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MORPHOLOGICAL CHANGES IN THE DENTURE BEARING AREA  
FOLLOWING THE EXTRACTION OF MAXILLARY TEETH

by David M. Watt, F.D.S., H.D.D. R.C.S. Edin.

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INTRODUCTION.

The atrophy of the alveolar process after the loss of the teeth is a matter of common observation and it is apparent, from general clinical experience, that the amount of the atrophic change in the residual alveolar ridges and the rate at which it takes place varies greatly between individuals and between different parts of the same mouth.

Although the growth of the alveolar processes with the eruption of the teeth and the development of the human jaws have been carefully studied, the atrophic changes following the loss of teeth have received scant attention. Nevertheless these changes are important to the practice of prosthetic dentistry. The design of prostheses to replace lost teeth and resorbed alveolar ridges is largely determined by the position and amount of morphological change in the denture bearing areas of the jaws, and to a certain extent, the optimum time for fitting prostheses depends upon the rate of change being minimal.

It is generally accepted that the rate of change slows considerably three to six months after the extraction of the teeth and is less when immediate dentures are fitted, but there is little evidence to support these assumptions which are based on clinical observations.

Very little biometric data could be found on the morphological changes in the denture bearing area following the extraction of maxillary teeth. A search of the

literature revealed only three detailed studies which together comprised data from 16 patients.

In three of the patients the investigation was limited to changes following the extraction of maxillary incisors and covered a period of one year. In ten, the morphological changes following maxillary incisor and canine loss were studied but the period was only 60 days and in the remaining three patients the post-extraction changes in the region of the maxillary posterior teeth were investigated. In two of the studies the errors in the measurements were not given and in the third the points at which the measurements were made were not defined.

There was an apparent need for further data on the subject and for this reason the present investigation was undertaken.

#### Definition of "The Denture Bearing Area".

The area comprising intra-oral mucosa covered surfaces of the alveolar and palatine processes of the maxilla and horizontal plate of the palatine bone. In the edentulous mouth it represents the area normally covered by full upper denture prostheses.

AIM OF THE PRESENT STUDY.

To devise a method for the measurement of changes in surface form of the denture bearing area following the extraction of maxillary teeth and to describe the changes observed in a selected sample of human adults.

REVIEW OF THE LITERATURE.

In this search of the literature it has not been possible to find any complete study of the morphological changes which follow the loss of the teeth. This deficiency has been noted by LISOWSKI (1944) and by LONBERG (1951). Both these workers searched the literature and, as far as can be discovered, these are the most comprehensive studies on the subject. There are, however, several papers which bear less directly on the problem but yield relevant data and these are also reviewed.

1. TECHNIQUES FOR THE INVESTIGATION OF MORPHOLOGICAL CHANGES BY SERIAL CASTS OF THE MAXILLARY DENTURE BEARING AREA.

VAN LOON (1915) STANTON (1918, 1922 a and b, 1931) and SIMON (1926) were among the first to design instruments for the orientation and comparison of dental casts, but these instruments were for the purpose of orthodontic diagnosis. Stanton's instruments made graphic tracings of the dental arcade and some of his ideas were incorporated in the instruments used in the present study.

Several techniques were devised for the specific purpose of measuring the morphological changes following tooth extraction. LISOWSKI (1944) used a tracing instrument called a "dento-contourograph" which is similar in principle to the vertical tracing instrument of the present study. He also used a modified face bow for the orientation of casts so that tracings would pass through

equivalent parts of pre-extraction and post-extraction casts. This method of cast orientation was however found to be inaccurate owing to the difficulty of duplicating the face bow position at successive visits of the patient. The rather light construction of the "dento-contourograph" may have caused additional errors in Lisowski's work but no data on the accuracy of his technique was supplied.

KROGH-POULSEN, PAFFENBARGER and SCHOONOVER (1948) of the National Bureau of Standards Washington D.C. described a method of orientating upper edentulous casts in an identical manner. Spots tattooed on the median raphe of the palate were used as reference points and sagittal, coronal, and horizontal planes were constructed. The "mucosal" surface contours of the casts were then compared either by cutting sections of the casts with reference to the planes or by measurement by means of a microscope with a dial gauge attachment. The authors pointed out that both methods of comparing casts had disadvantages. The sectioning method destroyed the casts and the microscope method, which was very time consuming, did not measure the contour of undercuts and was inaccurate on steeply sloping surfaces.

In a paper chiefly about aesthetics in full denture construction, POUND (1954) described a method of sectioning casts to illustrate the relationship of the natural teeth to the resorbed edentulous ridges. He neither gave details of how the edentulous casts were orientated nor how the positions of the sections were located and only four

photographs of sectioned casts illustrate the paper.

LAM (1960) investigated the changes in contour of the anterior part of the maxillary alveolar ridge after forceps extraction of incisor teeth in three Chinese women. Two of the women each had three incisors extracted and the third had four. Partial immediate dentures were inserted with the teeth fitted into the extraction wounds. The dentures were frequently relined and labial flanges were fitted one month after the extractions. Casts were made one day after extraction of the teeth and at intervals up to one year. Posterior teeth were present in all three patients and were used as "fixed points" for the identical orientation of the casts. The casts were mounted successively on an acrylic base by means of a hinged jig, in such a way that four points on the occlusal surfaces of the posterior teeth were in a horizontal plane. Plaster impressions were taken of the anterior parts of successive casts. These impressions included part of the acrylic base on which the casts were mounted and this provided a register for the superimposition of tracings of sagittal sections of the impressions. Lam observed the morphological changes following the extraction of the incisor teeth by measurement of the superimposed tracings.

The method had the advantage of avoiding sectioning of the casts but the impressions could not be extended on to the palate as this prevented their withdrawal from undercuts on the labial surface of the alveolar ridge. Thus the full extent of the palatal change could not be observed.

Vertical measurements of "loss of height" and horizontal measurements of "loss of labial thickness" were made on the superimposed tracings but no details of the location of the measurements were given.

Lam observed that the "average loss of labial thickness" one month after extraction was from 70% to 75% of the loss observed at one year and the loss of height one month after extraction was from 63% to 90% of the loss after one year.

No changes were observed between the fifth and the twelfth post-extraction month.

HARPER (1948, 1949, 1950) designed an instrument called the "Gnathotransit" which he attached to pre-extraction casts and then, by means of a palatal index device, transferred this to post-extraction casts of the same mouth in order to measure the "dimensional transitions of the maxillary jaw following extractions". He used adjustable spirit levels, clamped to the handle of the impression tray, to register the horizontal plane when impressions were taken with "the head held in an upright position" (1949). By this means he constructed casts with bases parallel to the horizontal plane. The "Gnathotransit" comprised a swinging arm which carried a calibrated pointer sliding in a vertical sleeve and when attached to a cast the arm swung in a horizontal plane parallel to the base of the cast. Harper measured the post-extraction changes with the calibrated pointer from a "horizontal papilla plane" which he defined as "a mechanical plane touching the surface of the incisive papilla" and parallel to the base of the cast. From these measurements he constructed diagrams to illustrate the post-extraction

changes. He described (1950) the changes observed in the study of "several cases" but gave no indication of how many and his only illustrations were diagrams of the morphological changes following tooth extraction in three patients (1950).

Harper found that the palatal index device which he used for transferring the "Gnathotransit" between casts accurately fitted the vault of the palate of all the casts of a series and concluded that this area of the palate was relatively stable. He noted the great variability of post-extraction changes from patient to patient and on opposite sides of the same mouth. He concluded (1948) that the incisive papilla did not change position up to seven years after tooth extraction, but did not present enough evidence to support this conclusion.

The present investigation showed that the position of the incisive papilla changed relative to the vault of the palate after tooth extraction and it is difficult to see how accurate measurements of change in surface form can be made by the method which Harper employed. It is possible that the "hypertrophic transition" which he described in one case may be due to a change in the "papilla plane".

RUPP, DICKSON, LAWSON & SWEENEY (1957) described a method for measuring the mucosal surface contours of impressions, casts and dentures by means of a pantographic type of comparator, a modification of "the dentograph" manufactured by G.R. Kern. In a series of five remountings of a cast with one repositioning for each mount the standard deviation of experimental error within a single mount was 0.001 inch and when differences due to remounting were

included, was 0.0018 inch. The degree of accuracy was impressive but the instrument was more suitable for the investigation of small differences between very similar objects than for the study of changes of the order of 5 mm. which occur after tooth loss. The method of mounting the casts was laborious. The instrument could not trace undercut areas as the stylus was fixed vertically and it was difficult to define the position of the change measured since the traverse of the stylus was in an arc rather than a straight line.

Two examples of the use of the instrument were given in the paper viz.:- The comparison of two dentures cured by different techniques in the same mould and measurement of the dimensional accuracy of an alginate impression of a stone cast poured in a metal mould.

SZMYD, McCALL and ALLEN (1958) briefly reviewed previous work on the study of "topographic" change in dental casts and defined the features which they felt should be incorporated in this type of study:-

- (a) An easily performed accurate procedure for mounting successive dental casts in an identical position.
- (b) A means by which mounting errors could be reduced.
- (c) A way of expressing in terms of area, the "topographic" changes in successive casts.

They described a technique for the study of "topographic" change in dental casts.

Their method of cast orientation by using a composition palatal index was rejected in the present study as it was not

found to be particularly accurate but the provision of superimposing "cassettes" which held the tracing paper in the tracing instrument which they used undoubtedly reduced the errors caused by faulty cast positioning.

The instrument consisted of a stylus which was drawn across the casts and, by means of a rather complex rack and pinion system, a pen traced the contour of the first of a series of casts on transparent paper held in a fixed "cassette". An adjustable "cassette" was also provided to accept the trace of the second cast which could then be aligned with the first trace by moving the "cassette". The fixed "cassette" was then removed and the first cast repositioned on the base of the instrument and the tracing repeated on the adjustable "cassette" so that it carried superimposed tracings of the first and second casts. The "topographical" change between the two tracings was measured as an area by means of a planimeter.

The average percentage errors in the technique were estimated as follows:- Instrument error 0.8%, impression mounting error 1.4%, and planimeter error 0.9%.

The authors stated that they used the instrument to measure the effect of immediate and conventional dentures on mucosal topography but they gave no data.

BUNN & TURNER (1956) published an ingenious technique for representing the contours of a skull by photographing it partially submerged in a tank of water. A source of light below the surface of the water illuminated the meniscus and provided a clear cut contour of the skull at

that level. This method has much to recommend it but has not been applied to the study of dental casts in the present investigation since immersion of a cast with its base horizontal would obscure the contours of the buccal undercut areas and immersion with the base held vertically would obscure the palatal contours. Another reason for the rejection of this type of contouring method in the present investigation was the difficulty of presenting the data in a manner which could be easily interpreted in terms of full denture design.

Photogrammetric methods for the measurements of dental casts have been described by THAM (1946) and NYQUIST & THAM (1951) but the same difficulties in contouring the buccal undercuts and palate were encountered with these methods. Neither of these papers presented any data on morphological changes following the loss of teeth.

It is evident that many methods are available for the investigation of morphological change in serial casts of the mouth but the data published on the change following the extraction of teeth is very scanty.

The most extensive work was by LISOWSKI (1944). It comprised data from ten patients, referred only to the upper anterior teeth and covered a period of only two months. All the patients had immediate dentures fitted and had either radical or conservative bone trimming carried out at the time of extraction of the teeth. His thesis did not show how much of the change was due to the surgery and how much to the normal process of resorption and no attempt was made to

calibrate the accuracy of the technique. Lisowski's measurements in five cases subjected to "conservative surgery" showed that the height and buccal surface of the residual alveolar ridge in 321/123 region were reduced on average by about 2 mm. 60 days after extraction, while the radical surgery group (5 patients) showed a similar reduction in height but twice as much buccal reduction.

Apart from this the only other data available were from the three cases of Harper and the three of Lam. The greatest period covered by one of Harper's cases was eight months but the accuracy of his measurements is questionable and the amount of evidence presented is insufficient to support the conclusions contained in his paper. Lam's study covers a period of one year but was limited to the changes following the extraction of 10 incisors from 3 Chinese women and his method did not illustrate palatal changes.

## 2. THE HEALING OF WOUNDS CAUSED BY TOOTH EXTRACTION.

This section of the literature is singularly unproductive of information on the effect of extraction of teeth on the surface form of human jaws.

### Animal Experiments:

Descriptions of the healing of extraction wounds are to be found in standard text books KRONFELD (1949) WEINMANN & SICHER (1955) but they are based chiefly on animal experiments and give little or no information on the

morphological changes observed in human subjects. SPITZER (1911) EULER (1923) SZABO (1928) SCHRAM (1929, 1948) and CLAFLIN (1936) (1937) studied the healing of extraction wounds in dogs. EULER (1923) reviewed the earlier literature and SZABO's paper (1928) included a serial Roentgenographic study of mandibular extraction wound healing in 63 patients, five of these were reported in detail. However the variation in positioning of his radiographs precluded their use for the study of surface change. It is of interest to note that HUBBELL & AUSTIN (1941) and SIMPSON (1956) considered that radiographs had little or no value in the study of healing of extraction wounds.

A vertical section diagram which compared the effect of alveolectomy and forceps extraction on the shape of the residual alveolar ridge in dogs was included in SCHRAM's paper (1929) but as far as could be seen, no measurements were used in its construction. CLAFLIN's work (1936) on dogs was very similar to SCHRAM's and provided no data on morphological change applicable to the present study. However he concluded that in the limited sample (3 dogs) healing of extraction wounds followed by alveolectomy was more rapid than the healing of simple extraction wounds. This he attributed in part to the closure of the wound and partly to the reduction of the depth of the socket by removal of bone.

SIMPSON (1956) and RADDON (1959), in similar histological studies of material from *Macacus Rhesus*

monkeys, investigated the healing process at intervals up to 63 days, in wounds caused by the removal of teeth by various methods. The literature was reviewed by both these workers. RADDON confirmed SIMPSON's conclusion that the least reduction of the residual alveolar ridge was to be found in cases where simple extraction of the teeth with forceps was carried out, provided excessive force had not been used. RADDON also concluded that the healing process which most nearly approached that of "first intention" was to be found when a surgical technique was used with minimal reflection of the mucoperiosteum, removal of sufficient bone to permit ready elevation of the teeth and subsequent careful apposition of freshened epithelial edges.

Apart from general conclusions on the height and shape of the residual alveolar ridges, which, SIMPSON (1956) stated were left largely to judgment and could be assessed only approximately; neither of these papers provided information about surface changes.

Simpson found that the ossification of the socket contents advanced to the level of a line joining the alveolar crests or reduced alveolar plates and thereafter made little progress other than the formation of early cortex by the end of eight weeks. He concluded that because of this limit to new bone formation the configuration of the healed alveolar ridge is strongly influenced by the extraction technique employed. Forceps extraction wounds showed a rounded alveolar crest with its highest point towards the lingual side of the socket. He also noted that "the

pronounced resorption of the buccal or labial alveolar plate had little effect on the form of the ridge as by the time any great degree of resorption occurred the new bone was able to maintain the height and approximately the shape of the ridge".

#### Human Experiments:

Studies of extraction wound healing in human subjects provided little data on morphological change. Many papers were in the nature of clinical observations on the value of various agents such as vitamins, antibiotics, haemostatics and other medicaments in the healing of extraction wounds. Examples of those were CAMPBELL & COOK (1942) Vitamin C, HITCHIN & LATUER (1945) local use of penicillin, SHARP (1948) human fibrin foam and thrombin, GURALNICK & BERG (1948) "Gelfoam" gelatine sponge, NATHAN (1948) oxidized cellulose. There were however some histological studies of the healing of human tooth extraction wounds.

MANGOS (1941) reported on the healing of human upper lateral incisor tooth sockets from a study of biopsy and autopsy material. He found that the epithelium took twice as long to heal in man as in dogs and the repair of bone took three times longer in man. No details of morphological changes during the healing process were given in this paper but he observed in one specimen, taken fifteen weeks after extraction, that the new bone had completely filled the socket.

CHRISTOPHER (1942) studied normal and delayed healing in human biopsy material from tooth sockets up to ten days

after extraction. By comparing the progress of healing at this stage with the healing found in animal experiments by other workers, he inferred that normal bone healing in human beings would be complete in about eighteen weeks. He also noted that, in the early stages, the greater part of the resorption took place at the margins of the socket and that there was a natural tendency of the bone to round over and become smooth but apart from such general observations no details of surface change were given.

SUTTON (1948) made histological sections of human biopsy material to show the effect of gelatin sponge on extraction wound healing. His specimens were unsuitable for the study of morphological change. This is not surprising when one considers the implications of removing sufficiently large biopsy specimens from the human mouth.

SWINBURN (1952) in a similar study found no significant differences in the time of healing and histological changes observed in alginate treated and untreated human extraction wounds. He noted however that osteoclastic activity reached its maximum on the 14th day and was chiefly located on the third of the buccal plate nearest the socket margins, but there was very little resorption of the actual crest and of the inner surface of the socket.

It is obvious that animal studies provided little useful data on the morphological changes in the human mouth and the few human studies in this section of the literature were of such a nature that the progress of surface change was not illustrated.

LISOWSKI's (1944) and LAM's (1960) longitudinal studies on resorption of alveolar ridge tissue under immediate dentures, which have already been mentioned, were apparently the only studies which provided a modicum of data on the morphological changes which followed human tooth extraction.

There are however some general observations in this section of the literature which are relevant to the present study viz.

- (1) The residual alveolar ridge is apparently least reduced in cases where teeth have been extracted with forceps provided the minimum trauma has been used.
- (2) A general tendency for the alveolar process to round off and become smooth has been observed.
- (3) The amount of bone deposited has not been found to extend beyond the level of the socket margins.
- (4) It is possible that the bony healing of human tooth sockets may be completed 15 to 18 weeks after extraction but, since the only data available was one post mortem specimen and some deduced evidence this assumption is not reliable.

### 3. RESORPTIVE CHANGES IN THE JAWS FOLLOWING LOSS OF THE TEETH.

Little information on morphological changes following the loss of teeth can be gleaned from radiographic studies.

In a study of 1000 full mouth intra-oral X-rays taken by a standardised technique McKEVITT (1932) concluded that the alveolar processes before the extraction of teeth fell into three groups - hypercalcemic, normal and hypocalcemic.

Following closely a paper by JACKSON (1929) he defined three types of post-extraction change - uniform atrophy, serrated atrophy and mixed atrophy and "hypertrophy" and attempted to correlate these changes with the type of bone found in pre-extraction radiographs. Apparently the types of bone were assessed chiefly from visual appraisal of the density of the radiographic shadow since no mention of a densitometer is made. His radiographic technique made no allowance for variations in soft tissue thickness and no details are given of the 1000 cases on which the study is based.

The validity of the evidence presented in both McKEVITT's and JACKSON's papers is questionable and the evidence is insufficient to support their conclusions. Other similar work of a clinical nature on small numbers of patients was published by MACMILLAN (1924 - 1926, 1928a and b, 1937), YOUNG (1937) and HUGHES (1939).

A radiographic cross-section study of "changes in the size of the lower jaw on account of age and loss of teeth" by LÖNBERG (1951) is probably the most extensive investigation of its kind. Lonberg compared 151 young men with 300 elderly men by direct and radiographic measurements. Each group comprised dentulous and edentulous patients. He used notched markers to calibrate the errors inherent in the measurements from radiographs but it is doubtful whether the points of measurement which he used in his cross-sectional study to compare dentulous and edentulous jaws of different individuals were sufficiently comparable to make his results valid. He found that the average mandibular

height decreased in the second molar region after the loss of teeth by  $5.57 \pm .51$  mm. in old men and by  $5.31 \pm .52$  mm. in young men. Similar decreases of  $4.30 \pm .67$  mm. and  $4.07 \pm .59$  mm. took place at the symphysis menti in old and young men respectively on the loss of teeth. In addition he demonstrated the surface area of the body of the mandible on profile radiographs decreased after the loss of teeth by  $3.46 \pm .39$  cm.<sup>2</sup> in young men and  $3.49 \pm .39$  cm.<sup>2</sup> in old men.

He demonstrated a probable increase in the total depth of the mandible, from the incisal edges of the lower anterior teeth to the lower border of the mandible took place in the older group, presumably owing to eruption of the teeth progressing with age.

On average the height of the ascending ramus increased in older persons with teeth by  $3.44 \pm 0.75$  mm.

A decrease of the depth of jaw itself at the symphysis menti was found to take place in persons with teeth the older group showed  $1.57 \pm 0.46$  mm. less mandibular depth than the younger group by radiographs and  $2.62 \pm .72$  mm. less depth by direct measurements.

ATWOOD (1957) investigated the variability in the rate of bone loss following the extraction of teeth by means of profile cephalometric radiographs in 32 patients. His measurements in the median plane were as follows:-

Nasion to residual maxillary ridge crest.

Crest of maxillary ridge to crest of mandibular ridge.

Gnathion to crest of residual mandibular ridge.

The 32 patients fell into two groups:-

- (1) Those whose vertical dimension with the denture in occlusion exceeded their resting vertical dimension (without dentures) were considered to have inadequate free-way space.
- (2) Those whose vertical dimension with the dentures in occlusion was at least 1.0 mm. less than their resting vertical dimension (without dentures) were considered to have adequate free-way space.

These criteria on which Atwood based his estimate of adequacy or inadequacy of the free-way space are of doubtful value especially in view of his findings on the variability of the resting vertical dimension after loss of occlusal contacts. It is felt that THOMPSON (1946) and TALLGREN (1957) used more dependable criteria in their studies which will be reviewed later. Atwood was unable to show any correlation between the adequacy of the free-way space and the amount of bone loss. He attributed this to the interplay of many factors affecting the rate of bone loss.

He did however give some data on the rate of bone loss before and after the insertion of dentures but since the times of insertion varied from immediately after extraction of the teeth to 8 months and the "post insertion" periods varied from 5 months to 46 months, it is doubtful whether the division into "pre-insertion" and "post insertion" periods has any value. For example his average figures for "pre-insertion" bone loss in different groups varied

from 0.37 to 1.26 mm/month while the "post-insertion" change varied from 0.1 to 0.21 mm/month. He pointed out that the pre-insertion figures were large because they included the rapid resorption immediately following extraction.

Nevertheless two immediate denture cases were included in the post-insertion cases and naturally would influence the average post-insertion figures.

ATWOOD (1957) observed that the rate of bone loss was rapid during the first three or four months but tended to become slower thereafter. He illustrated this by plotting the curves of vertical bone loss against a time base of up to fifty months in two patients. He also noted that these curves showed no appreciable deflection at the time of insertion of the dentures.

#### Clinical Studies:-

Papers based on purely clinical observations of changes in the residual alveolar ridge following the loss of teeth have been published by ANDUEZA (1947) SCHLOSSER (1950) LAMMIE (1956).

Most of the conclusions in these papers have too little evidence to support them but it is apparent that there is a wide range in the amount of resorptive change in different individuals and many factors operate to influence the rate and amount of change in each individual.

4. CHANGES IN FACE HEIGHT AND MANDIBULAR POSITION FOLLOWING LOSS OF THE TEETH AND PROSTHETIC TREATMENT.

Two papers by CLAPP (1923) give very brief descriptions of facial changes following the loss of teeth. Each paper is based on clinical observations on one edentulous patient and is of little value.

J.R. THOMPSON (1946) carried out an X-ray cephalometric analysis of thirty patients wearing full or partial denture prosthesis. One of the objects of this study was to assess the effect of denture wearing on the resting position of the mandible, over periods of up to  $6\frac{1}{2}$  years. Measurements were made of face height (nasion to gnathion) and of "nose height" (nasion to anterior nasal spine).

In twelve patients, at the time of insertion of the prosthesis, the face height with the dentures in occlusion was greater than the pre-extraction "resting face height" but in all these cases Thompson observed that the resorption of the alveolar processes continued until the resting face height was re-established with a free-way space of 2-3 mm. between the occlusal surfaces of the artificial teeth.

