.0 C	17.9 C	18.9 T					14.8 T	15.4 C	17.4 C	17.4 T
I 44 7.42	M	19.0 C	18.5 C	18.9 T	20.0 T	18.3 C	18.2 C	18.4 T	19.0 T				
I 48 7.25	M					16.5 C	16.5 C	19.9 T	19.4 T	15.8 C	16.6 C		
I 49 6.83	F									16.5 T	16.0 T	18.6 T	18.0 T
I 60 6.50	F	16.6 C	15.9 C	17.0 T	17.0 T	16.8 C	16.0 C	16.6 T	16.8 T			15.7 T	16.6 T
K 1 6.00	M	16.3 C	16.4 C	17.1 T	16.8 T	16.3 C	16.4 C	16.9 T	16.5 T	16.2 C	16.1 C	16.3 T	16.3 T
K 2 6.16	M	17.6 C	16.2 T	18.0 T	17.9 T	17.3 C	16.4 T	17.9 T	17.7 T	17.3 C	16.5 T	17.7 T	17.7 T
K 3 6.00	M	16.6 C	17.0 C	19.0 T	18.4 T	17.3 C	16.8 C	18.3 T	18.7 T	16.5 C	16.7 C	17.6 T	18.0 T
K 4 6.00	M	19.1 C	18.9 C	20.2 T	20.9 C	19.5 C	19.1 C	20.7 T	21.2 C	19.5 C	19.4 C	20.1 T	21.5 T
K 5 6.00	M	16.7 C	17.5 C	19.2 T	18.9 C	17.7 C	18.3 C	18.9 T	19.1 T	17.3 C	17.5 T	19.4 T	19.4 T
K 6 6.75	F					17.5 T	17.6 C	19.0 C	18.6 T	18.3 T	18.1 C	18.6 C	18.9 T

SUBJECT CODE AGE (YRS)	SEX	MAY 80 UR	MAY 80 UL	MAY 80 LR	MAY 80 LL	NOV 80 UR	NOV 80 UL	NOV 80 LR	NOV 80 LL	MAY 81 UR	MAY 81 UL	MAY 81 LR	MAY 81 LL
I 30 8.16	M					17.2 C	15.2 T	18.8 T	20.1 C	17.4 C		19.0 T	20.2 C
I 31 8.08	M					16.5 T			18.5 T	17.5 T			16.9 T
I 33 7.58	F	18.0 C	17.0 T		19.3 C	18.2 C	16.8 T		19.9 C	18.1 C	16.9 T		19.4 C
I 34 7.42	F	17.7 C	17.4 T	18.5 T	19.2 T	17.6 C	17.3 T	18.7 T	18.7 T.	17.5 C	17.4 T	18.6 T	18.3 T
I 35 7.33	F	15.8 T	15.9 C			15.8 T	15.9 C				15.8 C		
I 37 7.33	F	15.8 T	15.8 C		16.6 T	15.7 T	15.7 T			16.3 T	15.7 T		
I 41 7.83	M	16.6 T	16.7 T	17.3 T	17.4 T	16.4 T	16.9 T		17.5 T	16.2 T			17.2 T
I 43 6.00	F	15.2 T	14.6 T	18.0 C	17.3 T		14.2 T	18.0 C	17.1 T		14.2 T	17.2 C	17.0 T
I 44 7.42	M	18.0 C	17.6 C	18.6 T	19.5 T	18.0 C	17.6 C	18.4 T	19.0 T	18.1 C	17.8 C	18.2 T	18.7 T
I 48 7.25	M	16.3 C	16.3 C			16.5 C	16.2 C			16.4 C	16.4 C		
I 49 6.83	F	15.8 T	15.7 T	19.3 T	17.7 T	15.1 T	15.6 T		17.3 T	15.8 T	16.2 T		17.5 T
I 60 6.50	F			16.2 T	16.2 T			16.5 T	16.3 T				16.5 T
K 1 6.00	M	16.1 C	15.8 C	16.5 T	16.4 T	16.0 C	16.0 C	16.4 T	16.2 T	15.9 C	15.9 C	16.6 T	16.5 T
K 2 6.16	M	17.1 C	16.5 T	17.8 T		17.4 C		17.5 T		17.0 C			
K 3 6.00	M	16.6 C	17.2 C	17.5 T		16.1 T	16.7 C	17.3 T		15.9 T	16.3 T	17.5 T	
K 4 6.00	M	18.9 C	18.4 C	19.9 T	20.5 T	18.6 C	18.6 C	19.7 T	20.4 T	19.2 C	18.8 C	19.7 T	20.4 T
K 5 6.00	M	16.9 C	16.9 T	18.2 T	18.1 T	16.7 T	16.9 T	18.0 T	18.1 T	16.7 T	16.7 T	17.7 T	18.1 T
K 6 6.75	F	16.8 T	17.6 C	19.1 C	18.6 T	16.7 T	17.5 C	18.9 C	18.3 T	16.9 T	17.4 C	18.9 C	18.2 T