It is of interest to note that although the resorptive change exceeded 6 mm. in some cases, none of his illustrative tracings showed changes in the level of the palate or floor of the nose. The greater part of the resorption appeared to take place in the mandibular ridge.

Thompson's main conclusion from this and other parts of his study was that the resting position of the mandible was constant. Later work by TALLGREN (1957) and ATWOOD (1956,

1957, 1958) did not confirm this conclusion and in a later paper THOMPSON (1954) himself may have had second thoughts on the subject since he mentioned that variation of the normal mandibular resting position may exist and was related to abnormalities of muscle tone.

JENSEN (1959) studied the face height in edentulous patients wearing full dentures. He used electromyographic data to establish the rest position of the mandible and took cephalometric radiographs for measurement of face height. He found such small variation in the resting vertical dimension of the face before and up to four months after the insertion of dentures, that he concluded that the resting vertical dimension was constant. He found however that more than half the patients had a greater than average free-way space, which would seem to indicate either that the vertical dimension of the prosthesis when fitted was less than the pre-extraction figure or that alveolar ridge resorption following extraction was responsible for this increased inter occlusal clearance.

ATWOOD (1956) made an X-ray cephalometric study of the clinical resting position of the mandible in forty two patients before and after the removal of occlusal contacts. He found that the resting vertical dimension in edentulous patients varied significantly between different readings at a single sitting, between average readings of different sittings and between readings with and without dentures. Even greater variations occurred between pre- and post-extraction readings.

Of the forty two patients eleven showed an increase in resting vertical dimension following the removal of occlusal contacts, nine fluctuated about their individual base lines and twenty two showed a decrease in vertical dimension.

ATWOOD (1958) also investigated over thirty clinical factors, presented in six groups, which he felt might affect the resting position of the mandible, but, while interesting trends were shown for each group of factors, no single factor or group of factors was exactly correlated with the degree of variability observed in the rest position in all patients.

TALLGREN (1957) in a Röntgen cephalometric study investigated the changes in adult face height due to ageing, wear and loss of teeth and prosthetic treatment. Much of her thesis was devoted to the study of normal cases with teeth and cases of attrition but there was also included a study of forty five patients who had worn dentures for ten years or more and a longitudinal study of eighteen completely edentulous patients and twenty patients who had either an edentulous maxilla or mandible opposed by a partially edentulous jaw. The longitudinal study covered a period of one year and the following findings are of interest:-

- (1) After loss of teeth the resting face height showed an average reduction of 1.4 mm. as compared with 3 mm. average closure in the twenty two of Atwood's cases which showed a reduction in vertical dimension. The average for Atwood's whole sample would of course be less.

- (2) The restored "morphologic face height" after dentures were fitted (i.e. the face height with the dentures in occlusion) was on average 3.3 mm. larger than the pre-extraction "morphologic face height" and corresponded to the pre-extraction resting face height. This increase, caused by prosthetic treatment, was found to be greater in persons with low face height.
- (3) After six months of denture wear the morphologic face height showed an average reduction of 2 mm. with a corresponding rest face height reduction. During the second half-year of denture wear much smaller reductions in face height took place ( $0.73 \pm 0.13$  mm.) and at the end of a year the morphologic face height remained greater than the pre-extraction measurement.

In a study of long term denture wearers, however, it was obvious that the reduction of face height continued and became less than the pre-extraction measurement, and Tallgren assumed that this was chiefly due to resorption of the alveolar ridges.

Tallgren regarded the most important conclusion of the study was that the resting face height seemed to adapt itself to changes in the morphologic face height.

On balance the evidence seems to indicate that the height of the face (nasion - gnathion) with the mandible at rest is not constant and therefore cannot be used with any confidence as a baseline for the measurement of alveolar ridge resorption. It seems likely that a reduction in face height is to be expected, after the extraction of the

teeth, in at least fifty per cent of patients. The "morphologic face height" in edentulous patients i.e. the face height with the prosthesis in occlusion, seems to vary considerably and apparently depends on the individual who registers the "bite". In the majority of Tallgren's patients it was greater than the pre-extraction dimension, less than half of Thompson's patients showed this increase and more than half of Jensen's patients possibly showed a decrease in "morphological face height" below the pre-extraction figure.

5. RADIOGRAPHIC EVIDENCE OF THE CONSTANCY OF THE POSITION OF THE PALATE AND NASAL FLOOR RELATIVE TO THE CRANIUM IN DENTURE WEARING ADULTS.

A feature of the foregoing X-ray cephalometric work which is of some importance to the present study, is that none of the observers noted changes in the position of the nasal floor or palate shadows following the loss of teeth and the wearing of dentures. Although this evidence of the stability of these structures is rather negative in character there can be little doubt that had any appreciable change occurred it would have been observed since the palatal shadow and cranial contours were superimposed in all the above studies. Radiographic evidence of a more positive nature has been supplied in a personal communication from Professor H.F. Atkinson (1960) of the University of Melbourne. He carried out a serial radiographic study of twelve patients to determine whether or not a change in the position of the palatal shadow was apparent after full

dentures were fitted and stated that no change could be detected radiographically over a period of one year in any of the patients.

6. CHANGES IN THE MOUTH FOLLOWING THE WEARING OF DENTAL PROSTHESIS.

Papers on the effect of prosthesis on the tissues of the mouth have been published by STANSBERRY (1928) MACMILLAN (1928) WRIGHT (1929, 1933) GROHS (1935) PENDLETON (1935, 1936, 1951) CHICK (1949) VAN HUYSEN (1954) FROHLICH (1952, 1954, 1958) NYQUIST (1952) KOIVUMAA (1956) LYTLE (1957) OSTLUND (1958) and many others. Several of these publications are in the form of reports based on clinical observations and only such experimental work as is relevant to morphological change will be reviewed here.

In a histological study of the jaws from five autopsy subjects who had worn prosthesis GROHS (1935) concluded that, in the course of time, the tissues adjust themselves to the base of the denture. In areas where the denture causes an increased pressure bone is resorbed and if the pressure is relieved the bone is in a condition of rest or there is moderate new formation of bone but if the occlusion of the denture is unbalanced or the base fits very badly the trauma continues and resorption outstrips repair until the jaws are "put into an irreparable condition".

In Groh's study of autopsy material, evidence was lacking as to the nature of the forces on the dentures which produced the changes he observed. Nevertheless his

illustrations seemed to show that the presence of the dentures was closely connected with the changes. For example in one of his specimens a groove on the surface of the mandible exactly corresponded in position and shape with the flange of the denture which had been worn for a number of years. Active resorption of bone was seen at the depth of the groove while bone deposition was evident elsewhere. Other specimens of a similar nature provided the rather scanty evidence on which his conclusions were based.

PENDLETON and GLUPKER (1935) and PENDLETON (1936) (1951) also investigated the effect of dentures on the jaws. In a histological study (1951) of biopsy material from 126 edentulous subjects comprising 39 denture wearers and 87 control patients who had not worn dentures, Pendleton concluded that "changes common to denture wearing individuals were equally prevalent in cases where no form of prosthesis had been worn". He also noted that "repair of bone lost by resorption was in evidence wherever bone was found in the material studied". "Reinforcement of the internal structure of the bone was evident in every instance where the outer surface had been affected by resorption".

In addition to his work on the reaction of the denture bearing areas of the jaws to dentures PENDLETON (1932, 1934, 1937) studied the minute anatomy of the edentulous jaws in decalcified sections of autopsy material, and with a series of dissections (1946) illustrated the anatomy of the face and mouth in relation to full denture prosthesis. In one study (1937) of material from the maxilla of a male who had

worn dentures, Pendleton attempted to draw conclusions on the effect of denture trauma on the residual ridge structures by reconstruction of the subject's occlusion on an articulator. While much of this work was of necessity rather conjectural, his findings tended to confirm those of GROHS (1935).

FROHLICH (1952, 1954, 1958) used autopsy material from 117 subjects who had worn dentures and 26 who had not, in a cross section study of the effects of dentures on the jaws. He confirmed Groh's findings on the adaptation of the tissues to the dentures and showed some cases of gross changes produced by poorly fitting unbalanced dentures where adaptation was not possible owing to the continuing trauma.

He also noted (1952, 1954) that the soft tissues overlying the resorbing alveolar ridges were thicker in cases where dentures had been worn over long periods of time. He assumed that this thickening altered the amount and direction of the force on the ridges and tended to reduce the trauma and consequent atrophy. He observed (1952) a tendency for the atrophy to be greater in the anterior than in the posterior parts of the maxillary ridge so that the angle between Camper's plane and the crest of the alveolar ridge increased with the length of time the dentures had been worn. The value of this type of study is of course limited by lack of information about the circumstances connected with the wearing of the dentures during life.

KOIVUMAA (1956) in a pantographic X-ray examination of 132 patients who had worn mucosa borne partial dentures for approximately six years, found that 92% - 98% showed resorption of the alveolar process and marked resorption was

more common in denture wearers (37% - 50%) than in those without dentures (20%).

CAMPBELL, R.L. (1960) measured in the median plane, the height and labio-lingual thickness of the residual alveolar ridges on casts of 69 edentulous persons, 38 of whom wore dentures and 31 did not. He found the ridges were lower and narrower in the 38 denture wearing patients but it is doubtful if his method of measurement was sufficiently accurate to enable him to draw valid conclusions from his study.

KOIVUMAA (1956) observed inflammation of the mucosa covering the edentulous parts of the mandibular ridges in 8% of patients who wore mucosa borne partial dentures "always" and in 5% of patients who wore similar dentures only during the day. The palatal mucosa on the other hand showed inflammation in 42% of patients in the former class and 13% of patients in the latter.

NYQUIST (1952) carried out an extensive clinical study of the inflammatory lesions of the oral mucosa in denture wearing patients. He classified the dentures into two main groups, ideal and traumatizing. He found that in 405 patients with "ideal dentures" 1.7% had "denture sore mouth" and this condition was present in 35.2% of 685 patients with "traumatizing dentures". He also found a direct relationship between the number of traumatizing factors present in the dentures and the incidence of "denture sore mouth".

He concluded that "trauma is a deciding factor in the occurrence of denture sore mouth".

The morphological changes produced by inflammation of the palate have not been completely investigated but some information is available in a cross-section study by ÖSTLUND (1958) of biopsy specimens of palatal mucosa from 291 patients. He found no statistically significant difference in thickness between inflamed and normal mucosa but this may have been due to the method of preparation of the specimens before measurement. He observed, as a general trend, that the mucosa in the area studied increased in thickness with the length of time dentures were worn. The amount of thickening was not significant and was probably due to differences in size and composition of the samples in each group. One group of patients who had worn dentures 2 - 3 years comprised 26 males and 14 females and showed an average mucosal thickness of 2.93 mm.  $\pm$  0.11 mm. as compared with 2.77 mm.  $\pm$  0.17 mm. for normal mucosa in a sample of 7 males and 7 females who had not worn dentures. It is likely that this difference of 0.16 mm. which is obviously not significant, was chiefly due to a difference in sample since Östlund found that the mucosa of males was slightly thicker than that of females. The difference of mean mucosal thickness between males and females was 0.26 mm.

LYTLE (1957) described the use of Rupp's instrument (RUPP et al 1957) in measuring the amount of tissue recovery which took place on the removal of ill fitting dentures in a male patient who had worn them for two years. The maximum change of contour observed was 0.055 inch (1.39 mm). Well fitting balanced dentures were then fitted and worn for 15 months and the maximum change of contour on their removal

was found to be 0.01 inch (0.25 mm.). The measurements were made by Rupp and no details were given as to the method employed in the location of the parts traced and measured.

Lytle also described, in the same paper, a radiographic technique for the measurement of mucosal recovery after the removal of ill fitting dentures, but it is doubtful whether the accuracy of his method was sufficient to produce valid measurements of the relatively small changes which took place.

It appears from the foregoing review that there is a scarcity of really sound evidence on the oral tissue changes which accompany the wearing of dental prosthesis but in general terms, the changes to be expected are soft tissue compression, atrophy and resorption of bone in areas of increased pressure by the denture and oedema and hyperplasia of the soft tissues and possibly bone deposition in areas of decreased pressure. Thus, in time, the tissues may tend to adapt themselves to the fitting surface of the prosthesis. It also appears that these changes, to a certain extent, are reversible and when the denture is not worn for some time a measurable amount of tissue recovery may take place. It is a matter of common experience that a denture which has been worn for many years without relining may appear to fit quite well but if not worn for a few days fits badly. The owners of such dentures generally prefer to wear them overnight as otherwise the dentures feel loose when inserted in the morning but become firmer after being worn for an hour or two. Such overnight change on removal of the denture is probably due to reduction

of oedema and recovery of localised areas of tissue compression.

The amount of morphological change produced by the adaptation of the tissues to the dentures is likely to be minimal in cases where the fit is good and the articulation balanced. It is obvious that the balance of the occlusion and accuracy of the fit of a denture are relative values based on clinical criteria which vary considerably between different observers and with a single observer on different patients. The accuracy of dentures is discussed on page 121 and the implications of a general tendency of the tissues to adapt themselves to the fitting surfaces of dentures on pages 121 & 122.

#### SUMMARY.

1. Many methods have been devised for studying the morphological changes in the jaws following the loss of teeth but very little data in the form of measurements of changes has been published.
2. The average measurements by various workers which might serve as a comparison with those of the present study are as follows:-

LISOWSKI (1944) in 5 patients where 321/123 were extracted with forceps followed by conservative bone trimming about 2 mm. vertical loss and 2 mm. buccal loss were observed 60 days after extraction.

LAM (1960) found that the loss in height of the alveolar ridge one month after extraction was from 63% to

90% of the loss in height observed at one year and the loss of labial thickness at one month was from 70% to 75% of the loss at one year.

The mean of the loss in height of the alveolar ridge observed, in his three patients, one month after extraction of the teeth was 2.7 mm. and at five months and one year was 3.7 mm. The corresponding means of loss in labial thickness were 3.2 mm. at one month and 4.1 mm. at five months and one year. The measurements at five months and one year were identical.

LONBERG (1951) in a cross section study of 151 young men and 300 elderly men found that on average the loss of the lower posterior teeth was accompanied by a reduction of the depth of the mandible in the second molar region of  $5.57 \pm .51$  mm. in old men and  $5.31 \pm .52$  mm. in young men. The loss of the lower anterior teeth reduced the depth of the mandible in the median plane by  $4.30 \pm .67$  mm. in old men and  $4.07 \pm .59$  mm. in young men. Details of the length of time since the extraction of the teeth are not given. ATWOOD (1957) in a radiographic study of 32 denture wearing patients estimated the combined loss of alveolar ridge height in the median plane of maxilla and mandible varied from 0.37 to 1.26 mm. per month before the insertion of dentures and from 0.1 to 0.21 mm/month after insertion of the dentures.

THOMPSON (1946) in a similar study found the total vertical bone loss to exceed 6 mm. in some cases. The greater part of this loss apparently took place in the mandible. TALLGREN (1957) in a radiographic study of face

height found that six months after prosthesis which "propped the bite" had been fitted the face height with the dentures in occlusion showed an average reduction of 2mm. During the second half-year of denture wearing an average reduction of  $0.73 \pm 0.13$  mm. was observed.

3. Studies of the healing of extraction wounds show:-

(a) There is least loss of alveolar ridge height when a simple forceps extraction technique is used provided the trauma is minimal.

(b) The bone fills the sockets to the level of their margins or to the level of the reduced alveolar plates in cases of alveolectomy.

(c) The human tooth socket may possibly be filled with bone about 15 - 18 weeks after extraction.

(d) There is a general tendency for the bone to round over and become smooth after tooth extraction.

4. Loss of the teeth is accompanied most often by a reduction in the resting face height owing to a change in the resting position of the mandible, but increases in resting face height after the loss of the teeth have been observed (ATWOOD 1956).

5. The face height of edentulous patients with prostheses in occlusion depends chiefly on the judgment of the clinician when he registers the "bite". Variations above and below the measurement of face height with the natural teeth in occlusion are apparently common.

6. A general tendency for the denture bearing tissues to adjust themselves to the shape of the fitting surface of the dental prosthesis has been observed.

7. Observations on edentulous and partially edentulous patients with and without dentures seem to indicate that more alveolar ridge loss takes place in patients with dentures.
8. The vault of the palate appears to be relatively constant in its relationship to the rest of the cranium in denture wearing adults.

DEFINITIONS.

"Tracing" and "trace":- Used as nouns these words are interchangeable, but in the text:-

"A tracing" is the line traced on the cast by the stylus of the tracing instrument.

"A trace" is the outline of the cast, either on paper or as a photograph, which has been produced by a tracing.

"Horizontal Tracings":- Tracings on a cast in a plane parallel to the "occlusal plane" as defined by three points on the occlusal surfaces of the teeth before extraction. The casts were oriented so that the latter plane was horizontal.

"Vertical Tracings":- Tracings in planes perpendicular to the "occlusal plane" of a cast.

The "Median plane":- A plane defined by one anterior and one posterior point on the median raphe of the palate and perpendicular to the "occlusal plane" of the cast.

"Sagittal tracing":- A vertical tracing in a plane parallel to the "median plane" of a cast.

"Coronal tracing":- A vertical tracing in a plane perpendicular to the median plane of a cast.

"Palate" and "Hard Palate":- The mucosal covered surface of the upper jaw bounded anteriorly and laterally by the lingual surfaces of the maxillary teeth and posteriorly by the anterior border of the soft palate.

"Buccal":- Includes labial.

MATERIALS & METHODS.

The changes in the mucosal surface form of the denture bearing area of the upper jaw following the extraction of teeth was observed in a sample selected from patients attending the prosthetic clinic of Edinburgh Dental Hospital.

Impressions were taken before and at intervals after the extraction of the teeth and vertical section tracings of the pre- and post-extraction casts were made as follows:-

Tracings in sagittal planes:- Through the median plane and central incisors.

Tracings in coronal planes:- Through canines, first and second premolars and first, second and third molars.

Thus in the whole sample eight regions of the maxillary denture bearing area were studied but in each series of casts vertical section traces were made only where teeth were present at the start of the study.

The post-extraction traces of a region were superimposed in turn on the equivalent pre-extraction trace and five measurements of the post-extraction changes were made at each tooth position on each trace of the series. Thus ten measurements were made of traces passing through symmetrically positioned teeth at each post-extraction interval.

Horizontal section tracings parallel to the occlusal plane, as defined by three points on the occlusal surfaces of the teeth, were made through the alveolar ridges of the first and last cast of each series. These provided a more general picture of the changes which occurred during the period of study as they crossed areas which were not included in the vertical tracings.

### The Sample.

The exacting and time consuming nature of the technique which was necessary for the investigation of the relatively small morphological changes which follow the loss of teeth, made it impracticable to use a large sample for this longitudinal study. It was recognised that in a long term study losses from the sample could be expected.

Seventy-one individuals (35 males and 36 females) were selected from patients attending the prosthetic clinic of Edinburgh Dental Hospital. The only criterion applied in the selection was that each of the patients should have at least four maxillary teeth to be extracted. In every case the teeth were extracted with forceps and no bone trimming or suturing was carried out.

These patients had pre- and post-extraction casts made and attended the clinic at varying times in diminishing numbers as the study progressed, up to a period of four years. It was particularly difficult to persuade some patients to return for further impressions after dentures had been fitted, and many of the series of casts terminated at that point. As a result only fifteen of the males and ten of the females had adequate series of casts made at intervals over periods of  $2\frac{1}{2}$  years or more. The post-extraction intervals at which casts were made varied considerably between patients and between different groups of extractions in the same patient, but as far as possible an attempt was made to obtain casts at fortnightly intervals for/

for the first two months , and at the third, sixth, ninth and twelfth post-extraction month, and thereafter at six-monthly intervals.

In all 1285 vertical section traces and 50 horizontal section traces were made of 206 casts from the 25 patients, and comprise the material for this study.

Only one of the 25 patients had a full complement of maxillary teeth and therefore in each of the 8 regions traced, the number of individuals studied is less than 25.

Distribution of males and females.

The number of males and females represented in the samples of each of the eight regions studied is shown in Table 1 .

TABLE 1.

|              | <u>Median</u> | <u>1/1</u> | <u>3/3</u> | <u>4/4</u> | <u>5/5</u> | <u>6/6</u> | <u>7/7</u> | <u>8/8</u> |
|--------------|---------------|------------|------------|------------|------------|------------|------------|------------|
| Males        | 12            | 13         | 6          | 7          | 4          | 3          | 4          | 2          |
| Females      | 6             | 9          | 9          | 8          | 5          | 5          | 5          | 6          |
| <b>Total</b> | <b>18</b>     | <b>22</b>  | <b>15</b>  | <b>15</b>  | <b>9</b>   | <b>8</b>   | <b>9</b>   | <b>8</b>   |

It can be seen that the males predominate in the larger samples of anterior teeth; the females predominate in the smaller samples of posterior teeth.

Distribution by age.

Table 2 shows the distribution by age of the 25 patients in the sample.

TABLE 2.

| <u>Age in years<br/>at first visit</u> | <u>Number of<br/>patients.</u> |
|--|--------------------------------|
| 16-20                                  | 1                              |
| 21-25                                  | -                              |
| 26-30                                  | 5                              |
| 31-35                                  | 7                              |
| 36-40                                  | 2                              |
| 41-45                                  | 4                              |
| 46-50                                  | 3                              |
| 51-55                                  | 2                              |
| <u>56-60</u>                           | <u>1</u>                       |
| Total                                  | 25                             |

Exclusions:-

Certain teeth and equivalent post-extraction areas were excluded from being traced for the following reasons:-

1. In the median plane where one incisor was missing before the start of the study. The remaining incisor "drifted" across the median plane and intercepted the plane of the tracing.
2. In certain instances the interval between the extraction of the various teeth made it impossible to obtain tracings of the later extractions over the full  $2\frac{1}{2}$  year period.
3. Obvious pre-extraction swellings.

4. Subsequent surgical extraction of roots which had been left at the original time of the extraction of the teeth.
5. When fracture of the buccal alveolar plate during extraction had resulted in its removal.
6. When circumstances connected with the extraction necessitated removal of bone or suturing.
7. Faults in pre-extraction casts at a position of measurement, e.g. minute "blebs" or "blow holes" which had escaped detection until after extractions had been completed. Where similar faults in the line of a trace did not interfere with superimposition or measurement the trace was included and the line was interrupted at the faults.

Table 3 shows the numbers of teeth (and equivalent post-extraction areas) through which series of tracings were made and the number excluded in each of the eight regions studied. The average number of traces in each series was 8 and the total number of traces 1285.

TABLE. 3.

|                       | Median<br>Plane | <u>1/1</u> | <u>3/3</u> | <u>4/4</u> | <u>5/5</u> | <u>6/6</u> | <u>7/7</u> | <u>8/8</u> |
|-----------------------|-----------------|------------|------------|------------|------------|------------|------------|------------|
| No. of teeth traced   | 18 <sup>#</sup> | 37         | 28         | 26         | 16         | 12         | 14         | 12         |
| No. of teeth excluded | 7               | 6          | 7          | 2          | 7          | 6          | 7          | 6          |

<sup>#</sup> 18 series of traces in the median plane were made in patients who had both central incisors extracted during the study.

Extractions:-

The extraction of the teeth was carried out by staff and students in the local and general anaesthetic departments of Edinburgh Dental Hospital. All the teeth included in the sample were extracted with forceps and no bone trimming or suturing was carried out. The fracture of teeth and surgical removal of roots, the fracture and removal of the buccal plate of alveolar bone and other surgical difficulties involving bone trimming or suturing led to the exclusion of many teeth from this study.

Impressions and Casts:-

All the impressions were taken with an alginate impression material (Zelex) and were cast immediately by dental technicians with a mixture of equal parts by weight of plaster of Paris and "Kaffir D" artificial stone. The water/powder ratios varied. The effect of this variation on the dimensions of the casts is discussed on p 106 . Most of the impressions were taken by the observer but a few were taken by students and other members of the staff of the prosthetic department.

Dentures:-

Twelve of the patients had full or partial dentures fitted immediately after extraction of some of their teeth and thirteen had full dentures fitted at periods varying from 4 weeks to 52 weeks after the remaining teeth were extracted. The majority of patients were finally rendered edentulous but 11 were in a partially edentulous state for varying/

varying periods before the extractions were completed. Of these 4 had partial dentures fitted as an interim measure before all the teeth were lost and 3 were still in a partially edentulous state at the conclusion of this study.

All the dentures had labial flanges and were made of a polymethylmethacrylate (Kallodent 333) by technicians in the dental prosthetics laboratory. The clinical work in connection with the dentures was carried out by the observer. In the preparation of the casts on which the immediate dentures were constructed the teeth were cut off at the level of the gingival margins so that no "sockets" were formed on the casts.

In order to minimise the changes produced by the dentures in the present study particular attention was paid to the maintenance of their occlusal balance and fit. These were checked at every visit by the observer. As deficiencies in fit developed they were corrected by relining the dentures and deficiencies in the balance of the articulation were corrected by selective grinding of the teeth.

To allow the maximum amount of tissue recovery to take place and avoid the masking effect of adaptive tissue changes, all patients were asked to remove the dentures at night and brush the mucosa vigorously with a soft mouth brush for at least two minutes before going to bed. They were questioned at each visit to ensure that/

that these instructions were carried out. It was apparent however that nearly half the patients neglected the mouth brushing especially where six months or more elapsed between the later visits in a series, but once the habit of removing the dentures at night was established the majority of the patients continued to do this. Sometimes the first sign that relining of the dentures was necessary was, that the patients on being questioned, admitted that the dentures felt loose before breakfast.

The material comprised traces through individual tooth positions before and after extraction and fell naturally into two groups.

Group A Traces where teeth were replaced by prostheses immediately after extractions.

Group B Traces where teeth were replaced by prostheses after healing of the extraction wounds.

In some of the immediate denture patients who had full dentures fitted, the posterior teeth were first extracted and after the sockets had healed the anterior teeth were extracted and the denture fitted at the same visit. In these cases therefore the traces of posterior teeth were in Group B of the material while the traces of the anterior teeth were in Group A. Only one posterior tooth was replaced by prosthesis immediately after extraction so that in considering the possible effects of immediate dentures on the morphology of the residual ridges the study was limited to the central incisors and canines.

Many patients had teeth extracted a few at a time with short intervals between each group of extractions. Thus it was impracticable to take post-extraction impressions at definite intervals after each group of extractions without subjecting these patients to an excessive number of impressions. For example, a single post-extraction cast might represent one area 2 weeks after extraction and other areas at 3 and 6 weeks after extraction. Horizontal traces of such a cast would represent the different areas at different post-extraction periods. (Figs. 49 & 50 ). Data of this kind from different patients could not be compared easily and for this reason vertical traces through individual tooth positions were used. These vertical traces were classified in terms of type of teeth and time in weeks since extraction and thus comparisons between similar areas in different patients were made. Horizontal traces of the first and last casts of each series were used only to give a general picture of the change in that section of the maxillary denture bearing area. No measurements were made of these traces.

#### ORIENTATION OF THE CASTS.

One of the greatest difficulties encountered in this study was in the development of a method for orienting the casts of a series in a similar way with sufficient accuracy to allow comparison of the traces of one cast with those of another./

another. It was essential that the casts were mounted as nearly as possible in an identical manner as differences of antero-posterior or lateral tilt would result in the tracing point passing over parts of the serial casts which were not equivalent to each other. This would of course, invalidate any conclusions drawn from a comparison of the traces. The accuracy of mounting the casts was therefore fundamental to this study and for this reason, will be described in detail.

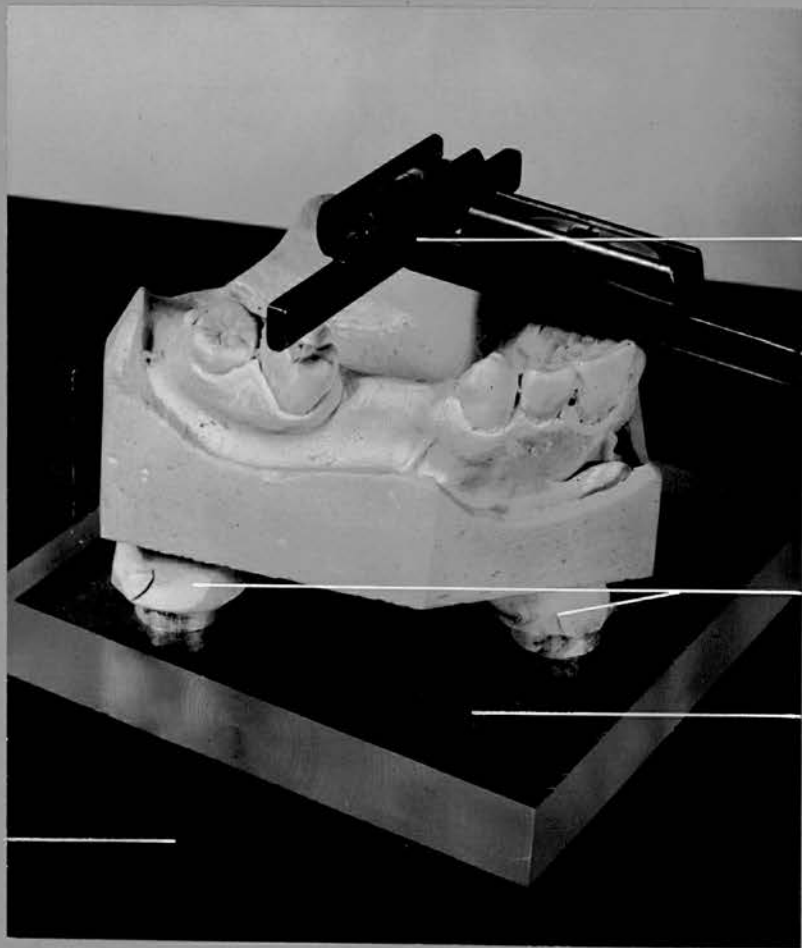
Two methods are commonly used to mount a series of casts of the same mouth so that they will be similarly oriented when the bases of the casts are placed upon a flat surface.

The first method relates the casts to the Frankfort plane of the skull or rather to its surface marking, the eye-ear plane. The idea was originated by VAN LOON (1915) but his method was rather elaborate and it was not until SIMON (1922) devised the "gnathostat" that casts with their bases parallel to the eye-ear plane (gnathostatic) became more widely used. LISOWSKI (1944) used a similar method to position the casts in his investigation of changes following the loss of teeth but it was not found to be sufficiently accurate for the present study. The mobility of the soft tissues of the ear and face make it virtually impossible to locate the "plane-bow" with any confidence to within limits of accuracy of 3 mm. at successive visits of the patient and further errors may be introduced during the "plane-bow" transference. Apart from its use in orientation of/

of casts, the eye-ear plane has been criticised by a number of writers on the grounds that the points which define it cannot be located with sufficient accuracy to enable it to be used interchangeably with Frankfort plane of the skull in cephalometric radiography. BJORK (1947) (1954), MARGOLIS (1940), MUZJ (1955), STEINER (1953).

The second and most widely used method of making similarly oriented casts is by using as a reference, a plane defined by 3 or 4 points on the occlusal surfaces of the teeth and by trimming the bases of the casts parallel to this plane and at a fixed distance from it EBY J.D. (1922), STANTON (1931). This method was obviously not directly applicable to the edentulous casts in the present study. However, in order to make it possible to compare the series of casts of one patient with those of another, the first pre-extraction cast of each series was mounted by means of a T-shaped spirit level, in the earlier cases, and an engineers' surface gauge in the later cases, so that the mesioincisal point and the tips of the mesiolingual cusps of the upper second molars lay in a horizontal plane (Fig. 1 ). In cases where one of the second molars was missing or badly displaced the spirit level or gauge was placed on the distolingual cusps of the first molars, but if they were also missing the third molars were used. In some cases the premolars and molars were absent, and in such cases the level was placed across the tips of the canines to eliminate lateral tilt/

POSITIONING THE  
PRE-EXTRACTION CAST  
BY MEANS OF THE "T"  
SHAPED SPIRIT LEVEL.



"T" shaped spirit level

Plasticine pillars

Perspex base

Level surface table.

Fig. 1.

tilt and then the long arm of the T was placed on the central incisors to level the cast antero-posteriorly.

It is appreciated that this method is not ideal, but it was the most satisfactory that could be devised to produce a similar orientation of all pre-extraction casts. The other partially edentulous and edentulous casts in each series were then mounted, with reference to the first pre-extraction cast, by a method to be described later, so that the final orientation of all the casts was with bases parallel to the horizontal plane as represented by 3 points on the occlusal surfaces of the teeth before extraction.

Since reference points on the first pre-extraction cast were used for orienting the subsequent casts of a series it might be argued that gnathostatic pre-extraction casts would facilitate the comparison of the post-extraction change between different patients. After careful consideration this was rejected as it was found that the orientation of casts to the latter plane was subject to wide variations, between patients, produced partly by individual differences of maxillary development and partly by errors of transference. This is confirmed by DOWNS (1956), KORKHAUS (1957), BJÖRK (1955) and BROADBENT (1937) in their work on cephalometric radiography. It was found that this variability was much less marked on comparing different series of casts oriented to the "occlusal plane". Hence more useful comparisons could be made between traces from different patients.

In a study such as this, confined to the denture bearing area of the maxilla, an intra-oral reference plane would therefore seem to be more suitable than an extra-oral one such as the eye-ear plane, KORKHAUS (1957)

The general orientation of the first pre-extraction cast in each series has been described since upon it depended the orientation of subsequent edentulous casts, but more must be said about the method of mounting each series of casts as it was based on evidence that little change took place during the period of investigation in an area near the vault of the hard palate. The radiographic evidence has already been reviewed, but is of limited value since mucosal surface changes are not seen in the radiographs. A careful study was therefore made of the 25 pre-extraction and 181 post-extraction casts from patients in the sample together with 46 pre-extraction and 138 post-extraction casts from the patients who were originally selected but did not return for impressions over the full  $2\frac{1}{2}$  year period.

These 71 series of casts were examined with a hand lens and at least four points in the mucosal pattern, which could be clearly identified throughout each series, were marked on each cast in an area of the palate bounded anteriorly by the third pair of primary rugae, laterally by sagittal planes 10 mm. from the median raphe and posteriorly by a coronal plane 5 mm. anterior to the posterior border of the hard palate. Comparative measurements were/



were then made between the points on the casts of each series. Where a change in relationship of points was observed the point nearest the periphery of the area was rejected and a new point was found nearer the centre of the area. Further details of the identification of the points will be given later but at this juncture it is sufficient to state that in all the casts of each of the 71 series, at least four such points could be identified in the palate which maintained their relationship to within 0.3 mm. This was accepted as additional evidence of the relative stability in the form of the mucosal surface in this area of the palate.

It is recognised that stability of any part of the human body is only a relative value and it is not implied that changes were totally absent in the "stable area" of the palate but rather that the changes over the two-and-a-half years period of this study were negligible when compared with those of the alveolar ridges, so that valid measurements of morphological changes following tooth extraction could be made relative to this area.

The vertical tracings were then arranged to cross this stable area in every cast of a series, so that, by superimposing the stable portions of the traces, changes which occurred in the other parts could be measured.

SZMD et al (1958) made use of the central portions of the palate as a stable area to facilitate the mounting of a series of casts. They made impressions or registers of this/

this area and mounted the casts by placing each in turn against the register. This method was tried in one of the early series of casts but was found to be inaccurate as slight irregularities of the surface in contact with the register produced quite large discrepancies in orientation of the casts. The method was therefore abandoned and instead, four points within the stable area, which were common to all the casts of a series, were used for the "vertical" orientation of the casts, i.e. their positioning with reference to the first cast as regards antero-posterior and lateral tilt and depth from the vault of the palate to the under-surface of the base on which the first cast was mounted.

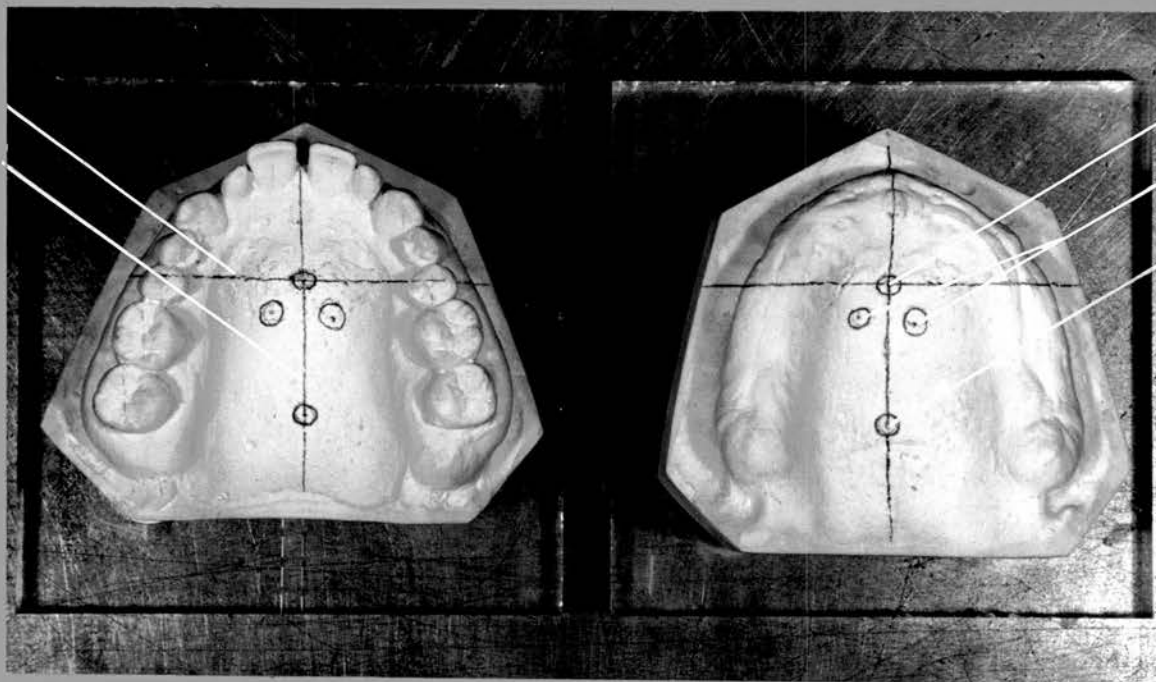
To define the "horizontal" placement of the casts and the position and direction of the traces it was necessary to select vertical planes at right angles to each other which intersected at a line passing through the "stable area".

The vertical planes selected were the median plane as defined by one anterior and one posterior point on the median raphe of the palate and a coronal plane which intersected the median plane and the stable area of the palate at a point R, (Fig. 2), which lay near the medial ends of the 3rd and 4th pairs of "primary" rugae LYSELL (1955). The position of this point varied between series but was identical in all the casts of the same series. The coronal plane was designated the reference plane (R. plane) and the point /

PRE- & POST-EXTRACTION  
CASTS SHOWING POINTS  
AND PLANES USED IN  
THEIR ORIENTATION.

"R" plane

"M" plane.



"R" point

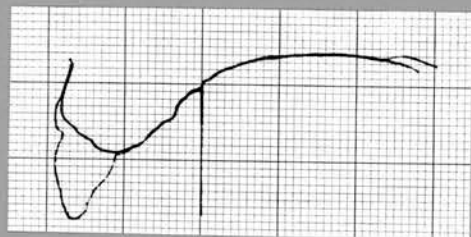
Lateral points

"M" point

54

Fig. 2.

Fig. 3.



"R" line



"M" line

Fig. 4.

point through which it passed on the median raphe the R. point. In each sagittal trace the intersection of the coronal reference plane with the plane of the trace is represented by a vertical line - the R. line - (Fig. 3 ) and in each coronal trace the intersection of the median plane (M. plane) with the plane of the trace is represented by a similar line - the M. line - (Fig. 4 )

#### SELECTION OF POINTS TO DEFINE M AND R PLANES.

##### (1) The Reference Point (R. point) (Fig. 2 )

The reference point or R point, as it will be called hereafter, represented the point at which the line of intersection of M and R planes met the surface of the cast. It was selected in the following manner:-

All the casts of the series to be mounted were carefully examined with a powerful hand lens, and a mark was made with a sharp pencil at a point on the median raphe near the medial ends of the third or fourth pair of primary rugae. The choice of the point depended on finding a crevice, wrinkle or other characteristic detail near the rugae which was easily identifiable in all the casts of the series and which bore a constant relationship to the medial ends of the 3rd and 4th rugae and to other points which will be mentioned later.

This registration point was identical in all the casts of a series, but its position varied between different series, as did the form of the rugae, and the availability of an identifiable point.

(2) The posterior Median Point (M point):-

To define the direction of the median plane another point, in addition to the R point, was found on the median raphe about 5 mms. from the posterior end of the hard palate.

Examination with the hand lens located a permanent surface configuration which represented this point, and it was marked on all the casts of the series. In some cases where the palate was particularly smooth an identifiable point could not be found on the raphe in this area, and the procedure then adopted was to find characteristic points on either side of the raphe, which were constant in their relationship throughout the series and, after checking them by measurement, a line was drawn between them. The M point then lay at the intersection of this line with the raphe. However, in one of these cases, the raphe could not be identified on the cast anywhere along the line joining the two characteristic points. In this case the raphe was evident behind the transverse line, and by projecting a line from the R point through the identifiable part of the raphe to intersect the transverse line, the point M was defined at the intersection. Its position was then checked on all the casts of the series by measurement from the ends of the transverse line and from the R point.

This method of defining the posterior point may seem rather elaborate and it is reasonable to ask why the M point was/

was not placed in a more anterior or posterior position where the raphe was discernable.

In many cases the raphe curved appreciably to left or right of the median plane. In such a case if the M point was placed near the R point, the M plane projected through these points, might diverge as much as 3 mm. from the raphe at the posterior end of the hard palate.

On the other hand, if the M point was located too near the posterior border of the hard palate, its vertical relationship altered from cast to cast since the mucosa in this area was affected by movements of the soft palate. In the first few attempts at mounting casts by this method the M point was located immediately anterior to the palatine fovea, but it was found that while the horizontal relationship of the fovea to the anterior points was relatively constant, their vertical position showed a random variation of up to 2 mm. This was attributed to different degrees of elevation of the soft palate during impression taking (Fig. 24 ). Measurements from the fovea were used, in some cases as an additional check on the antero-posterior position of the M point, but could not be used in every case as in some casts they were impossible to identify; in others they were so ill defined and shallow that an exact point could not be determined within them, and in some casts of a series they were obscured by a bead of mucus which had indented the impression at that point and consequently showed as a pimple on the cast.

(3) The lateral points:- (Fig. 2 ).

The M and R points defined the median plane and the position of the casts in respect to antero-posterior tilt, but additional points to the right and left of the median plane were required to orient the casts correctly in respect to lateral tilt. These points were found by examination of all the casts of a series with the hand lens and were usually located on identifiable parts of the 4th pair of rugae not more than 6 mm. to right and left of the median plane. Points more than 6 mm. from the median plane often fell on part of the palate which was affected by change following the extraction of the teeth and consequently could not be used in the mounting of the casts. Theoretically only one point lateral to the median plane was necessary to orient the casts, but in practice two points were used - one right and one left, since this simplified the mounting procedure.

After the points had been marked on all the casts of a series, the following measurements were made with fine pointed calipers to check the relationship of the points to each other:-

- (1) M point to R point
- (2) Right lateral to left lateral
- (3) Right lateral to R point
- (4) Right lateral to M point
- (5) Left lateral to R point
- (6) Left lateral to M point

The casts were not mounted unless each of the above measurements was found to be constant throughout the series to within 0.3 mm. This limit of accuracy was due to the fact that even the sharpest pencil point produced a dot which varied between 0.1 and 0.3 mm. in diameter as measured with a Brinell microscope. In the first few series of casts it was found that the relationship of some points did not remain constant throughout the series, owing to their being placed in areas which changed after the extraction of the teeth. In these cases new permanent surface configurations which were constant in their relationship to each other, were found and marked nearer the median raphe and on or behind the third pair of primary rugae.

It was appreciated that caliper measurements between the points checked only the constancy of their horizontal relationship to each other, and that vertical differences between the points on different casts of a series might be present without being detected by the caliper measurements. However, a change in the vertical relationship of one point to the others could not have occurred without producing either antero-posterior or lateral tilting of the cast and this would have been detected on sagittal and coronal traces made for the calibration of such errors. These are described on page 114 .

#### METHODS OF MOUNTING THE CASTS.

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When the points on a series of casts had been marked and checked, each of the casts was mounted on a perspex base which had three button magnets embedded in it. The bases were half an inch thick and measured  $3\frac{1}{2}$ " x  $3\frac{1}{2}$ ". Their edges were machined square, to a tolerance of plus or minus one thousandth of an inch. This ensured that the sagittal and coronal traces were at right angles to each other.

Two methods were used to mount the casts on these bases. The first method was employed in the early series of casts, but was found to be rather time consuming, and was later discontinued when an instrument became available which did the job more quickly and as accurately.

The first method of mounting the casts:-

Three pillars of plasticine were stuck to a perspex base lying on a level surface table. The first cast of the series to be mounted was placed on the plasticine and levelled by means of the T-shaped spirit level. Plaster of Paris mixed with anti-expansion solution No. 8 (SODEAU & GIBSON 1927) was then flowed between the pillars of plasticine to hold the cast firmly to the base. With a Solution/Plaster ratio of 0.6, the expansion of the set plaster was .06%. The effect of this expansion on the accuracy of the mounting was negligible and was accepted as it operated on all the casts.

ORIENTING THE SECOND  
CAST OF A SERIES BY  
MEANS OF SURFACE  
GAUGES PREVIOUSLY  
SET TO POINTS ON THE  
FIRST CAST.