SUBJECT CODE AGE (YRS)	SEX	NOV 81 UR	NOV 81 UL	NOV 81 LR	NOV 81 LL	APR 82 UR	APR 82 UL	APR 82 LR	APR 82 LL	NOV 82 UR	NOV 82 UL	NOV 82 LR	NOV 82 LL
I 30 8.16	M												
I 31 8.08	M												
I 33 7.58	F	18.3 C			19.4 C								
I 34 7.42	F	17.5 C	17.7 T	18.4 T	17.9 T			18.9 T					
I 35 7.33	F		15.9 C										
I 37 7.33	F	15.7 T	15.4 T										
I 41 7.83	M	16.7 T											
I 43 6.00	F		14.2 T	17.7 C	16.8 T		14.0 T	17.4 C	16.8 T			17.4 C	16.7 T
I 44 7.42	M	18.2 C	17.7 C	18.0 T	18.6 T								
I 48 7.25	M	16.7 C	16.1 C			16.8 C	16.5 C			16.5 C	15.9 C		
I 49 6.83	F	16.0 T	16.0 T		17.0 T	15.0 T	16.5 T		17.3 T	15.0 T	15.7 T		17.1 T
I 60 6.50	F				16.6 T								
K 1 6.00	M	15.8 T	15.9 C	16.8 T	16.1 T		15.7 C	16.4 T	15.9 T		16.1 C	16.5 T	
K 2 6.16	M	17.1 C											
K 3 6.00	M	15.8 T	16.3 T	17.2 T		15.8 T	16.2 T			15.5 T	16.4 T		
K 4 6.00	M	18.7 C	18.7 C	19.7 T	20.9 T	19.7 C	19.1 C	20.0 T	20.5 T	19.0 C	18.6 C	19.8 T	20.6 T
K 5 6.00	M	16.3 T	16.2 T	18.2 T	18.2 T	16.2 T	16.1 T	18.5 T	18.0 T	15.7 T		17.6 T	18.3 T
K 6 6.75	F	16.5 T	17.4 C	19.0 C	18.4 T	16.4 T	17.1 C	18.9 C	18.0 T	16.5 T	17.2 C	19.1 C	18.1 T

<u>APPENDIX I (Contd.)</u>

SUBJECT CODE AGE (YRS)	SEX	NOV 78 UR*	NOV 78 UL	NOV 78 LR	NOV 78 LL	APR 79 UR	APR 79 UL	APR 79 LR	APR 79 LL	NOV 79 UR	NOV 79 UL	NOV 79 LR	NOV 79 LL	MAY 80 UR	MAY 80 UL	MAY 80 LR	MAY 80 LL
C 27 6.00	F	17.0 T	17.8 C	18.6 C	18.9 C	16.0 T	17.4 C	18.9 C	18.4 C	15.6 T	17.3 C	18.3 C	18.4 C	15.7 T	16.2 C	18.6 C	18.7 C
I 25 7.17	F	18.6 C	18.3 C	19.1 T	18.6 T	19.0 C	19.0 C	19.9 T	18.6 T	18.3 T	18.8 C	19.7 T	18.3 T	17.5 T			
I 32 8.17	F	15.9 T	16.7 C	17.5 C	17.2 T	15.6 T	16.5 C	17.7 C	17.7 T	15.7 T	16.3 C	17.2 C	17.2 T	15.5 T	16.6 C	17.6 C	16.8 T
I 36 8.17	F					17.4 C	17.5 C		17.7 T	17.5 C	16.5 C		17.3 T		16.5 C		17.3 T
I 42 8.17	F	15.2 C	14.8 C		17.2 C	15.7 C	14.6 C		17.5 C	15.7 C	14.6 C						
K 11 5.75	M	18.2 C	18.3 C	19.9 C	19.8 T	18.2 C	18.3 C	19.6 C	19.6 T								
K 16 5.67	M	16.7 C	16.6 C	18.4 T	18.2 T	17.0 T	16.7 C	17.8 T	18.5 T	16.6 T	17.1 C	17.4 T	18.0 T	17.1 T	16.4 T	17.7 T	
P 12 9.50	F	16.9 C	17.3 C	17.8 T	16.9 T	17.3 C	17.3 C	17.4 T		17.3 C	17.2 C			17.0 C			
P 15 8.50	M	17.6 C	17.0 C	20.0 C	19.5 T	16.7 C	16.8 C	20.1 C	19.4 T	Imp bad here	16.8 C	20.8 C	19.5 T	17.0 C			
P 24 10.42	F				17.7 C				17.5 C								
P 28 9.58	F	16.9 T		18.6 C		16.7 T											
P 32 8.58	M		15.9 C	17.9 C	17.7 C		15.8 C	17.8 C	17.6 C		14.9 C		16.9 C				18.1 C
P 36 9.25	M	16.5 T		17.3 T	17.5 T	15.9 T		17.0 T	16.3 T								
P 39 9.42	F	14.2 T	14.6 C	17.1 C	17.5 C	14.1 T	14.9 C	17.1 C	17.1 C	13.9 T		18.1 C	18.1 C			17.4 C	17.5 C
P 43 8.83	F		16.8 C	18.9 C	16.8 T		17.3 C	18.8 C									
P 61 9.42	F	14.8 T	14.3 T	15.1 T	17.0 C					15.2 T			17.0 T				
P 62 10.42	F	18.5 T		18.2 T	16.9 T	18.1 T		18.3 T	18.5 T								
P 67 10.42	F		17.1 T	19.5 C				18.6 T				18.2 T					
P 80 10.42	F	15.1 T	14.3 T	17.6 C	17.2 C	15.0 T	14.5 T	18.2 C	17.4 C	14.7 T		17.7 C	17.9 C	15.8 T			