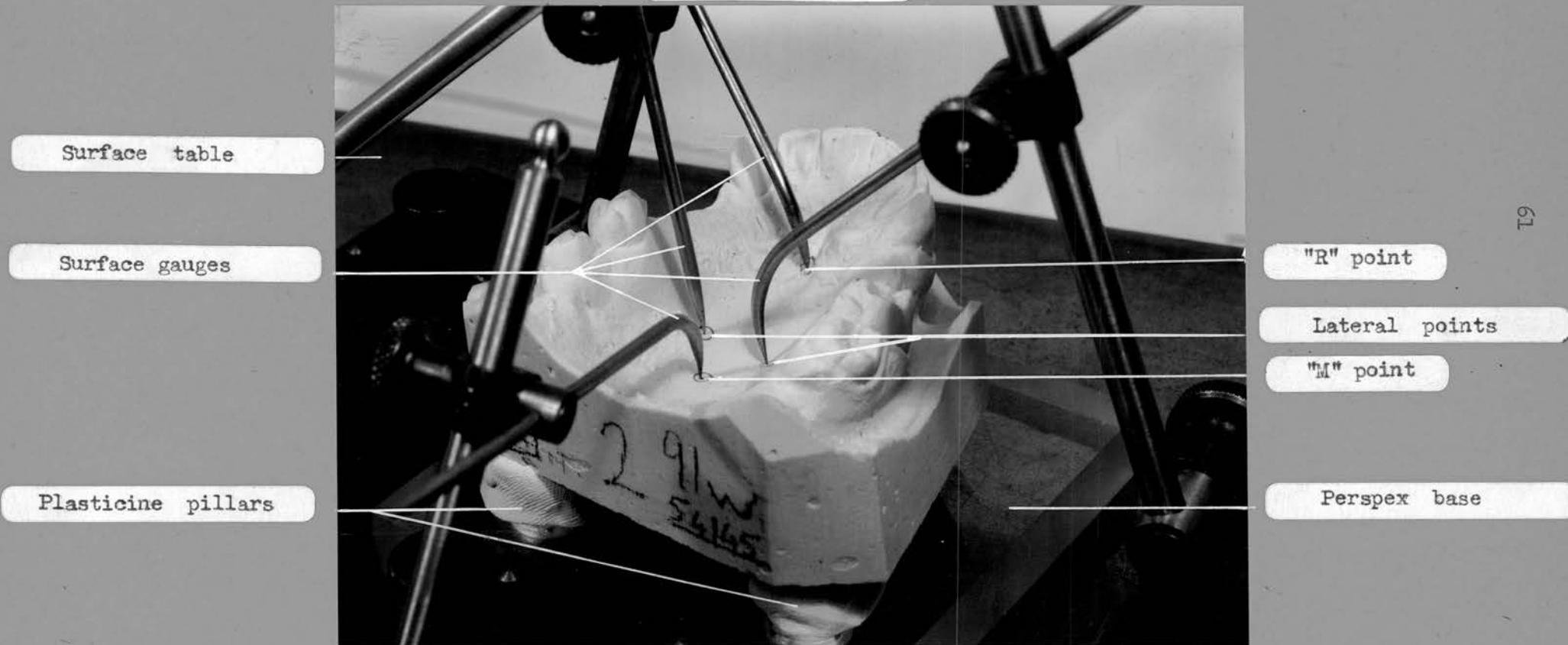


Fig. 5.

The mounted first cast was replaced on the surface table and surface gauges were adjusted to touch the cast at the R point, M point and both lateral points. The four gauges were then firmly locked so that they registered the height of each of the four points from the surface of the table. The first cast mounted on its base was then removed from the surface table and a new base was placed in position. This also carried plasticine pillars and the second cast was pressed into position and adjusted until the gauges touched the M, R and lateral points on this cast (Fig. 5 ). This oriented the second cast very critically and accurately in the same manner as the first cast as far as its vertical position was concerned, but its position in the horizontal plane was not at all critical as this was adjusted when the cast was placed on the tracing instrument. The procedure was repeated with all the casts of the series and when their mounting was completed, the accuracy was checked by making "combined" calibration traces of all the casts on one piece of paper, in the median plane and on another piece of paper in the coronal plane in the region of the first molar (Fig. 26 ). Casts which showed more than plus or minus 0.35 mm. divergence in the "stable area" of the palate were remounted before tracing.

Casts mounted by this method were oriented correctly in the horizontal plane on the tracing machine before tracings were made. This was comparatively easy as the R and M/

R. and M. points provided a reference for their positioning. The disadvantage of the method was that, once positioned, all the traces of a cast had to be made to save time in repositioning casts between traces. It was much more convenient to use the mounting instrument which later became available since it positioned the casts in the same horizontal as well as vertical relationship to their bases so that all the mounted casts of a series could be placed in exactly the same position on the table of the tracing instrument, instead of requiring individual horizontal adjustment before tracing.

Instrument for mounting casts:-

The mounting instrument (Figs. 6 & 7 ) which superseded the first method for mounting the casts comprised a jig with four adjustable points mounted on the vertical sliding rod of a Ney surveyor arm which was clamped on the edge of an engineers' surface table. The method of using the instrument was as follows:-

The first cast was positioned so that the posterior point of the jig lay exactly on the M. point and the anterior point met the R. point of the cast. The T-shaped spirit level was dispensed with when this instrument was used, but the "occlusal plane" was levelled in a similar manner by means of an engineers' surface gauge set at a predetermined height. The two lateral points on the jig were fixed 1 cm. apart so that they fell within the "stable area"/

THE INSTRUMENT FOR  
MOUNTING THE CASTS.

Upright support of Ney  
surveyor clamped to  
edge of surface table.

Posterior arm of jig.

Set square

Vertical sliding rod.

Mounting jig.

Engineers' surface table

Perspex base

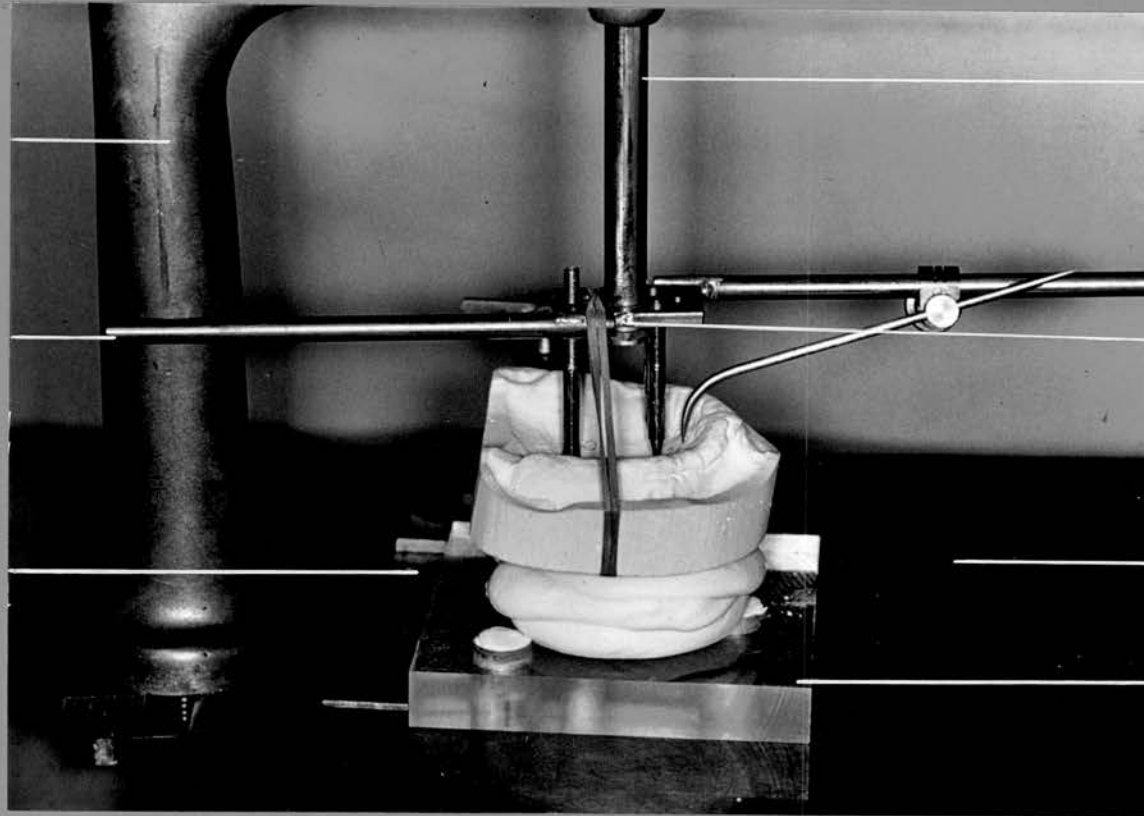


Fig. 6.

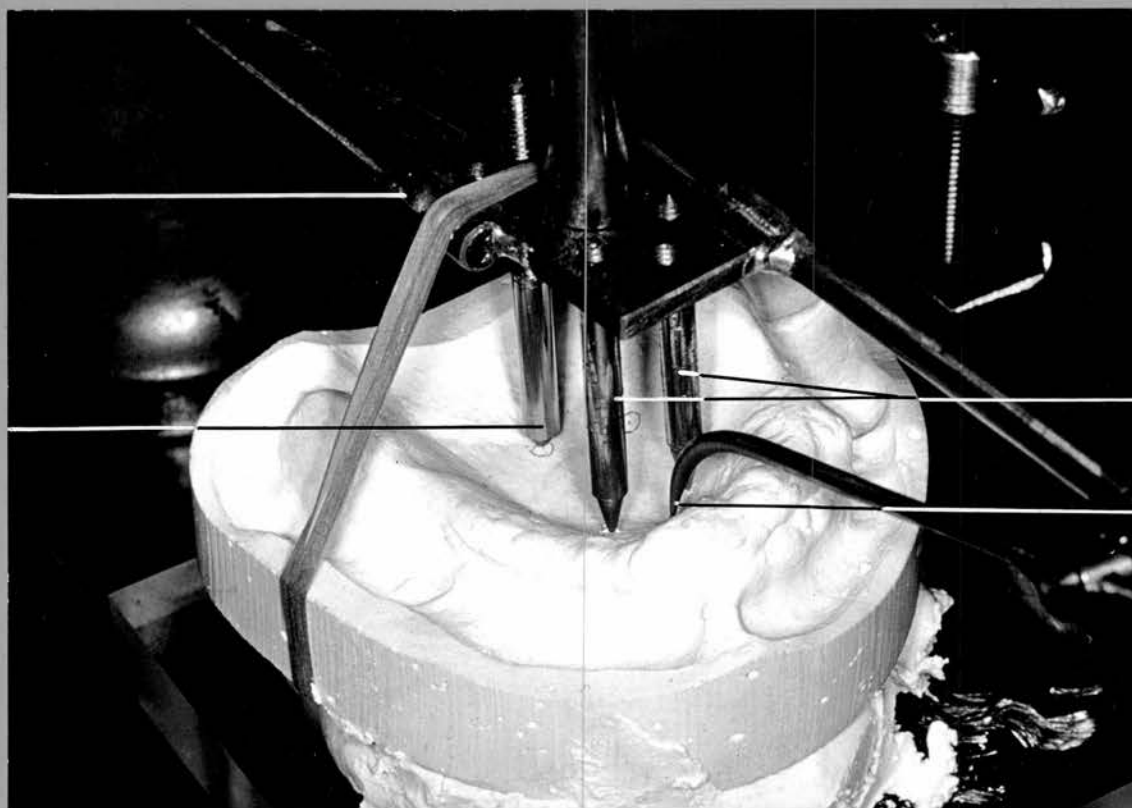
"stable area" of the palate. The posterior and lateral points were then adjusted so that the orientation of the cast was such that the surface gauge, used for levelling, contacted the mesio incisal point and the molar points. After adjusting the jig to position the first cast correctly, the positions at which the lateral points of the jig contacted the cast were circled with a sharp pencil. The first cast was then removed and each cast of the series was placed against the jig in turn in the same manner with reference to the M. and R. points and the positions of the lateral points were marked on it. These lateral point positions were then examined with a hand lens to make sure that there were no blebs or faults within the circled areas on any of the casts since these would give rise to faults in mounting.

The first cast was repositioned and fixed to the jig by means of elastic bands passing beneath the cast and over the upper surface of the jig. The level of the cast was again checked with the surface gauge and when all was ready the cast was lowered close to the surface table by releasing the locking screw on the sliding upright arm. A perspex base was placed beneath the cast in a set square clamped to the surface table in such a way that the median plane of the cast was parallel to the side of the base. The set square ensured that all the bases of a series were held in the same position. An arm projecting from the back /

THE INSTRUMENT FOR  
MOUNTING THE CASTS,  
DETAILS OF THE JIG.

Posterior arm of jig.

Posterior point of jig  
on "M" point of cast.



Lateral points of jig.

Anterior point of jig  
on "R" point of cast.

Fig. 7.

back of the jig bearing on the fixed upright of the mounting instrument kept each cast of a series in the same relationship to the base in respect to rotation about its vertical axis. The cast was then raised and mix of plaster with SODEAU-GIBSON anti-expansion solution No. 8 (W/P ratio 0.6) was placed on the perspex base and the cast was again lowered on to this until the vertical rod of the surveying arm met a stop which was set at a predetermined height for each series of casts. The rod was then locked until the plaster had set. The elastic bands were cut to free the cast from the jig and the mounted cast was removed from the surface table. The same procedure was adopted for all casts of the series.

#### THE INSTRUMENT FOR MAKING VERTICAL

#### TRACINGS OF CASTS. (Fig. 8 )

The base of the instrument for making the tracings was an engineers' surface table. A vertical steel plate, the paper holder, was bolted to the back of the table. The traces were made upon papers which were fastened to this holder by button magnets.

The main part of the instrument comprised a double jointed, counterpoised surveying arm clamped to the right side of the table. This arm moved in a plane parallel to the surface of the paper holder. At the free-end of the surveying arm a cranked rod passed through two bearings and /

and rotated about a horizontal axis which remained perpendicular to the surface of the tracing paper no matter what the position of the surveying arm. A stylus with a rounded steel point of 0.75 mm. diameter was fixed to the front end of the cranked rod in such a manner that the point lay exactly in the axis of rotation of the rod. Thus the stylus could be rotated through  $360^{\circ}$ , moved up and down, and from side to side but remained in a vertical plane parallel to and twenty centimetres from the tracing paper.

A pen of the type used in barographs was mounted on a spring loaded hinged bar attached to the surveying arm. The spring held the pen away from the tracing paper but pressure on a button on the right or a lever on the left of the table activated push rods which brought the pen into contact with the paper when a trace was made. The right hand button was provided with a knurled locking knob so that the pen could be held against the paper leaving both hands free to manipulate the stylus.

The point of the pen when in contact with the paper lay exactly in the horizontal axis of the cranked rod and thus bore a constant relationship to the point of the stylus. Rotation of the stylus about the horizontal axis, as it passed over the surface of the cast in no way altered this relationship, so that it could be held at a right angle to /

INSTRUMENT FOR  
MAKING VERTICAL TRACES  
OF THE CASTS.

Paper holder.

Tracing pen mounted  
on spring loaded  
hinged bar on the  
surveying arm.

Pointer on side arm  
of bevel registers  
position of the cast  
on a mm. scale which  
is attached to the  
table by two magnets.

Engineers' surface table

Surveying arm.

Cranked rod.

Point of tracing stylus

The front arm of the  
bevel locates the  
mounted cast which  
lies against the  
middle stop on this  
arm when coronal  
traces are being made.

Lever and Button  
operate the tracing  
pen. The knurled  
knob locks the pen  
against the tracing  
paper

Fig. 8.

to the surface of the cast in the plane of the tracing. The angle between stylus and cast measured in other planes varied with the form of the cast, but generally was within  $15^{\circ}$  of a right angle. The advantage of a rotating stylus was that under-cut areas could be traced, and as a rule the end and not the side of the point contacted the cast. In the instruments of HARPER (1950) and RUPP et al (1957) the stylus was fixed vertically so that undercuts could neither be traced nor measured, and the side instead of the point of the stylus made contact with inclined parts of the cast particularly when the inclination exceeded  $45^{\circ}$ . This gave rise to inaccuracies.

Stanton recognised this difficulty and incorporated the principle of a stylus rotating about an axis through its point in his instruments for making horizontal section traces of casts for orthodontic diagrams. (STANTON et al 1931).

The casts on their perspex bases were positioned on the table by means of a steel bevel which was held in place by powerful pot magnets. One arm of the bevel, (the side arm), had a pointer attached to it which registered on a millimetre scale on the surface table while the arm itself lay in close contact with the left side of the table. Thus the bevel was guided forwards and backwards along a path normal to the paper holder. The antero-posterior travel of the bevel was read on the millimetre /

millimetre scale which was fastened to the table by magnets. The other arm of the bevel (the front arm) had two stops soldered to it four inches apart, one at the free-end and one about the middle of the arm. The cast lay against the end stop with its median plane parallel to the paper when the sagittal traces were made and against the middle stop, with its median plane perpendicular to the paper, when the coronal traces were made. This ensured that the same corner of the perspex base as entered the set square on the mounting instrument, was used for the localisation of each cast. In this way slight differences in dimensions of the bases did not alter the relative positions of the casts.

METHOD OF USING THE VERTICAL TRACING INSTRUMENT. (Figs. 10-12)

Series of casts mounted by means of surface gauges were positioned individually on the tracing instrument and all the tracings of each cast were completed before the next cast of the series was positioned and traced. On the other hand, where series of casts were mounted by means of the mounting jig, a single tracing was made on each cast in turn before proceeding with the next. For instance, all the median traces in the series were completed before the right central incisor traces were made.

To avoid repetition in describing the technique of using the tracing instrument, the method of locating and making all the tracings on a single cast will be described since /

since it was essentially the same whether the casts were mounted by the first or second methods. The only difference was the order in which the tracings were made.

The Tracing Paper:-

The first cast of each series was made from an impression of the upper jaw before the teeth were extracted and subsequent casts were made after extraction of some or all of the teeth. Traces of the first cast represented the baseline from which post-extraction change was measured by superimposing subsequent traces.

All pre-extraction traces were made on square millimetre graph paper while traces from post-extraction casts were made on thin good quality tracing paper (Fig. 9 )

The graph paper for the first cast tracings was carefully aligned on the paper holder so that the horizontal ruling was parallel to the surface table which formed the base of the instrument. Positioning of the tracing paper for post-extraction traces was not so critical since the R. and M. lines on the traces provided references for their superimposition on the first trace.

Positioning the mounted casts on the instrument prior to tracing:-

After the paper had been fastened with magnets the first cast of a series was placed on the surface table so that its median plane (M plane) was parallel to the paper and in the plane of movement of the stylus. This was /

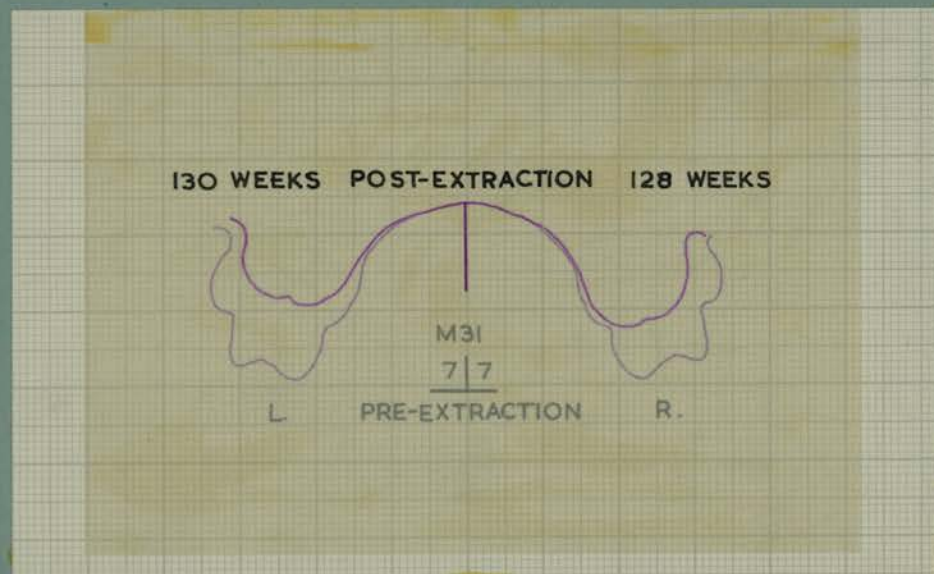
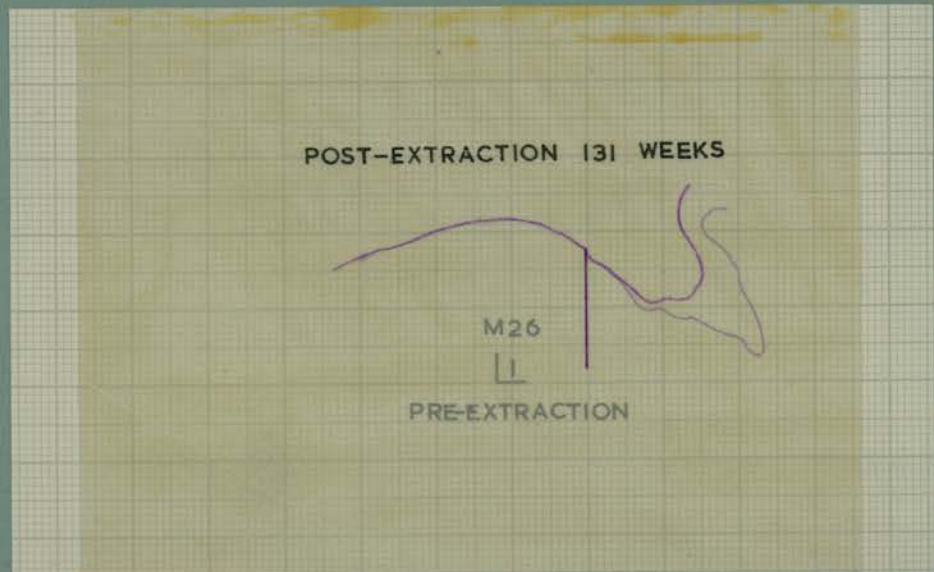


Fig. 9.

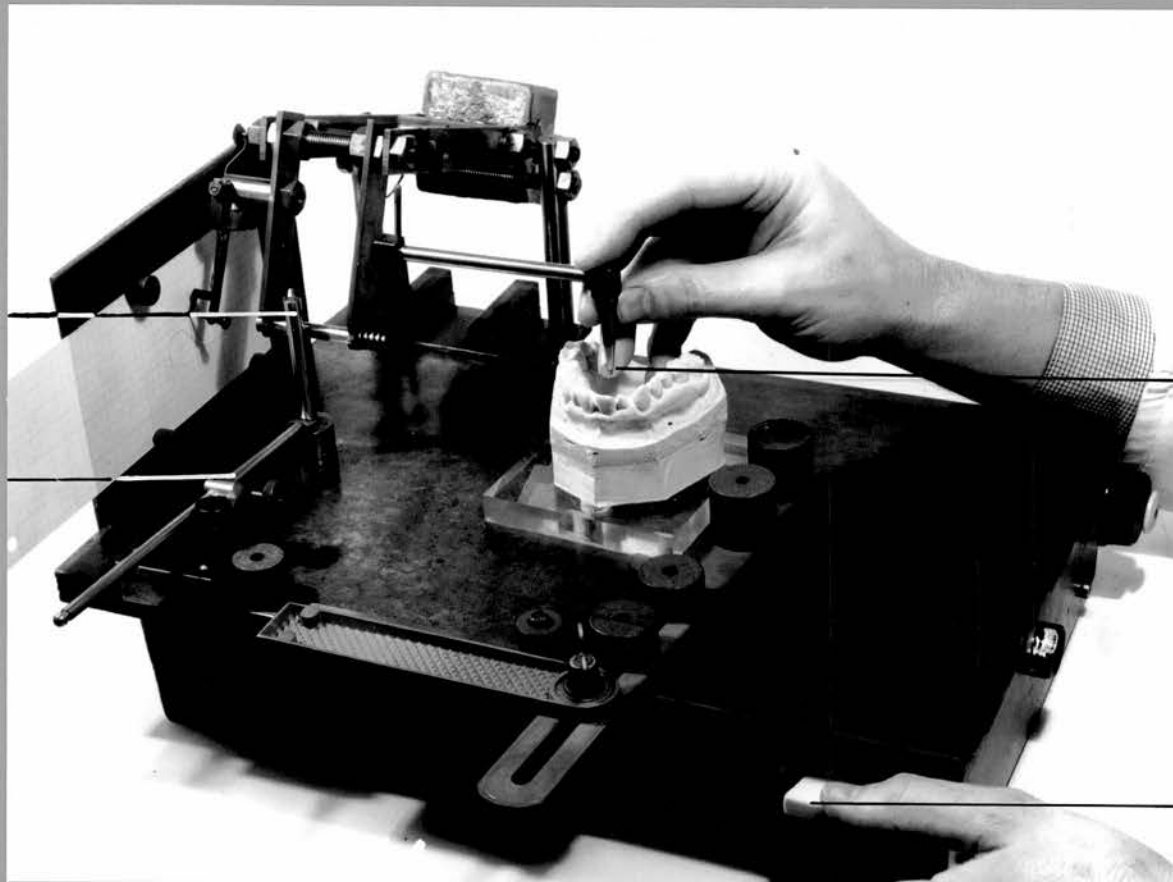
was checked by bringing the stylus into contact with the M. and R. points on the cast. The button magnets in the perspex base of the cast held it in position on the surface table. The joint of the bevel was then loosened and, with the side arm pressed firmly against the side of the table, the front arm was brought gently into close contact with the side of the perspex base and adjusted so that the end stop on the arm contacted the back edge of the base. The locking nut on the bevel was tightened and the cast position was checked with the stylus to make sure that no movement of the cast had taken place.

Additional pot magnets were placed on the bevel to hold it firmly in position. The millimetre scale was now moved until the indicator point on the side arm of the bevel registered an exact number on the scale. This number was noted as it represented the position of the cast for the median plane tracing. From this point the bevel with the cast held against it could be moved in a horizontal plane normal to the tracing paper and thus traces could be made parallel to the median plane through the right and left central incisors on the cast. The distances of these incisor tracings from the median plane were read on the scale.

After making the tracing in the median plane, but before the paper or the cast was moved, it was necessary to mark the vertical R. line on the trace to indicate the position /

MARKING THE "R" LINE  
ON THE MEDIAN TRACE  
OF A PRE-EXTRACTION  
CAST.

Indicator bar in contact with the cranked rod.



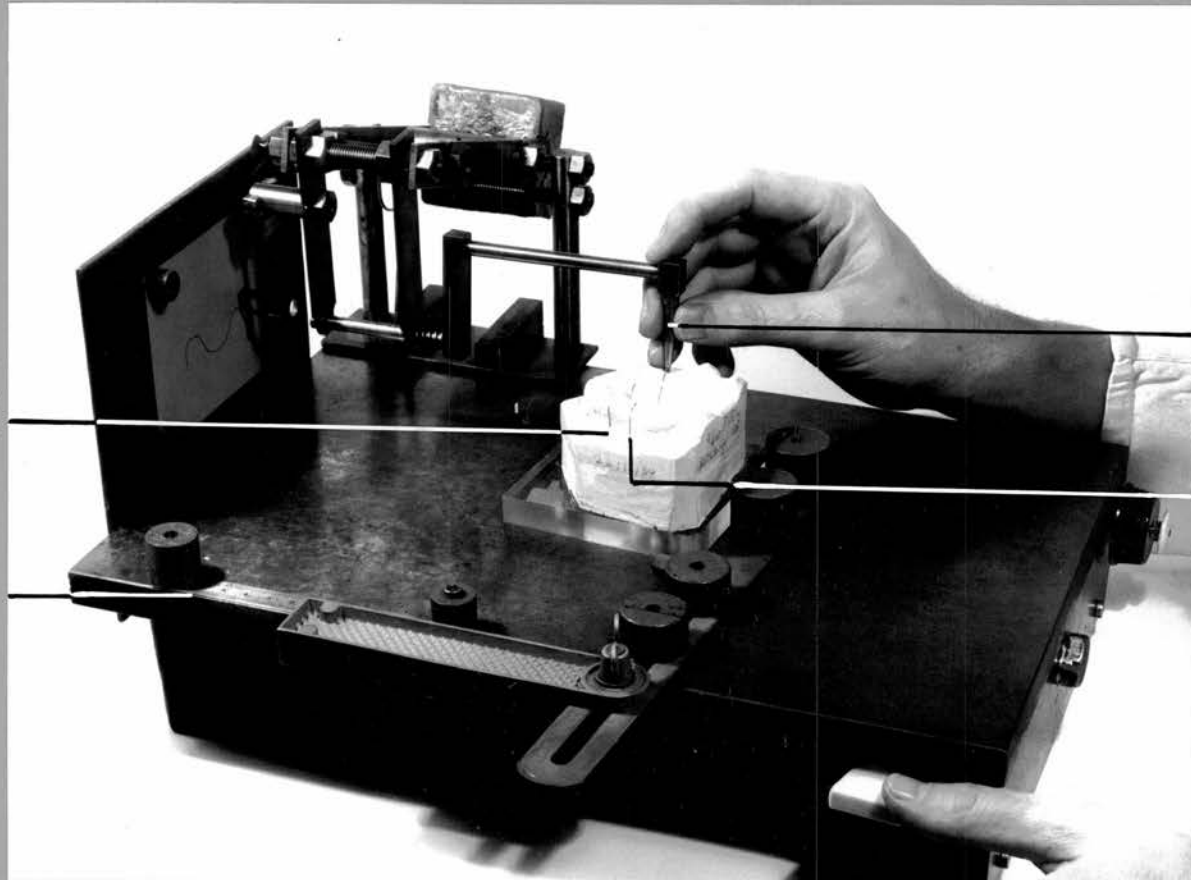
Locating crutch for repositioning the indicator bar when "R" lines are marked on other sagittal traces.

Point of stylus is directly above "R" point on the cast.

Depression of lever makes the pen contact the paper and draw the "R" line as the stylus is raised from the "R" point of the cast.

Fig. 10.

MAKING A CORONAL  
TRACE OF A POST-  
EXTRACTION CAST.



"R" plane marked on cast.

Millimetre scale.

Tracing stylus held normal to the surface of the cast.

Position of 6/6 post-extraction tracing located by measurement from "R" plane.

Fig. 11.

on a sleeve concentric with the point of the stylus was now locked in position and a line was drawn across the cast to represent the R. plane (Fig. 12 ). The millimetre scale was again adjusted until the pointer on the side arm of the bevel registered an exact number which was noted. This number represented the position of the R. plane and all the coronal tracings on pre- and post-extraction casts could be located by measurements in millimetres anterior or posterior to this plane.

Before coronal tracings were made, the indicator bar and locating crutch were adjusted to contact the cranked rod when the stylus was held against the cast in the median plane. Thus a vertical line (the M. line) could be drawn to represent the median plane on each coronal trace.

Positioning the tracings:-

Tracings were made through all the remaining teeth in each pre-extraction cast of a series and through the positions they formerly occupied, on each subsequent cast. The only exceptions were the lateral incisors. They were excluded from this investigation as sagittal tracings through them passed over changing areas of the palate and the pre- and post-extraction traces could not be positioned for measurement of the change except by cross reference measurements from the coronal traces.

The positions of the teeth in terms of tilt and rotation varied considerably, but the direction of the tracings /

MARKING THE "R" PLANE  
ON A CAST.



Fig. 12.

tracings was fixed in the sagittal and coronal planes by the method employed in this study. It was impracticable to adjust the orientation of the casts so that every tooth was traced in its long axis. Cusps, or fissures on the teeth could not be used to locate the position of the tracings since a tracing through the tip of the buccal cusp in a badly rotated and tilted premolar would possibly not even cross the extraction wound in subsequent casts of the series while a tracing through the same point of an upright premolar would. Every tracing was therefore positioned in such a way that it passed through the sagittal or coronal diameter of the tooth at its gingival margin (Fig. 13 ). Thus post-extraction tracings crossed the middle of the extraction wounds at the mucosal surface, but the deeper parts of the sockets were not necessarily opposite the tracing unless the long axis of teeth concerned happened to be vertical. The variation in tooth positions undoubtedly gave rise to variations in the amount of change observed in different mouths and on opposite sides of the same mouth.

In mouths where the teeth were positioned symmetrically a single coronal tracing passed through the same type of tooth on right and left sides, but where "drifting" was present the teeth were traced separately on left and right.

The positions of the tracings through the teeth  
on /

position of the reference plane (Fig. 10 ). The point of the stylus was placed on the R, point of the cast and a vertical indicator bar, mounted on a pot magnet, was placed against that part of the cranked rod which lay between the bearings on the surveyor arm. This permitted only vertical movement of the stylus and by bringing the pen in contact with the paper, a vertical line was drawn on the trace which represented the line of intersection of the R. plane with the M. plane (Fig. 3 ).

A locating crutch which hooked on to the edge of the table was adjusted to contact the indicator bar before it was removed from the table, prior to making the right central incisor trace. This crutch ensured that the bar could be quickly repositioned when the R. lines were drawn on the right and left central incisor traces.

When the three sagittal traces (one median and one through each central incisor) had been made on separate pieces of paper, the cast was rotated through  $90^{\circ}$  so that its median plane was perpendicular to the tracing paper. The back edge of the perspex base now lay against the front arm of the bevel and the right side of the base which had previously contacted the front arm now lay against the middle stop (Fig. 11 ).

The bevel together with the cast was moved forwards or backwards until the R. point on the cast lay immediately below the point of the stylus. A graphite point mounted on /

POSITIONS OF  
CORONAL TRACINGS  
THROUGH NORMAL &  
ROTATED PREMOLARS

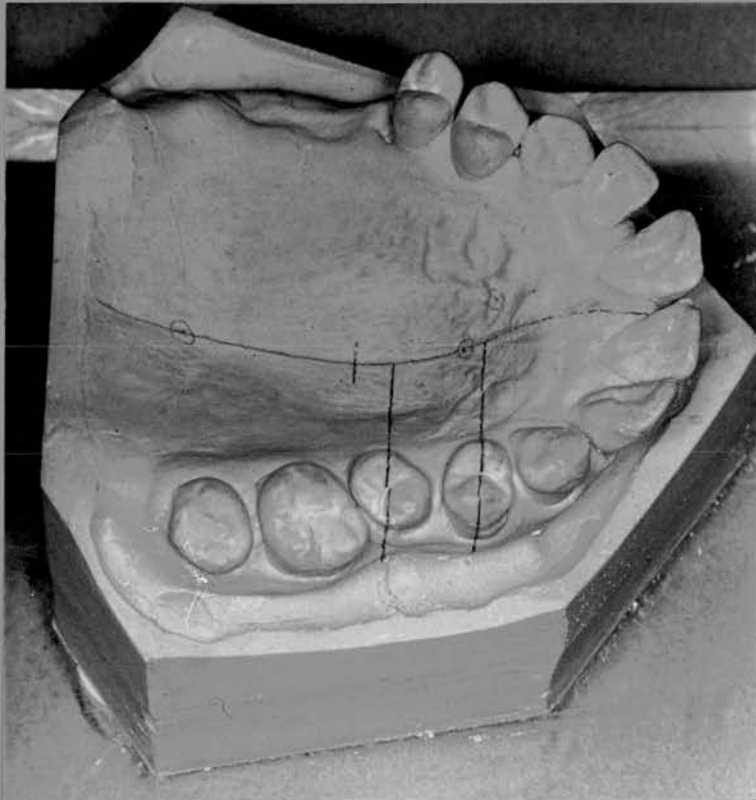


Fig. 13.

on the first cast of a series were all measured to the nearest 0.5 mm. from the R. and M. planes in the manner described. These measurements were recorded so that tracings could be placed in identical positions on the edentulous casts of the series.

Tracings anterior to the R. plane were assumed to fall on an area subject to change and in some of the early series an additional coronal trace through a fixed point on the stable area of the palate was made on the same piece of paper as each of the traces anterior to the R. plane (see traces on p.135 ).

These additional traces were called "positioning traces" and by superimposing them the relationship of the pre- and post-extraction traces anterior to R. could be found even although the post-extraction traces did not coincide at any point with the pre-extraction traces. Errors of antero-posterior tilt in cast positioning produced slight random discrepancies in the relationship between the positioning traces and the traces anterior to the R. plane. These discrepancies could not be corrected. For this reason the method was rejected in favour of one which reduced the errors produced by cast positioning and not only proved to be more accurate but also more rapid.

This method is illustrated by the median, incisor and canine traces on pages 129,131&.133. The median traces from /

from the pre- and post-extraction casts of a patient (F.11) were superimposed and photographed. This superimposition reduced errors of cast positioning as far as antero-posterior tilt was concerned. The R. line was marked on the median traces so that the point at which the canine trace crossed them could be located 9.5 mm. anterior to the R. line. The vertical measurement between the median traces at this point then represented the distance between the canine traces in the median plane. This "median vertical" measurement is further discussed on p. 93 .

Similar vertical measurements were then made at the intersection of the canine trace and sagittal traces through right and left central incisors and transferred to the appropriate positions on the canine traces thus reducing discrepancies arising from errors of lateral tilt of the casts. These "incisal vertical" measurements were used only for positioning the canine traces.

MEASUREMENT OF TRACES.

All the post-extraction traces of a series were superimposed in turn on the pre-extraction trace and direct contact photographs were taken by a standardised technique . Photographing the superimposed traces was necessary to permit visual comparison of post-extraction changes in a series without repetition of the pre-extraction trace for every post-extraction one.

Repetitive tracing of the pre-extraction cast would have had obvious disadvantages since inaccuracies would undoubtedly occur through abrasion of the cast in the lines of the tracings. The method of SZMYD et al (1958) can be criticised on this account.

Measurements were made on the developed negatives. This was found to be more satisfactory than direct measurement of the superimposed traces, because, owing to their small size, they were apt to move when direct measurement was attempted.

Two groups of measurements were taken of each series of traces:-

(1) Measurements of the pre-extraction traces:-

These were chiefly used to determine the average dimensions of the pre-extraction outlines in each region, for the construction of illustrative diagrams, but one of the measurements (R. H.) was used to locate the positions at which the buccal measurements of post-extraction changes were made.

(2) Measurements of Post-extraction changes:-

Measurements of the superimposed pre- and post-extraction traces to determine the amounts of post-extraction changes.

1. Measurements of pre-extraction traces (Fig.14-16).

$\frac{1}{2}$  P.B. "Half"the palatal breadth measured horizontally in the plane of the trace from the median plane to the point of the angle between "tooth" and "mucosa" where the trace crossed the lingual gingival margin (hereafter called the lingual gingival point). Where a unilateral extraction was carried out the  $\frac{1}{2}$  P.B. measurement was doubled to give a figure for palatal breadth but where the extractions were bilateral the sum of the two  $\frac{1}{2}$  P.B. measurements was used.

P.D. Palatal depth measured vertically in the plane of the trace from the upper edge of trace in the median plane to the intersection with a horizontal from the lingual gingival point.

In cases where right and left measurements of palatal depth differed, the mean was recorded.

P.L. Palatal Length was measured horizontally in the planes of the sagittal traces from from the lingual gingival margins of the central incisors to a coronal plane passing through the palatine fovea. This measurement is not shown in the figures. The fovea did not appear /

appear on the traces and the measurement was made on the cast by locating the lingual gingival point with the stylus of the tracing instrument, then sliding the cast and bevel forwards on the surface table until the stylus could be lowered to contact the intersection of the median plane and a line joining the fovea. The measurement was read on the millimetre scale to the nearest 0.5 mm., but in some cases its accuracy to within 1.0 mm. could not be regarded with any confidence owing to the variation in the forms of the fovea which have already been mentioned. The measurement could not be taken in two of the pre-extraction casts since the fovea could not be identified. The average measurement is therefore also inaccurate. It was accepted, however, for what it was worth, as it was used only to give an indication of the length of the palate in the sagittal diagrams of the average post-extraction change (pp.146 & 148) and of the position of the fovea in the diagram representing the average extent of palatal change (Fig. 52). Any inaccuracy which may have been present in no way affected the other measurements.

R.H. Ridge height - measured vertically in the plane of a series of superimposed pre- and post-extraction traces from the lingual gingival point on the pre-extraction trace to the mean level of the buccal terminations of the series of traces.

MEASUREMENTS OF THE TRACES.Key to FiguresPre-extraction measurements:-

|                    |                        |
|--------------------|------------------------|
| R.H.               | Ridge Height           |
| B.L.B.             | Bucco-lingual breadth  |
| $\frac{1}{2}$ P.B. | "half" palatal breadth |
| P.D.               | Palatal depth          |

Post-extraction measurements:-

|      |   |
|------|---|
| u    |   |
| B m  | Buccal upper, middle and lower measurements - the mean of these is shown as "Buccal change" in the graphs and diagrams. |
| l    |   |
| L.V. | Lingual vertical. The vertical change at the lingual gingival margin.   |
| P.   | Transverse or sagittal palatal change.  |

Fig. 14 Measurements of sagittal traces.


Fig. 15 Measurements of coronal traces anterior to the "stable area" of the palate.

Fig. 16 Measurements of coronal traces which crossed the "stable area" of the palate.

Fig. 14.

Fig. 15.

Fig. 16.



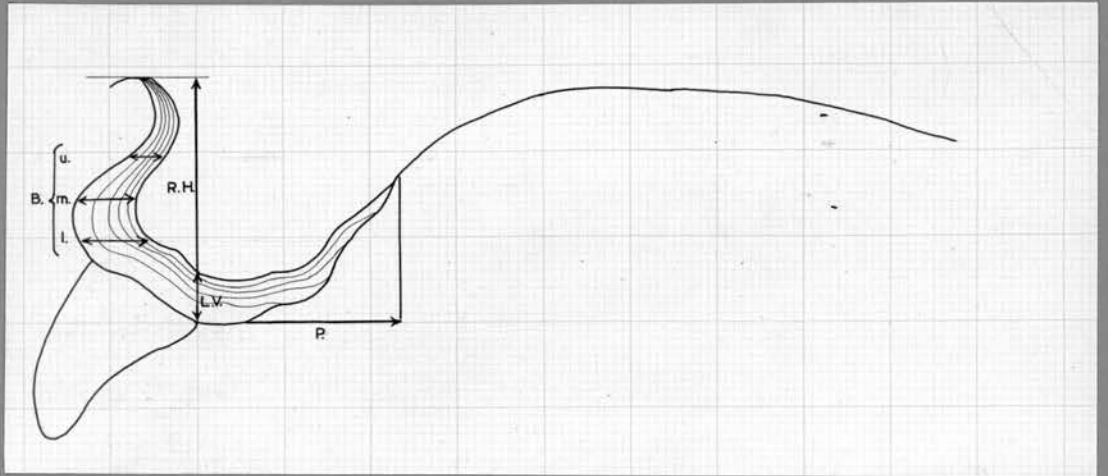


Fig. 14.

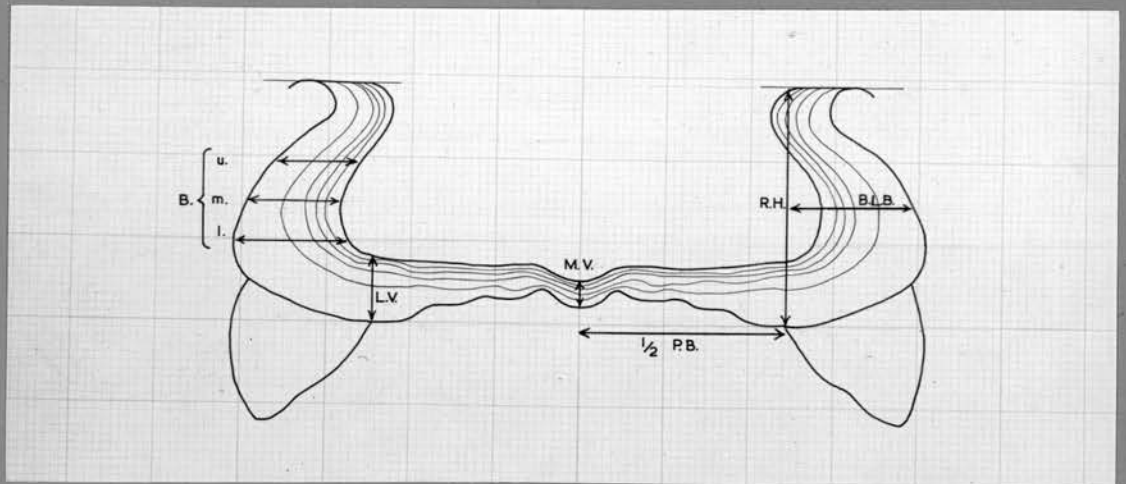


Fig. 15.

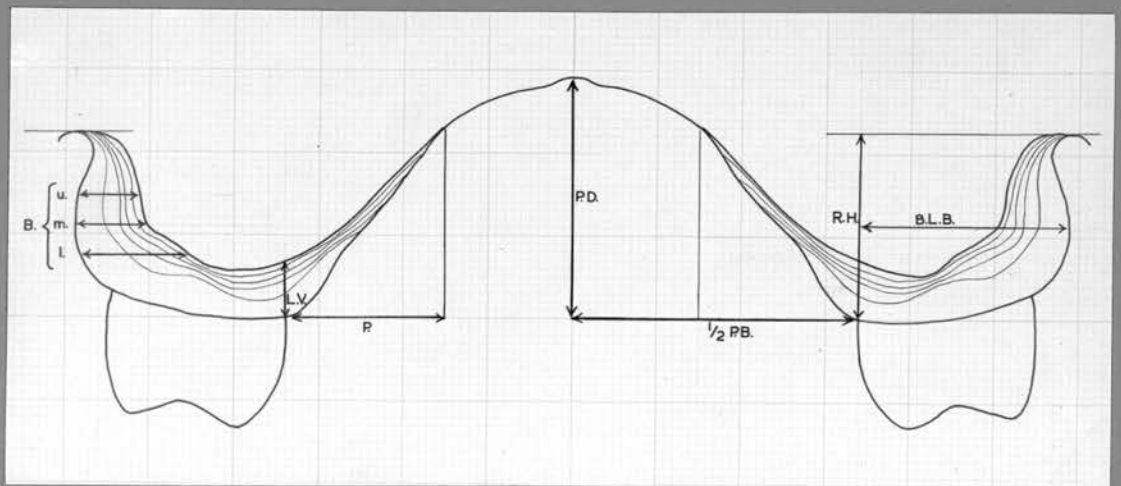


Fig. 16.

It was not possible to take a series of impressions without producing variations in the level of the reflected mucosa in the buccal sulcus. As a result random variations of up to 4 mm. were found in the levels of the buccal terminations of the traces. Variations of this sort were also found where buccal and labial fraenula or marginal blebs intersected the tracing point. (Fig. 23 p. 109)

B.L.B. Bucco-lingual breadth was measured horizontally in the plane of the trace from the mid-point of the vertical ridge height line (R.H.) to a point at the same level on the inner margin of the buccal part of the pre-extraction trace (hereafter called the mid buccal point.) This measurement varied considerably between traces of different areas in the same patient and between the equivalent areas in different patients, and was largely influenced by the tilt of the teeth and the angle between the alveolar ridge and the coronal or sagittal plane in which the measurement was made.

## 2. Measurements of Post-extraction Changes (Figs. 14-16 ).

Post-extraction changes were measured with a Brinell microscope calibrated in tenths of a millimetre. The measurements were made either horizontally or vertically in the plane of superimposed pre- and post-extraction traces from points on the inner edge of the pre-extraction line to points on the inner edge of the post-extraction line. The /

The mean thickness of the lines was 0.3 mm. The centre of the line represented the surface of the cast.

The positions of measurement are illustrated in Figs. 14 - 16 and are as follows:-

B (u) (m) (l) Buccal upper, middle and lower measurements.

These three measurements were made horizontally in the plane of the trace and were positioned as follows:-

B (m) at the mid buccal point.

B (u) at the junction of the upper third with the lower two thirds of the ridge height (R.H.)

B (l) at the junction of the lower third with the upper two thirds of the ridge height.

Buccal Change. The term "buccal change" was used to denote the mean of the three buccal measurements.

This method was used as it simplified comparison of the amount of change between patients with dissimilar forms of change. In very general terms the buccal areas between pre- and post-extraction traces were either roughly triangular in shape (where the greatest change took place near the gingival margin) or roughly rectangular in shape (where the change was more uniform) (c.f. Median and 3/3 series on pp.129 & 133). Intermediate shapes were of course observed. Because of this variation between patients single buccal measurements would give a misleading picture of the comparative amounts of change.

L.V. Lingual vertical change.