SUBJECT CODE AGE (YRS)	SEX	NOV 80 UR	NOV 80 UL	NOV 80 LR	NOV 80 LL	MAY 81 UR	MAY 81 UL	MAY 81 LR	MAY 81 LL	NOV 81 UR	NOV 81 UL	NOV 81 LR	NOV 81 LL	APR 82 UR	APR 82 UL	APR 82 LR	APR 82 LL	NOV 82 UR	NOV 82 UL	NOV 82 LR	NOV 82 LL
C 27 6.00	F					15.3 T	16.2 C	18.6 T	18.0 T	15.5 T	15.9 T	18.6 T	18.3 T			18.4 T	18.6 T				
I 25 7.17	F	18.2 T		19.2 T																	
I 32 8.17	F	15.3 T	16.5 C	17.3 C	16.6 T																
I 36 8.17	F		16.7 C		18.3 T																
I 42 8.17	F																				
K 11 5.75	M																				
K 16 5.67	M																				
P 12 9.50	F																				
P 15 8.50	M																				
P 24 10.42	F																				
P 28 9.58	F																				
P 32 8.58	M																				
P 36 9.25	M																				
P 39 9.42	F																				
P 43 8.83	F																				
P 61 9.42	F																				
P 62 10.42	F																				
P 67 10.42	F																				
P 80 10.42	F																				

* UR = Upper Right DE Space Measurement (mm.) (UL = Upper Left; LR = Lower Right; LL = Lower Left)
C = Control DE Space
T = Treatment DE Space

APPENDIX II

COMPARATIVE DE SPACE MEASUREMENTS OBTAINED FROM WAX-BITE IMPRESSION STUDY MODELS AND FROM ALGINATE IMPRESSION STUDY MODELS

SUBJECT CODE	MEASUREMENT * 1 (mm.)	MEASUREMENT ** 2 (mm.)	DIFFERENCE (mm.)
I6	14.2	13.9	0.3
	15.6	15.4	0.2
	17.0	17.3	-0.3
	14.9	14.9	0.0
I31	14.8	15.0	-0.2
	14.5	14.4	0.1
	15.3	15.2	0.1
	15.0	14.6	0.4
C25	8.9	8.5	0.4
	13.3	13.5	-0.2
	12.9	12.9	0.0
	14.0	14.3	-0.3
P33	14.5	15.2	-0.7
	14.1	14.4	-0.3
	14.7	14.7	0.0
	14.7	14.5	0.2
I42	13.0	13.3	-0.3
	12.8	13.2	-0.4
	14.2	14.2	0.0
	14.9	14.7	0.2
P32	14.2	14.2	0.0
	13.7	13.7	0.0
	13.8	14.1	-0.3
	14.7	14.5	0.2
P39	12.9	13.1	-0.2
	14.7	14.9	-0.2
	14.0	14.0	0.0
	13.8	13.6	0.2
P73	14.7	14.9	-0.2
	14.4	14.2	0.2
	15.9	15.8	0.1
	15.1	15.5	-0.4
C24	15.4	15.8	-0.4
	15.7	15.7	0.0
	15.6	15.7	-0.1
	15.5	15.6	-0.1
I24	15.1	15.1	0.0
	14.6	14.4	0.2
	15.2	15.2	0.0
	13.3	13.8	-0.5
Number	40	40	40
Mean	14.39	14.45	-0.06
Standard Deviation	1.26	1.31	0.25
Standard Error	0.20	0.21	0.04