Measured vertically

in the plane of the

trace from the lingual gingival point to the upper edge of /

of the post-extraction trace. The lingual gingival margin did not of course appear on the median traces and the point of measurement of vertical change was where a line joining the lingual gingival margins of the central incisors crossed the median plane. This point was located on the trace by transferring the horizontal measurement taken by means of the tracing instrument from the R. line of the casts. Median traces were made only in cases where both central incisors were present on the pre-extraction casts.

Occasionally, in the last post-extraction trace of a series, the point of measurement of lingual vertical change in the 3 / 3 region was removed by the buccal change (see 3 page 133 ). In such cases the tooth was rotated or tilted buccally before extraction so that the point at which the pre-extraction trace crossed its lingual gingival margin was further away from the median plane than usual. It is obvious that exclusion of such traces from the sample would give a false picture of change and the only alternative which could be devised was to take the measurements at an identifiable point which was most distant from the M. line on the traces.

P. Palatal Change.

This measurement should not be compared with those of buccal and vertical changes since it is of quite a different nature. It simply indicates the/

the extent of the palate which was affected by the change in the plane of the trace. It does not indicate the amount of the change. For this reason it is recorded as an interrupted line on the graphs.

The measurement was made horizontally in the plane of the trace from the lingual gingival point (or the equivalent point in the median plane) to the point at which the pre- and post-extraction traces first coincided. The point of coincidence was taken as the first point at which the combined width of the converging lines was 0.5 mm. as measured with the Brinell microscope. The measurement of the extent of the palatal change was read directly from the millimetre grid on the negative to the nearest 0.5 mm.

In some traces a divergence was observed nearer the median plane than the first point of coincidence of the traces ( 4/ F.30 page 135 ). Such divergences were particularly common in the first premolar region and were chiefly caused by changes in the position of the rugae following extraction of the teeth.

In these cases the horizontal extent of the divergent and coincident parts of the traces between the first point of coincidence and the median plane were measured. If the coincident part exceeded the divergent part the measurement was taken as already described and the divergent part was not included. On the other hand, if the divergent part was greater than the coincident part the change was regarded as having/

having extended to the medial end of the divergent part and was measured from the lingual gingival point to the point of convergence nearest the median plane or, in the sagittal traces, nearest the R. plane.

The reliability of measurements of palatal change could not be regarded with much confidence since very small changes in the mucosal surface of the palate or in the superimposition of the traces produced relatively large differences in the palatal measurements (see graph on p.136). Nevertheless it was felt that the measurements gave some indication of the average extent of the "stable area" at the vault of the palate.

M.V. Median Vertical.

In the canine and some first premolar traces the palatal change extended right across the median plane so that the palatal change measurement became equal to "half" the palatal breadth. In depicting change after this point it was necessary to make vertical measurements between pre- and post-extraction traces in the median plane where it intersected the planes of the coronal traces. The measurements were made from the upper edge of the pre-extraction trace to the upper edge of the post-extraction trace and were recorded as the "median vertical change".

In all the canine traces the palatal change crossed the median plane and the M.V. measurement was recorded instead /

instead of "palatal change". The change in this area should not of course be interpreted as the result of the loss of the canine teeth since it was chiefly produced by the loss of the central incisors. The measurement was necessary for the construction of the  $\frac{3}{3}$  diagram.

In 8 of the 15 series of first premolar traces the palatal change did not extend across the median plane and only palatal change was measured. In the other 7 cases where the change crossed the median plane both palatal change and median vertical change were measured. The median vertical measurements in these cases were used only for the positioning of the traces and palatal change was plotted on the graphs as "half" the palatal breadth after the point where the change crossed the median plane. This is illustrated on pp.134 & 135.

#### Discussion of alternative Methods of measuring the Traces.

Many alternative methods of measuring the traces were tried before the method described was finally adopted. It was found to give the most consistent results and was the best that could be devised.

The method, advocated by SZMID<sup>\*</sup> et al (1958), of expressing post-extraction change as a measurement of the area between pre- and post-extraction traces, was rejected on the grounds that measurements of change in square millimetres /

millimetres had little practical value and could not be applied to the problems of full denture design. The reason for rejection of horizontal contouring methods have already been discussed. (p. 11 ).

Three methods of locating the positions of the buccal measurements were tried and rejected, viz.

(a) Horizontal lines were drawn across the traces at the levels of  $\frac{1}{2}$  and  $\frac{3}{4}$  the depth of the palate and measurements were made between pre- and post-extraction traces along these lines. Because of the great variations in palate depth between patients the lines did not cross the buccal parts of the traces at comparable points. This is illustrated in Fig. 17 .

(b) Attempts to locate measurements at fixed distances above the buccal gingival margin were not satisfactory, since this method did not take into account the marked variations in the ridge height as represented on the casts, and in many cases the buccal gingival margin was not clearly defined on the trace (see 1 and 3 p.131 and 133)

(c) Points on the teeth themselves could not be used since tilting, rotation, or over eruption produced greater discrepancies at their occlusal levels than it did at their gingival margins. This has already been discussed in connection with the location of the traces on the casts.

The chief criticism of the method which was finally adopted to measure the traces is that the lingual gingival point /

TRACES OF DEEP AND  
SHALLOW PALATES TO  
ILLUSTRATE THE  
IMPRATICABILITY OF  
POSITIONING BUCCAL  
MEASUREMENTS AT FIXED  
PROPORTIONS OF PALATAL  
DEPTH.



$\frac{1}{2}$  Palatal Depth

$\frac{3}{4}$  Palatal Depth

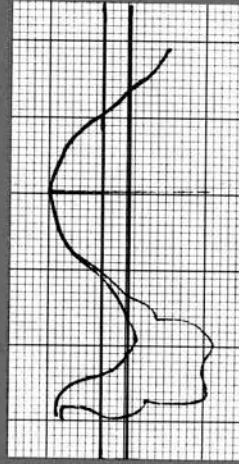


Fig. 17.

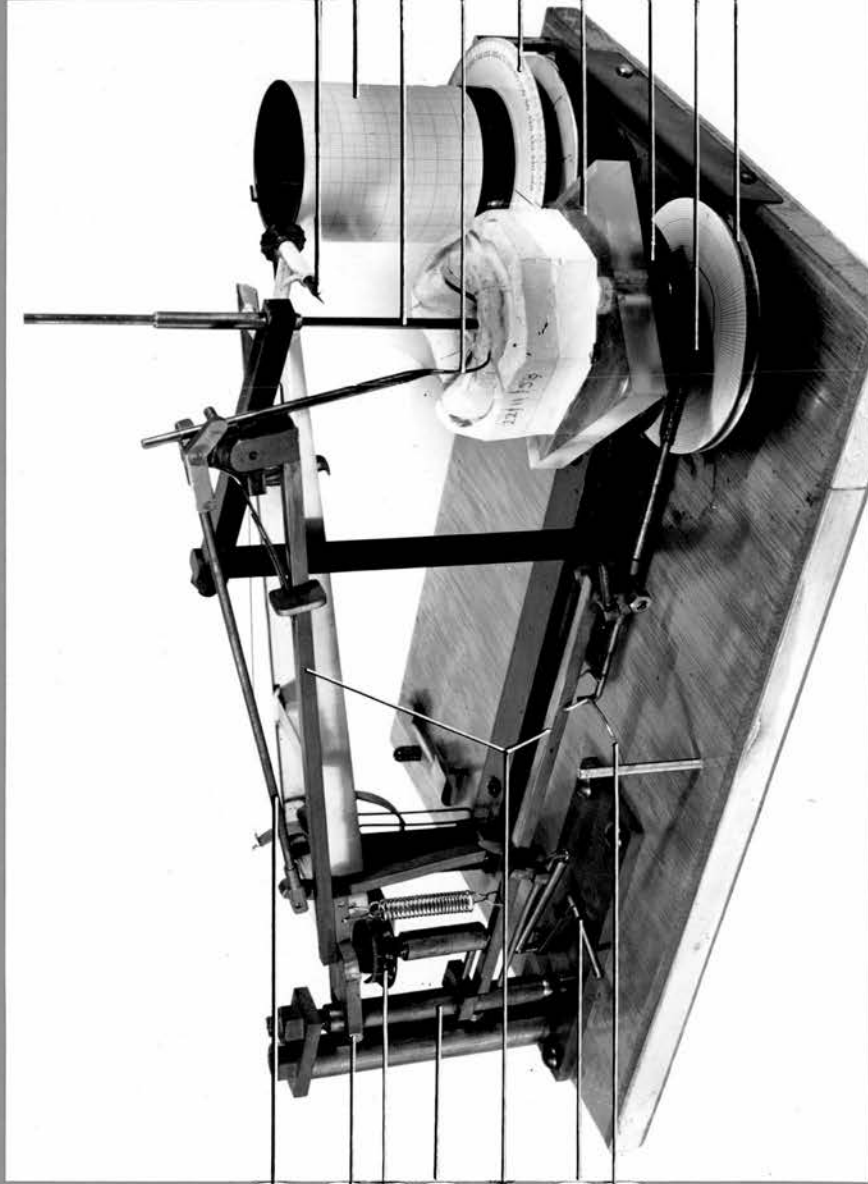
point on the pre-extraction trace was used as a "key" point for location of the measurements. The position of this point would obviously vary with the tilt of the tooth and the condition of the gingivae. Nevertheless it should be remembered that the measurements were directed to showing the changes in mucosal surface form following the extraction of the teeth, and it is appropriate that a point on the mucosa before extraction should be used for the measurement of post-extraction changes. The lingual gingival point was the most satisfactory point which could be found.

#### THE INSTRUMENT FOR MAKING HORIZONTAL TRACINGS OF CASTS.

The horizontal tracing instrument comprised a circular flat table, which rotated about a vertical axis, Two centimetres below the table and parallel to it, lay a disc which rotated synchronously about the same axis. The disc carried polar graph paper on which the traces were made. The table was mounted on a keyed sleeve so that it could be removed for positioning the paper on the disc. The paper was located by a central hole, through which passed the vertical rod on which the table rotated, and also by a hole near the periphery which engaged a stud on the disc. Mounted casts placed on the table were held by the button magnets embedded in their bases and were located on the table by a pointed rod which was lowered in a vertical sleeve concentric with the axis of rotation.

The /

THE INSTRUMENT FOR  
MAKING HORIZONTAL  
TRACINGS OF CASTS.



Subsidiary arm

Pivot of upper branch

Calibrated set screw

Axis of double arm

Branches of double arm

Arm control lever

Pen control lever

Median plane indicator  
on profile tracing arm

Profile tracing drum

Pointed locating rod

Cranked stylus

Adjustable protractor

Base of cast

Circular flat table

Pen

Disc

Fig. 18.

The tracing device consisted of a double arm, 35 cms. in length which swung on a vertical axis. A cranked stylus was fixed to the upper branch of this arm and the tracing pen to the lower branch of the arm. The upper branch could be raised and lowered through a range of 5 cms. calibrated in tenths of a millimetre by means of a set screw, near the axis of the arm. A subsidiary arm working on a parallelogram system, governed the point of the stylus so that it moved vertically although the arm itself moved in an arc on a horizontal pivot near the vertical axis of the arm. The pen attached to the lower branch of the arm lay vertically beneath the cranked stylus, so that any horizontal movement of the stylus was exactly duplicated by the pen. The stylus could be turned to trace the buccal or palatal contours of the casts without altering its relationship to the point of the pen. A light spring, operated by a lever, swung the double arm inwards or outwards to bring the stylus into light contact with the buccal or palatal surfaces of the cast. By releasing another lever, the pen made contact with the paper and the tracing was made by rotating the cast, with the stylus in contact with its buccal or palatal surface. The table and disc carrying the paper rotated together and were directly coupled to a drum on the opposite side of the instrument. A large adjustable protractor scale on the drum measured the degree of rotation of the cast.

A second arm which swung up and down about a horizontal axis was attached to the instrument on the same side as the drum. By means of this arm profile tracings of casts could be made on square millimetre graph paper wrapped round the drum. This arrangement produced tracings which were scaled correctly in the vertical dimension but not in the horizontal, as the circumference of the casts differed from that of the drum. It was found that this type of data (Fig. 19 ) was much less useful than the sectional traces produced by the vertical tracing instrument previously described, and only one series of ten casts was traced by this means.

The method used for orientating the casts of this particular series was by means of a palatal index mounted on a threaded tube which passed through a hole in the centre of the palate of each cast and engaged the vertical axle on which, latterly, the rotating table was mounted. The palatal index method was found to be rather inaccurate and this particular series of casts could not be used in later studies because of the holes which had been drilled in them. The second arm of the instrument was not therefore employed for making traces in the present study but was used to locate the degree of rotation of the cast placed on the horizontal table. The pointer which the arm carried was placed on the median plane when the protractor reading was zero. In this way all the casts of a series could be identically positioned on the rotating table before horizontal traces were made.

J. R. A. Male age 20 6/12

30. 11. 56

17. 3. 54

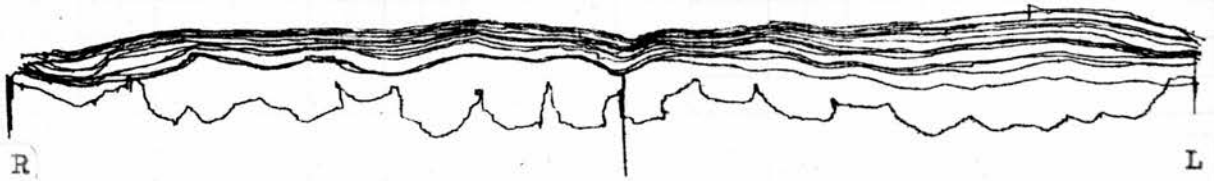


Fig. 19.

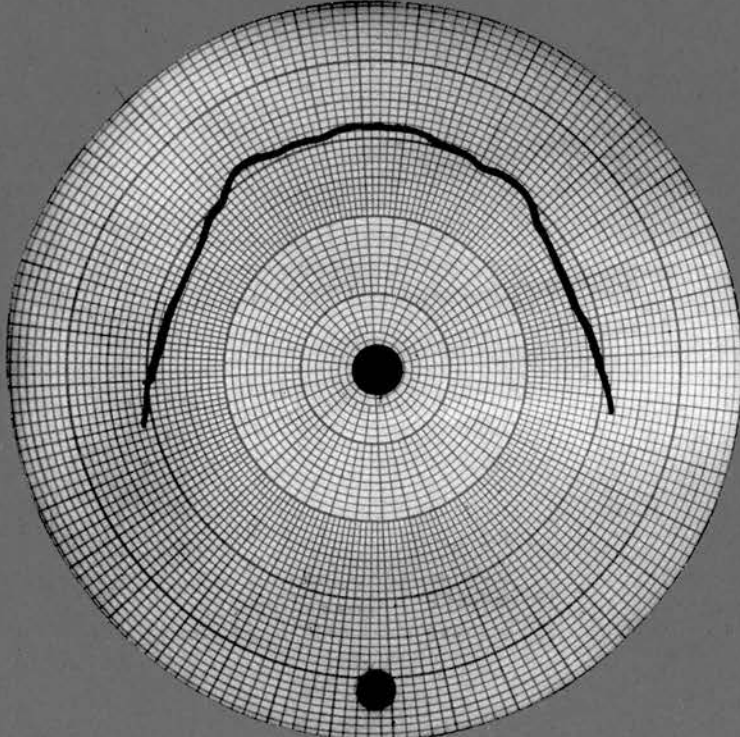


Fig. 20.

ASSESSMENT of ACCURACY of HORIZONTAL TRACING INSTRUMENT.

The horizontal traces were used only to illustrate in a general way the changes which occurred between the first and last casts of the series. They were not measured, as the points at which the horizontal tracings crossed the planes of the vertical tracings varied between the eight areas traced.

An assessment of the accuracy of the instrument was made by tracing, on the same piece of paper, five successive casts of the upper jaw of a dentulous patient (Fig. 20 ). The greatest breadth of the five lines was 1.0 mm. and since each line was 0.3 mm. broad, this represents a variation between the five casts in mounting, positioning and tracing of 0.7 mm.

INVESTIGATION OF ERRORS.

Errors from the following sources were investigated.

1. The instrument for making vertical tracings.
2. Impressions and casts.
3. Mounting the casts.
4. Superimposition of traces.
5. Measurement of traces.

1. THE INSTRUMENT FOR MAKING VERTICAL TRACINGS:-

Five successive traces of a standard 25 mm. diameter cylinder were made with the tracing instrument and measured with a dial gauge attachment on a measuring microscope. The range of error was + 0.05 to + 0.10 mm. with a mean of + 0.08 mm. (+ 0.32%). The traces were made with the stylus held as nearly as possible perpendicular to planes tangential to the surface traced. This relationship of stylus to surface (to within  $15^{\circ}$  of perpendicular) was present in the majority of tracings of the casts but in coronal tracings of the palatal areas in the premolar region and in the buccal areas of the casts in the canine region the angle between stylus and surface was about  $45^{\circ}$  (Figs. 21 & 22) To estimate errors which this angulation of the stylus produced, five tracings of the 25 mm. cylinder were repeated with the stylus held at  $45^{\circ}$  to planes tangential to its surface. The range of error in measurement of these traces was + 0.20 to + 0.30 and the mean + 0.26 mm. (+ 1.04%).

**Fig. 21** Relationship of tracing stylus to surface of cast  
in coronal tracing of 4|4 region.

**Fig. 22** Relationship of tracing stylus to buccal surface  
of cast in coronal tracing of 3|3 region.

Fig. 21

Fig. 22

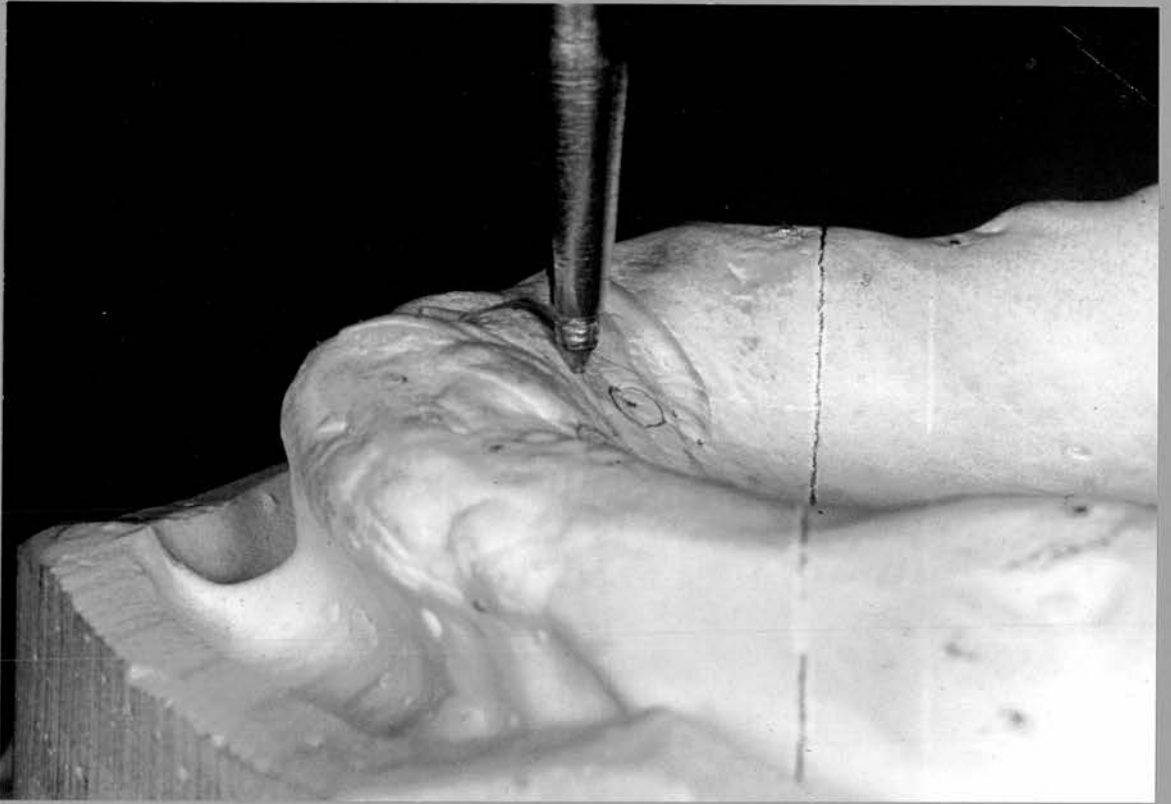


Fig. 21.

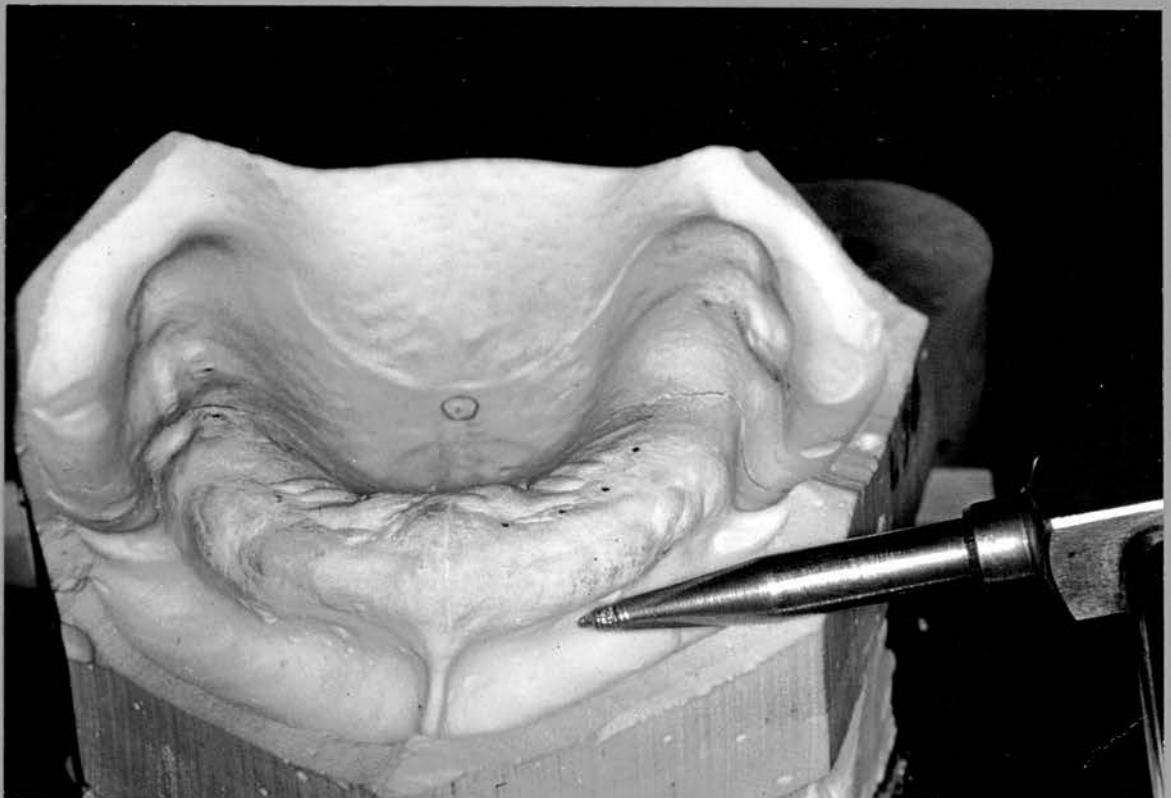


Fig. 22.

It was apparent from this experiment that the instrument error would vary slightly between traces at different tooth positions and between different parts of the same trace and was dependent on the angle between the stylus and cast surface. However in a series through a single tooth position the angle between stylus and equivalent parts of the surfaces of pre- and post-extraction casts was relatively constant and the effect of the instrument error was therefore to increase slightly the dimensions of equivalent parts of both pre- and post-extraction traces of that series. This had a negligible effect on the measurements of post-extraction changes.

## 2. IMPRESSIONS AND CASTS.

SKINNER & CARLISLE (1956) compared the accuracy of a number of agar-agar and alginate impression materials by comparative measurements between marks on a master model and impressions of that model. There was some variation in the impression error between different measurements. The figures given for Zelex (the alginate impression material used in this study) vary between + 1.2% and - 0.2% with a greatest error of 0.056 mm.

Data on the dimensional changes of mixtures of equal parts by weight of plaster of Paris and "Kaffir D" artificial stone could not be found. A series of 10 mixes was therefore made with water/powder ratios varying from 0.6 to 0.25 i.e. from the thinnest practicable mix to the thickest. The setting expansions observed after 24 hours varied from 0.22%

to 0.26% with a mean of .24%. This mean expansion would represent an increase on the cast of 0.08 mm. in the transverse measurement of a palate 34 mm. broad (i.e. average palatal breadth observed in the first molar region in the sample). Laboratory experiments however do not give exact estimates of the errors which may arise in the clinical use of the materials. The compressibility of the mucosa, faulty manipulation by the clinician or by the laboratory technician may produce larger dimensional changes than those inherent in the setting of the materials themselves.

An experiment was conducted in order to estimate the variations which might be expected to arise in taking impressions and making the casts. Variations in mounting the casts, which were used in this experiment, are also shown but a further study of variations in mounting of the serial casts in the sample follows later.

In the experiment five maxillary impressions by different clinicians were taken of an edentulous patient and five similar impressions by different clinicians of a patient with most of the maxillary teeth present. These 10 impressions were cast with a mixture of equal parts by weight of plaster and artificial stone by different technicians using unspecified Water/Powder ratios. The casts were mounted on perspex bases as previously described. Tracings of the casts were recorded in two ways:-

(a) "Combined traces". Each of the five casts of the edentulous patient was laid in turn on the tracing instrument and sagittal traces in the median planes of the casts were

made on the same piece of paper. Coronal traces through 6/6 region were then made of each of the five casts on another piece of paper. Similar sagittal and coronal tracings were made of the five casts of the edentulous patient. Thus 4 "combined traces" were obtained, each of which comprised five lines. (Figs. 23 & 24 ).

(b) "Superimposed traces". Sagittal and coronal tracings of each of the ten casts were repeated but each trace was recorded on a separate piece of transparent cellophane. Thus four groups of five separate traces were obtained. The five traces in each group were then superimposed to reduce the deviations caused by variations in the orientation of the casts.

The total widths of the five lines on the "combined traces" and on the "superimposed traces" were then measured with a Brinell microscope at the following points (see p. )

- (a) Mid buccal point - on right and left in the coronal traces and in the median plane.
- (b) Lingual gingival margin (dentulous patient) and ridge crest (edentulous patient) on right and left in coronal traces and in the median plane.
- (c) Highest point of palate in both coronal and sagittal traces.

Thus 3 buccal and 3 lingual gingival or ridge crest measurements and 2 palatal measurements were made on the "combined" and on the "superimposed traces" of each patient.

The total variation in each group of five traces at the points of measurement was found by subtracting the mean

CORONAL COMBINED  
TRACES OF FIVE  
EDENTULOUS CASTS.

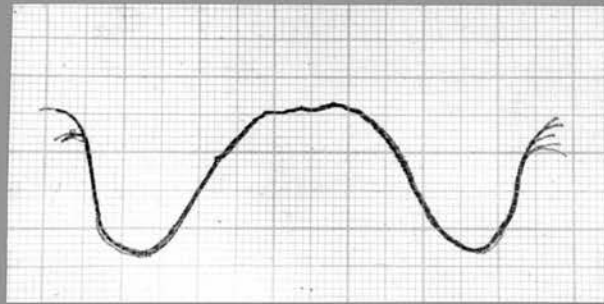


Fig. 23.

SAGITTAL COMBINED  
TRACES OF FIVE  
EDENTULOUS CASTS.

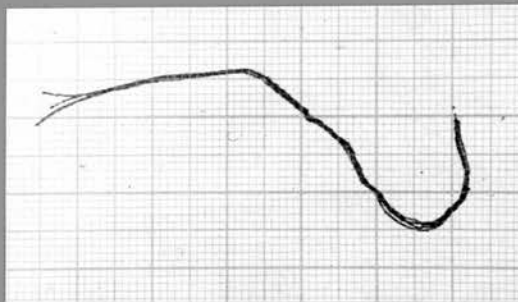


Fig. 24.

width of one trace (0.3 mm.) from these measurements.

The figures thus obtained for the "combined traces" included the variations in the orientation of the casts while those for the "superimposed traces" did not. The differences between the corresponding figures for "combined" and "superimposed traces" thus indicated the variation in the orientation of the casts and the figures for the "superimposed traces" indicated the variations in impression taking and casting.

Owing to the paleness of the lines and the diffusion of light through the five sheets of cellophane the variations between the "superimposed traces" appeared less on photographs than on the traces themselves. The measurements were therefore made directly on the traces which were stapled together. The range and means of the variations in the six mid buccal, the four palatal and the six lingual gingival or ridge crest measurements of "combined" and of "superimposed traces" of the 10 casts are shown in the following Table.

TABLE 4.

RANGE AND MEANS OF TOTAL VARIATIONS OBSERVED IN COMBINED AND SUPERIMPOSED TRACES OF 5 DENTULOUS AND 5 EDENTULOUS CASTS.

|                          | Positions of Measurements.         |      |                                     |      |                      |      |
|--------------------------|------------------------------------|------|-------------------------------------|------|----------------------|------|
|                          | Lingual vertical<br>or Ridge crest |      | Highest point of<br>vault of palate |      | Mid. buccal<br>point |      |
|                          | Range                              | Mean | Range                               | Mean | Range                | Mean |
|                          | mm                                 | mm   | mm                                  | mm   | mm                   | mm   |
| Combined<br>Traces       | 0.4 - 1.2                          | 0.8  | 0.1 - 0.5                           | 0.3  | 0.1 - 0.4            | 0.3  |
| Superimposed<br>Traces   | 0.2 - 0.5                          | 0.3  | 0 - 0.1                             | 0.1  | 0 - 0.3              | 0.1  |
| Variation<br>in mounting | 0.1 - 0.7                          | 0.5  | 0 - 0.5                             | 0.2  | 0 - 0.4              | 0.2  |

The superimposition of the traces made it impossible to use one of the lines as an arbitrary "base-line" to establish whether the variations were positive or negative. Even if it had been possible, the procedure is of doubtful value as the sign of the variations would have depended on which of the five lines was used. The mean therefore represents the sum of the total variations observed at equivalent points of measurement divided by the number of measurements.

It can be seen that the mean variation in the casts as represented by the measurements of the "superimposed traces" is least at the highest point of the palate and mid buccal points (0.1 mm.) and greatest at the lingual gingival margins and ridge crests (0.3 mm.). Errors in tracing, measurement and in superimposition of the traces are also included in these figures, and owing to the difficulty of superimposing five traces in each group, the latter error is likely to be larger than that in the study where only two traces were superimposed at a time.

The mean variation observed in the "combined traces" is reduced by approximately one third by superimposing the traces.

### 3. VARIATION IN MOUNTING OF THE CASTS.

Variations in the orientation of the casts were of importance only so far as they affected the positions of the lines along which the tracing stylus passed. Purely horizontal or purely vertical differences between the

mounted casts were unimportant, since measurements in the horizontal plane from the "R" and "M" planes, which were marked on the casts, (Fig. 2 ) located the positions of the tracings and the superimposition of the traces corrected pure vertical differences. On the other hand errors of antero-posterior tilt affected the position of the coronal tracings and errors of lateral tilt the position of sagittal tracings as the measurements which located these tracings were made in the horizontal plane.

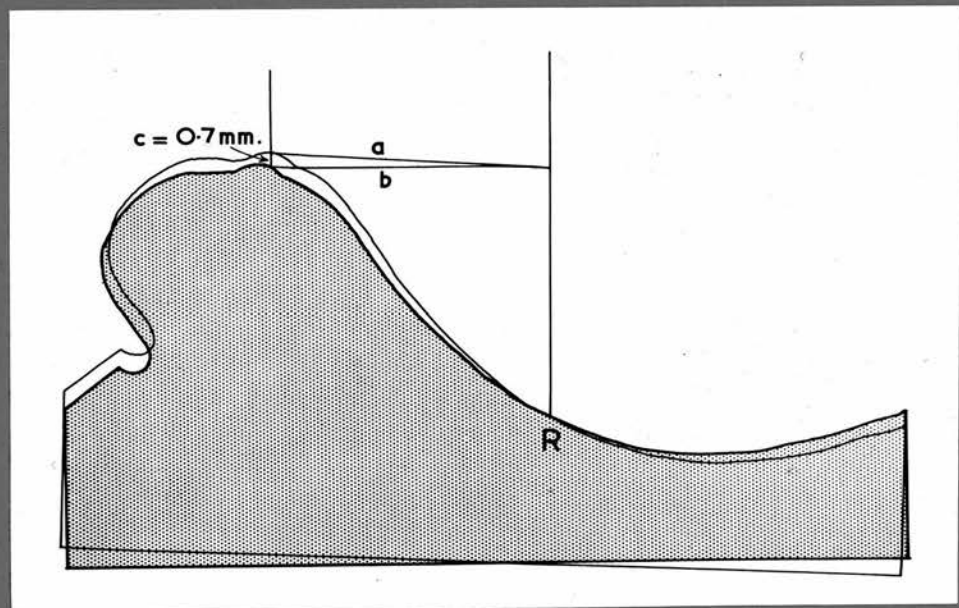
(a) Variations observed in mounting of the casts in the previous experiment.

The greatest variation in orientation of the casts observed in the previous experiment was 0.7 mm. at the crest of the ridge in the median plane of the edentulous casts. On the assumption that the whole of this was an error of antero-posterior tilt, its effect on the true position of a coronal tracing at the ridge crest can be calculated by Pythagorean theorem to be negligible. The base of the right angle triangle is the horizontal distance of the coronal trace from the axis of rotation in a correctly orientated cast. The perpendicular is the amount of tilt (0.7 mm.) measured in the fixed plane of the tracing stylus. The hypotenuse then represents the distance of the coronal tracing from the axis of rotation in a tilted cast. (Fig. 25 ).

(b) Variations observed in mounting the casts in the whole sample.

While the foregoing experiment showed variations in mounting in two groups of similar casts it was also necessary to calibrate the errors which occurred in mounting of the

THE EFFECT OF ANTERO-  
POSTERIOR TILTING ON  
THE POSITIONING OF  
A CORONAL TRACING.



- a: Hypotenuse
- b: Base
- c: Perpendicular  
(amount of tilt  
at position of  
coronal tracing)
- R: Axis of rotation

Fig. 25.

relatively dissimilar casts in each of the 25 series which comprised the material for this study.

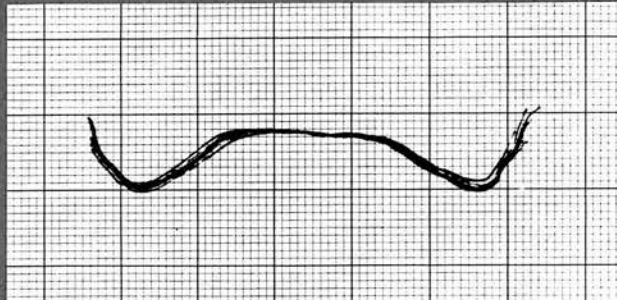
Sagittal and coronal "combined" traces were made of each of the 25 series of casts in the sample. This was done as soon as the mounting was completed in order to find any major errors of mounting which might have occurred accidentally. When such an error was found the cast was remounted.

Mounting errors were assessed from the thickness of the "combined traces" at the "stable area" of the palate. The post-extraction changes caused marked deviations in the other parts of the traces. The greatest thickness in the stable parts of the combined traces which was accepted without remounting was 1 mm. This represented a total variation between eleven casts of 0.7 mm. (Fig. 26 ). The total variation in the series representing the mode was 0.3 mm. (Fig. 27 ) but it should be remembered that as in the previous experiment this figure does not take into account whether the errors were plus or minus and it includes errors of vertical orientation as well as those of tilt.

#### 4. SUPERIMPOSITION OF TRACES.

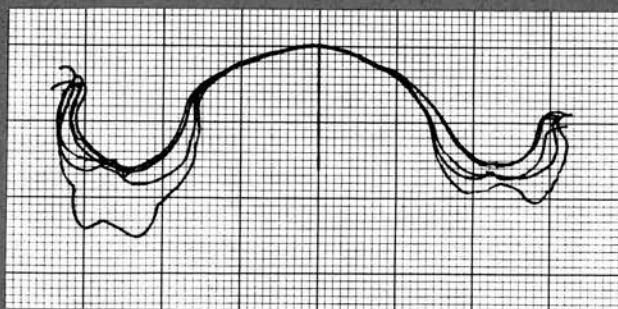
11 post-extraction traces were superimposed on the corresponding pre-extraction traces on 2 separate occasions and direct contact photographs were made of each pair of superimposed traces on each occasion. By measuring the post-extraction changes on the first and second photographs of each pair the effect of errors of superimposition of the

"COMBINED" TRACES  
SHOWING VARIATIONS  
IN MOUNTING OF SERIES  
OF CASTS IN THE SAMPLE.



MAXIMUM.

Fig. 26.



MODE.

Fig. 27.

traces was observed.

The post-extraction measurements which were made of each pair of traces were:- Mid. buccal, Lingual vertical and palatal. Where the measurement on the second superimposition of a pair of traces was greater than the first the difference between the measurements was indicated as a plus error and where the second was less than the first as a minus error. The results are recorded in Table 5.

TABLE 5.

ERRORS IN DOUBLE DETERMINATIONS OF POST-EXTRACTION MEASUREMENTS AT 2 SEPARATE SUPERIMPOSITIONS OF 11 PAIRS OF TRACES.

|                               |               | Positions of Measurements. |                     |         |
|-------------------------------|---------------|----------------------------|---------------------|---------|
|                               |               | Mid.<br>Buccal             | Lingual<br>Vertical | Palatal |
|                               |               | m                          | m                   | m       |
| No. of 2nd measurements       | >1st          | 5                          | 4                   | 4       |
| No. of 2nd measurements       | <1st          | 2                          | 1                   | 2       |
| No. of identical measurements |               | 4                          | 6                   | 5       |
| Total pairs of measurements   |               | 11                         | 11                  | 11      |
|                               |               | mm.                        | mm.                 | mm.     |
| RANGE OF<br>ERROR             | Max.          | +0.2                       | +0.1                | +1.0    |
|                               | Min.          | -0.1                       | -0.1                | -0.2    |
|                               | AVERAGE ERROR | +0.04                      | +0.03               | +0.2    |

5. MEASUREMENT OF THE TRACES:-

Measurements of post-extraction changes were repeated by the observer on photographs of 55 pairs of superimposed pre- and post-extraction traces which had already been measured. The results are shown in Table 6.

TABLE 6.

ERRORS IN FIFTY FIVE DOUBLE DETERMINATIONS OF MEASUREMENTS OF POST-EXTRACTION CHANGES ON SUPERIMPOSED TRACINGS.

|                               | Positions of measurements. |       |       |       |         |       |
|-------------------------------|----------------------------|-------|-------|-------|---------|-------|
|                               | B u c c a l                |       |       | Ling. | Palatal |       |
|                               | Upper                      | Mid.  | Lower | Vert. |         |       |
|                               | n                          | n     | n     | n     | n       |       |
| No. of 2nd measurements > 1st | 24                         | 18    | 25    | 19    | 15      |       |
| No. of 2nd measurements < 1st | 11                         | 14    | 15    | 13    | 8       |       |
| No. of identical measurements | 20                         | 23    | 15    | 23    | 32      |       |
| Total pairs of measurements   | 55                         | 55    | 55    | 55    | 55      |       |
|                               |                            | mm    | mm    | mm    | mm      | mm    |
| RANGE OF ERROR                | Max.                       | +0.6  | +0.2  | +0.4  | +0.5    | +1.5  |
|                               | Min.                       | -0.5  | -0.4  | -0.7  | -0.5    | -2.0  |
| AVERAGE ERROR                 |                            | +0.05 | +0.01 | +0.03 | +0.02   | +0.05 |

By comparing the average errors in the mid. buccal, lingual vertical and palatal measurements shown in the above table with the average errors in Table 5 it can be seen that the average error in 2 measurements of a single superimposition of traces is less than that of 2 measurements of traces superimposed at separate times. The differences of 0.03 mm. 0.01 mm. and 0.15 mm. in the average errors of Mid. buccal, Lingual Vertical and Palatal measurements respectively indicate the errors in the superimposition of the traces. The smaller range of errors in Table 5 reflects the smaller number of traces measured.

DISCUSSION OF ERRORS.1. Percentage Error:-

The mean variations observed in the "superimposed traces" in the experiment on Page 110 include errors in impressions, casts, tracing, and superimposition and measurement of the traces. The conditions under which the experiment was conducted tended to exaggerate the errors particularly those of superimposition of the traces.

If it is assumed that similar errors were present in post-extraction measurements of the sample then a rough estimate of the percentage errors can be made.

On this basis the percentage error of a measurement of 1.5 mm. post-extraction change at the mid. buccal point at 4 weeks would be 7.0% but if the change progressed to 6.5 mm. at 130 weeks the percentage error would be 1.5%. Similar vertical measurements would have errors of 20% and 4.6% respectively.

The small measurements were obviously less reliable than the larger measurements and the vertical measurements less reliable than the buccal measurements.

2. Interpolated Measurements:-

As the post-extraction intervals at which traces were made varied from patient to patient the use of interpolated measurements at regular intervals on the time base of graphs of post-extraction change was necessary for the comparison of changes between patients.

A general tendency to underestimate the interpolated

changes is likely to be characteristic of the method as the points on the graphs were joined by straight lines. Errors from this source were reduced as far as possible by ensuring that the interval between traces was short (two to four weeks) when the rapid change in the first three post-extraction months was taking place.

### 3. Random Errors.

Random errors which cannot be avoided or estimated are bound to be present in a study of this kind and have to be accepted. The nature of these errors is such that nearly equal numbers of positive and negative errors are likely to occur and will tend to cancel each other.

Apart from the random errors in interpolated measurements other possible sources of errors of this kind are as follows:-

(a) Errors in sections traced. The sections traced were either in sagittal or coronal planes thus the angles at which they crossed the alveolar ridge varied between teeth and between patients but in the majority of cases was within  $15^{\circ}$  of a right angle. In the canine region the angle between the coronal tracings and the buccal parts of the ridge was about  $45^{\circ}$ . As a result the post-extraction changes appeared to be greater in this region.

An alternative method of positioning tracings so that they crossed the ridge at right angles in all regions was rejected on the grounds that the palatal changes could not be compared between patients and the data obtained gave a less comprehensive picture of the changes in the maxillary denture bearing area as a whole.

(b) The sample. The small size of the sample and the fact that it was selected may have produced a bias towards greater or less post-extraction changes which could be detected only by far larger samples from a wider population. It was not possible in the present study to control numerous factors such as genetic background, diet and general health of the patients, the relative positions and periodontal condition of the teeth before extraction and many others. The conditions associated with the extraction could be controlled only in so far as the method was concerned. The degree of trauma required to dislodge the teeth varied in different teeth of the same patient and from patient to patient as did the many factors connected with the healing process. This undoubtedly contributed to the large variations observed between patients.

(c) Oedema of the oral mucosa. Obvious swellings which could be detected clinically before extraction led to the exclusion of some teeth from the sample since measurements of post-extraction changes in these areas would include the subsidence of the swellings. The effects of less obvious oedema associated with the dental and periodontal lesions which lead to the extraction of the teeth had to be accepted.

It was recognised that oedema caused by incidental infection or trauma may have occurred during the period of study and there is no reason to believe that the "stable area" of the palate was any less affected than other parts of the oral mucosa. The effect of oedema, localised in this area, on the measurements of post-extraction changes depended on whether it was present before or after extraction.

Pre-extraction oedema at the vault of the palate would reduce the measurements while post-extraction oedema would increase them.

(d) Dentures. The linear processing shrinkage of a full upper acrylic denture measured across the molars is usually less than 0.3 mm. and rather less than 0.2 mm. expansion from water absorption will compensate part of this shrinkage according to WOELFEL & PAFFENBARGER (1959). Thus dimensional inaccuracies of - 0.1 to - 0.3 mm. may be expected and soft tissue adaptive changes of this order may possibly have occurred. A general tendency of the tissues to adapt themselves to the fitting surface of the denture which was observed by GROHS (1935) FENDLETON (1937) and FRÖHLICH (1952, 1954, 1958) has the following implications in the present study.

- (a) Adaptive hyperplastic changes in the mucosa might be expected to mask progressive atrophy which otherwise would be observed and thus the surface form of the denture bearing area would tend to become stabilised after the dentures were fitted.
- (b) Hyperplastic changes confined to the "stable area" of the palate would tend to increase the amount of post-extraction change observed on superimposed traces, and atrophic changes would decrease it.
- (c) Occlusal forces on the prosthesis might over a large number of years cause a change in the relationship of the whole denture bearing area to the cranium with little concomitant change in the surface form of the denture bearing area itself. Direct evidence

(Atkinson) however, shows that such a change is unlikely to occur during the first year of denture wearing and indirect evidence indicates no change up to 10 years of denture wearing (Tallgren).

It was impracticable to have an equivalent control group of edentulous patients without prostheses over the period of the present study. Therefore every effort was made to reduce the effect of denture wearing by ensuring that the fit of the dentures was accurate, the occlusion balanced and the mucosa kept in a healthy condition by massage with a soft brush and removal of the dentures at night.

#### CONCLUSION.

The methods employed were sufficiently accurate and reliable for the purposes of this investigation.

THE PRESENTATION OF DATA.

1. Graphs of post-extraction changes in individual patients:-

The post-extraction times of the traces in different series did not coincide. Therefore, to compare the changes in different series at the same intervals after extraction, the measurements from the traces were plotted against a time base. Thus three graphs of post-extraction changes were constructed for every region of the mouth traced in each patient. The mean of the upper, middle and lower buccal measurements was plotted as "buccal change", the vertical measurement at the lingual gingival margin as "lingual vertical change" and the horizontal measurement of the amount of the palate affected by change as "palatal change". In cases of symmetrical extraction of teeth in the same patient the mean of the right and left sides was plotted. As the residual alveolar ridges were reduced in size following the loss of teeth, the post-extraction changes were plotted on the graphs as minus (- mm.). To save space the sign has not been included in the tables.

Examples of graphs from each of the eight regions traced in individual patients together with tables of measurements and photographic prints of the corresponding traces are shown on Pages 128-143

The majority of these illustrative traces were of a series of casts (F.30) in which the post-extraction changes were about average. Horizontal traces of the first and last cast of this series are also included (p.183 ). The

traces through the anterior teeth (F.11) and through the last molar (M.37) showed post-extraction changes approaching the maximum observed in the sample.

## 2. Graphs of average post-extraction changes:-

Measurements were taken from the individual graphs of post-extraction changes of all patients in the sample at the following post-extraction intervals on the time base 2, 4, 6, 8, 12, 16, 26, 39, 52, 78, 104 and 130 weeks. Thus the average post-extraction changes in the samples of each region were calculated and average curves drawn (Pages 145 - 160)

## 3. Diagrams:-

In order to give a diagrammatic representation of the average changes, the means of the pre-extraction measurements of each sample were calculated and are shown in Table 7.