1st Measurement v 2nd Measurement
t = 0.2083 (Not significant)

* Measurement of DE space obtained from wax-bite impression study model

** Measurement of DE space obtained from alginate impression study model

APPENDIX III

COMPARATIVE DE SPACE MEASUREMENTS OBTAINED INITIALLY AND FROM DUPLICATE MEASUREMENTS MADE OF THE SAME SUBJECTS

SUBJECT CODE	INITIAL MEASUREMENT (mm.)	DUPLICATE MEASUREMENT * (mm.)	DIFFERENCE (mm.)
K13	16.0	16.0	0.0
	16.9	16.5	0.4
	18.9	18.9	0.0
	18.9	18.9	0.0
K9	16.7	17.9	-1.2
	17.2	17.2	0.0
	19.5	19.5	0.0
	19.5	19.4	0.1
K3	15.5	15.4	0.1
	16.4	16.2	0.2
	16.1	15.1	1.0
	14.6	14.6	0.0
I3	16.2	16.2	0.0
	16.5	16.1	0.4
	16.5	16.6	-0.1
	17.8	18.1	-0.3
C18	16.7	16.9	-0.2
	15.5	15.3	0.2
	17.7	17.7	0.0
	17.1	17.1	0.0
I5	17.1	17.2	-0.1
	16.6	17.1	-0.5
	18.6	18.5	0.1
	19.0	19.0	0.0
K4	19.0	19.0	0.0
	18.6	18.6	0.0
	19.8	20.0	-0.2
	20.6	20.1	0.5
K5	15.7	16.7	-1.0
	15.3	15.2	0.1
	17.6	17.7	-0.1
	18.3	18.3	0.0
K10	16.7	16.3	0.4
	15.6	15.6	0.0
	17.0	17.2	-0.2
	15.7	15.7	0.0
K1	15.1	15.0	0.1
	16.1	16.0	0.1
	16.5	16.4	0.1
	16.0	15.9	0.1
I43	14.9	14.9	0.0
	14.5	14.6	-0.1
	17.4	17.4	0.0
	16.7	16.8	-0.1
K12	15.9	15.5	0.4
	15.9	15.4	0.5
	17.2	17.1	0.1
	18.4	18.2	0.2
C4	16.8	16.7	0.1
	15.2	15.2	0.0
	16.5	16.5	0.0
	17.5	17.5	0.0
K1	15.9	15.8	0.1
	15.9	15.9	0.0
	16.6	16.9	-0.3
	16.5	16.6	-0.1
C25	14.1	14.0	0.1
	14.9	14.7	0.2
	16.9	16.7	0.2
	15.5	15.4	0.1
K6	18.3	18.3	0.0
	18.1	18.0	0.1
	18.6	18.8	-0.2
	18.9	19.0	-0.1
P25	16.7	16.7	0.0
	16.8	16.9	-0.1
	18.5	18.6	-0.1
	18.9	18.8	0.1
P39	14.2	14.1	0.1
	14.6	14.8	-0.2
	17.1	17.0	0.1
	17.5	17.5	0.0
K5	16.9	17.2	-0.3
	16.9	16.9	0.0
	18.2	18.1	0.1
	18.1	18.1	0.0
K17	18.8	18.9	-0.1
	18.9	18.8	0.1
	19.7	19.9	-0.2
	19.9	19.8	0.1
K1	15.8	15.8	0.0
	15.9	15.6	0.3
	16.8	16.5	0.3
	16.1	16.1	0.0
Number	84	84	84
Mean	17.01	17.00	0.02
Standard Deviation	1.47	1.50	0.27
Standard Error	0.16	0.16	0.03

Initial Measurement v Duplicate Measurement
t = 0.0728 (Not significant)

* Duplicate measurements made on randomly selected study models at least one year after initial measurement made.