TABLE 7.

| REGION<br>TRACED | AVERAGE MEASUREMENTS OF PRE-EXTRACTION TRACES |                    |                  |                 |                              |
|------------------|---|--------------------|------------------|-----------------|------------------------------|
|                  | Palatal<br>Length                             | Palatal<br>Breadth | Palatal<br>Depth | Ridge<br>Height | Bucco-<br>Lingual<br>Breadth |
|                  | mm.   | mm.                | mm.              | mm.             | mm.                          |
| Median plane     | 43.94   | -                  | 15.12            | 11.44           | 7.27                         |
| <u>1 / 1</u>     | 43.80   | -                  | 13.43            | 14.32           | 6.51                         |
| <u>3 / 3</u>     | -   | 24.34              | 1.00             | 14.54           | 7.64                         |
| <u>4 / 4</u>     | -   | 28.06              | 8.58             | 11.96           | 9.25                         |
| <u>5 / 5</u>     | -   | 33.84              | 12.70            | 12.00           | 9.37                         |
| <u>6 / 6</u>     | -   | 34.00              | 14.54            | 11.20           | 12.40                        |
| <u>7 / 7</u>     | -   | 37.62              | 14.18            | 11.70           | 12.05                        |
| <u>8 / 8</u>     | -   | 44.18              | 13.70            | 12.13           | 10.31                        |

The pre-extraction trace which most closely corresponded to the average measurements of a region was projected by means of a photographic enlarger on to squared paper. By adjusting the enlarger and slightly altering the traces the projection was made to fit the average measurements which were already recorded on the paper. A pencil tracing was then made of the projected outline and the buccal and lingual gingival margins were joined with a smooth curve continuous with the "mucosal" contour of the trace. The appropriate post-extraction traces in the series were also projected and adjusted to fit the corresponding average post-extraction measurements and thus pencil diagrams were produced which gave a general indication of the average changes at 4, 12, 26, 52 and 130 weeks after extraction of the teeth.

The diagram illustrating the average extent of the stable area of the palate (p. 192) was originally drawn on squared paper to the average palatal dimensions shown in Table 7. The average extent of the palatal change in each region,  $2\frac{1}{2}$  years after tooth extraction, was then plotted and the points were joined to outline the "stable area". The casts showing minimum and maximum palatal change were selected on the basis of the  $2\frac{1}{2}$  year post-extraction measurements of palatal change in the planes of the traces. Additional traces were then made of the pre-extraction and  $2\frac{1}{2}$  year post-extraction casts at intermediate positions to provide additional points for outlining the stable area on the pre-extraction casts.

4. Traces illustrating the range of post-extraction changes.

The patients who showed the maximum and minimum amounts of buccal change did not necessarily show maximum and minimum amounts of change in the other measurements. For this reason, traces illustrating "maximum" and "minimum" post-extraction changes were selected on the basis that the sum of the buccal, lingual vertical and palatal measurements  $2\frac{1}{2}$  years after the extraction of the teeth was the greatest and the least in the sample.

5. Photographic prints of the traces:-

The negatives on which the measurements were made were exposed by transmitted light to show the graticule on the paper but were unsuitable for positive reproduction as the grain in the paper clouded the print. Accordingly, new slightly over-exposed negatives were made to suppress the grain in the paper and a graticule was printed separately by a double exposure technique.

6. Tables:-

Averages in the table have been worked out to the second decimal place and are presented in this form for clarity, but, in the tables of measurements, only the first decimal place is dependable.

Note:- Statistical treatment of the data was contemplated and advice was sought, but in view of the small sample and large range of the changes, the present treatment was considered to be adequate for the purpose of this study.

EXAMPLES OF TRACES, GRAPHS AND  
TABLES OF MEASUREMENTS FROM EIGHT  
SECTIONS OF THE DENTURE-BEARING  
AREA OF THE UPPER JAW.

( Pages 128-143 )

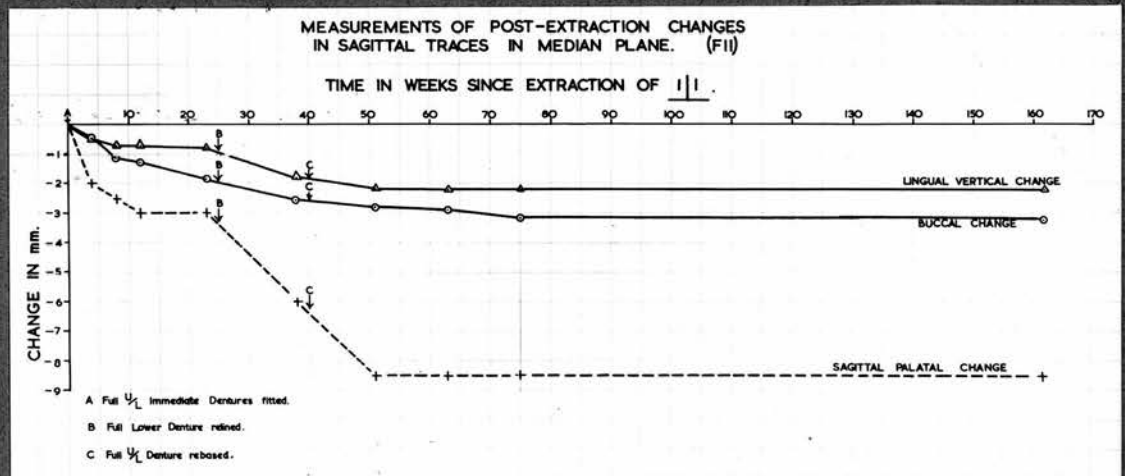


Table 8

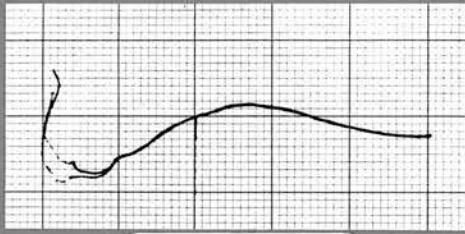
| POSITION OF MEASUREMENT | MEASUREMENTS OF POST-EXTRACTION CHANGES IN SAGITTAL TRACES IN MEDIAN PLANE |      |      |      |      |      |      |                |      |
|-------------------------|--|------|------|------|------|------|------|----------------|------|
|                         | Time in weeks since extraction of $\frac{1}{1}$                            |      |      |      |      |      |      |                |      |
|                         | 4  | 8    | 12   | 23   | 38   | 51   | 63   | $\frac{1}{75}$ | 162  |
| Upper                   | 0.2  | 0.5  | 0.7  | 1.1  | 1.7  | 1.7  | 1.8  | 2.0            | 1.9  |
| Middle                  | 0  | 0.8  | 0.8  | 1.7  | 2.7  | 3.0  | 3.2  | 3.5            | 3.5  |
| Lower                   | 1.2  | 2.1  | 2.3  | 2.8  | 3.3  | 3.7  | 3.7  | 4.0            | 4.3  |
| AVERAGE <sup>o</sup>    | 0.47   | 1.13 | 1.27 | 1.87 | 2.57 | 2.80 | 2.90 | 3.17           | 3.23 |
| LINGUAL VERTICAL +      | 0.5  | 0.7  | 0.7  | 0.8  | 1.8  | 2.2  | 2.2  | 2.2            | 2.2  |
| PALATAL *               | 2.0  | 2.5  | 3.0  | 3.0  | 6.0  | 8.5  | 8.5  | 8.5            | 8.5  |

<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

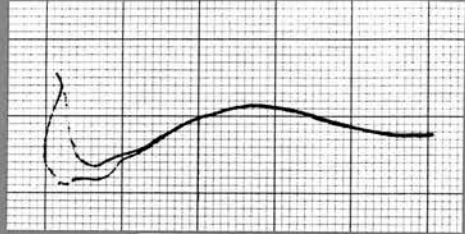
+ Measured at lingual gingival margin.

\* Horizontal extent of change in palate measured from point where line joining the lingual gingival margins of  $\frac{1}{1}$  intersects the median plane.

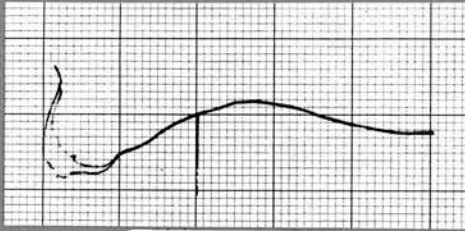
MEDIAN PLANE (F.11)



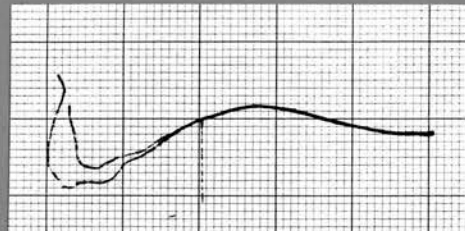
4 Weeks



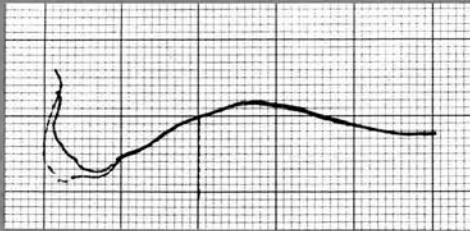
38 Weeks



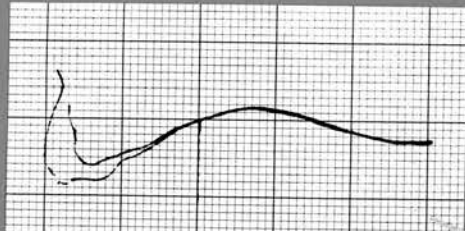
8 Weeks



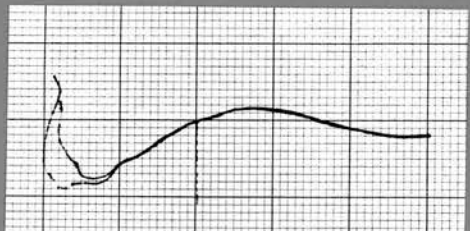
51 Weeks



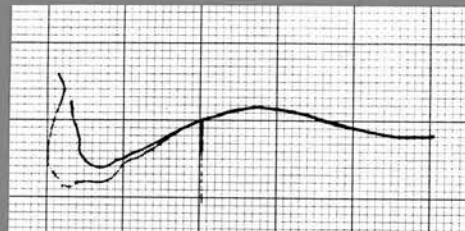
12 Weeks



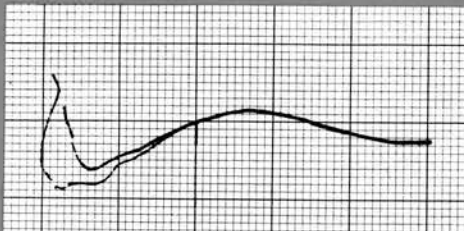
63 Weeks



23 Weeks



75 Weeks



162 Weeks

Fig. 28.

MEASUREMENTS OF POST EXTRACTION CHANGES  
IN SAGITTAL TRACES THROUGH 1. (F II)

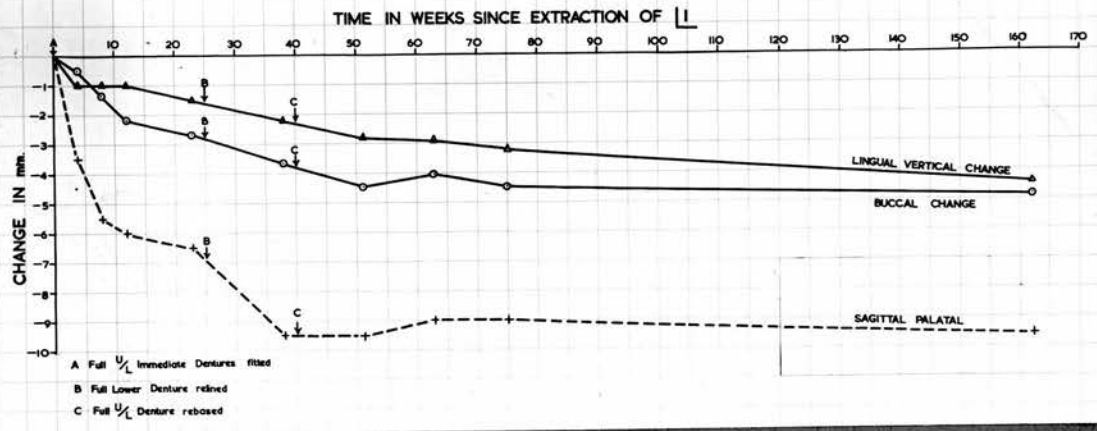


Table 9

| POSITION OF MEASUREMENT       | MEASUREMENTS OF POST-EXTRACTION CHANGES IN SAGITTAL TRACES THROUGH <u>1</u> (F.11) |      |      |      |      |      |      |      |      |
|-------------------------------|--|------|------|------|------|------|------|------|------|
|                               | Time in weeks since extraction of <u>1</u>   |      |      |      |      |      |      |      |      |
|                               | 4  | 8    | 12   | 23   | 38   | 51   | 63   | 75   | 162  |
| Upper                         | 0  | 1.2  | 1.7  | 2.0  | 2.7  | 3.4  | 2.6  | 3.3  | 3.7  |
| Middle                        | 0.5  | 1.3  | 2.1  | 2.8  | 3.8  | 4.5  | 4.3  | 4.5  | 4.8  |
| BUCCAL Lower                  | 0.9  | 1.8  | 2.7  | 3.5  | 4.4  | 5.5  | 5.2  | 5.5  | 6.0  |
| AVERAGE <sup>o</sup>          | 0.46   | 1.33 | 2.17 | 2.77 | 3.63 | 4.47 | 4.03 | 4.43 | 4.83 |
| LINGUAL VERTICAL <sup>+</sup> | 1.0  | 1.0  | 1.0  | 1.5  | 2.2  | 2.8  | 2.9  | 3.2  | 4.4  |
| PALATAL *                     | 3.5  | 5.5  | 6.0  | 6.5  | 9.5  | 9.5  | 9.0  | 9.0  | 9.5  |

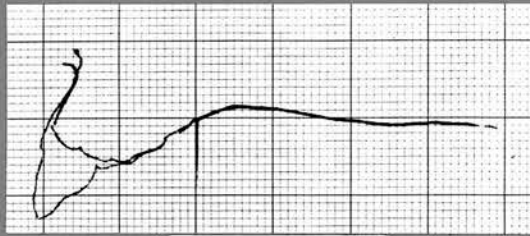
<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

<sup>+</sup> Measured at lingual gingival margin.

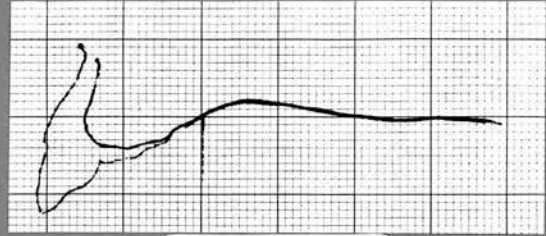
\* Horizontal extent of change in palate measured from lingual gingival margin.

Average Ridge Height 15 mm.

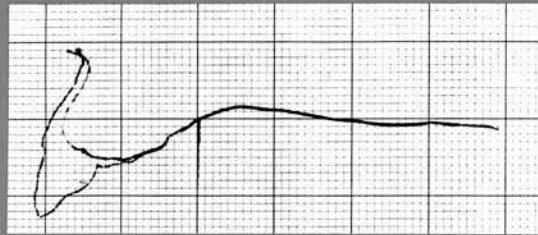
SAGITTAL TRACES 1 (F.11)



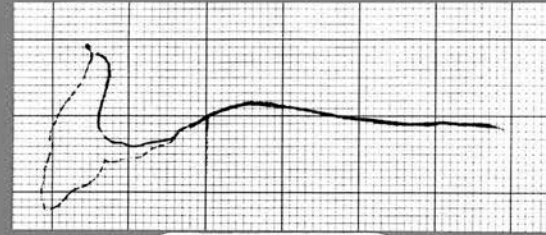
4 Weeks



38 Weeks



8 Weeks



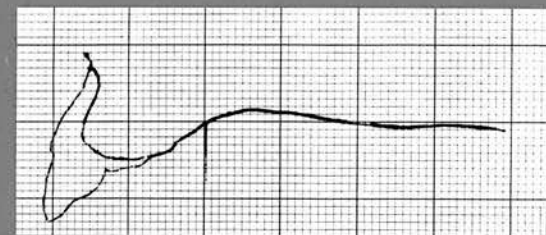
51 Weeks



12 Weeks



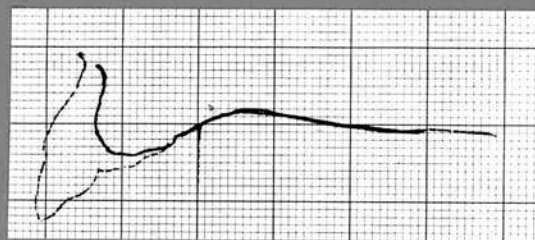
63 Weeks



23 Weeks



75 Weeks



162 Weeks

Fig. 29.

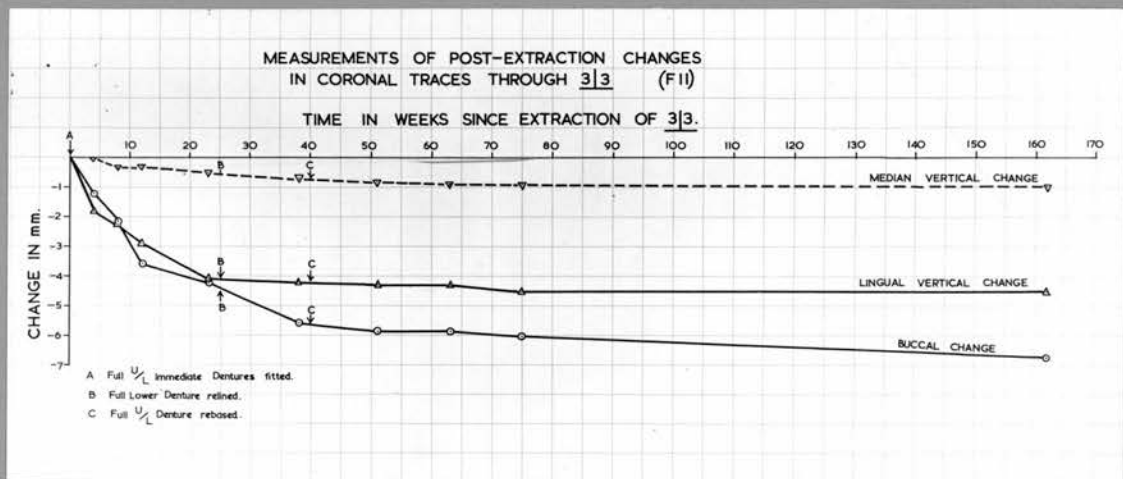


Table 10

| POSITION OF MEASUREMENT            | MEASUREMENTS OF POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH <u>3/3</u> (F.11) |      |      |      |      |      |      |      |      |
|------------------------------------|---|------|------|------|------|------|------|------|------|
|                                    | Time in weeks since extraction of <u>3/3</u>  |      |      |      |      |      |      |      |      |
|                                    | 4   | 8    | 12   | 23   | 38   | 51   | 63   | 75   | 162  |
| R.Upper                            | 0.6   | 1.1  | 1.8  | 3.0  | 4.1  | 4.6  | 4.2  | 4.9  | 5.0  |
| L.Upper                            | 0.8   | 2.8  | 4.3  | 4.7  | 7.0  | 7.0  | 6.9  | 6.8  | 7.4  |
| R.Middle                           | 0.5   | 0.9  | 1.6  | 2.7  | 4.6  | 4.9  | 5.1  | 5.0  | 5.4  |
| L.Middle                           | 1.5   | 2.9  | 3.3  | 4.8  | 6.1  | 6.7  | 6.4  | 6.5  | 7.8  |
| R.Lower                            | 1.9   | 2.1  | 6.8  | 4.6  | 5.6  | 5.7  | 6.6  | 7.0  | 6.1  |
| L.Lower                            | 2.0   | 3.1  | 3.6  | 5.5  | 6.1  | 6.2  | 5.9  | 6.0  | 8.6  |
| AVERAGE <sup>o</sup>               | 1.2   | 2.15 | 3.57 | 4.22 | 5.58 | 5.85 | 5.85 | 6.03 | 6.72 |
| Right                              | 1.8   | 2.0  | 3.1  | 3.8  | 3.8  | 3.85 | 3.9  | 4.3  | 4.3  |
| LINGUAL VERTICAL <sup>+</sup> Left | 1.8   | 2.5  | 2.7  | 4.4  | 4.6  | 4.7  | 4.7  | 4.7  | 4.7  |
| AVERAGE $\emptyset$                | 1.8   | 2.25 | 2.9  | 4.1  | 4.2  | 4.28 | 4.3  | 4.5  | 4.5  |
| MEDIAN VERTICAL *                  | 0   | 0.3  | 0.3  | 0.5  | 0.7  | 0.8  | 0.9  | 0.9  | 1.0  |

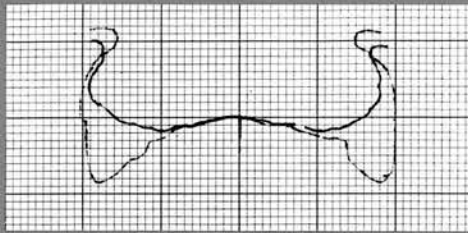
<sup>o</sup> Average of right and left upper, middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

<sup>+</sup> Measured at lingual gingival margin.

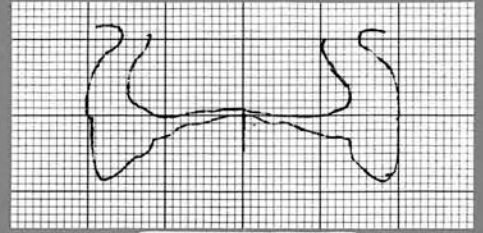
$\emptyset$  Average of right and left measurements of lingual vertical change plotted on graph to nearest 0.05 mm.

\* Measured in median plane.

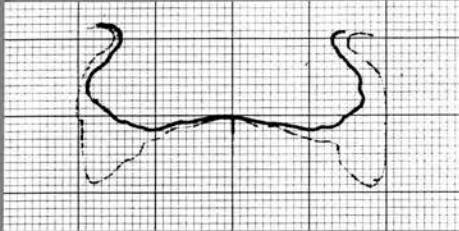
CORONAL TRACES 3/3 (F.11)



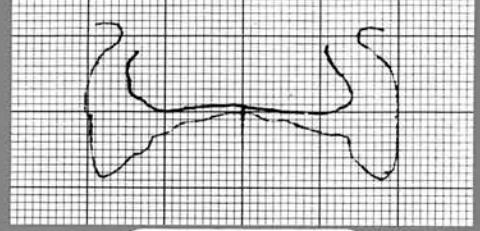
4 Weeks



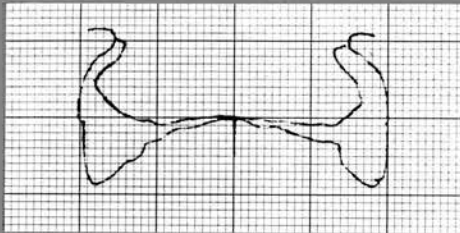
51 Weeks



8 Weeks



63 Weeks



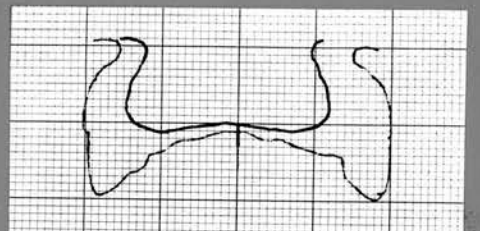
12 Weeks



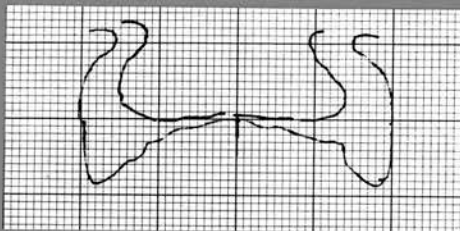
75 Weeks



23 Weeks



162 Weeks



38 Weeks

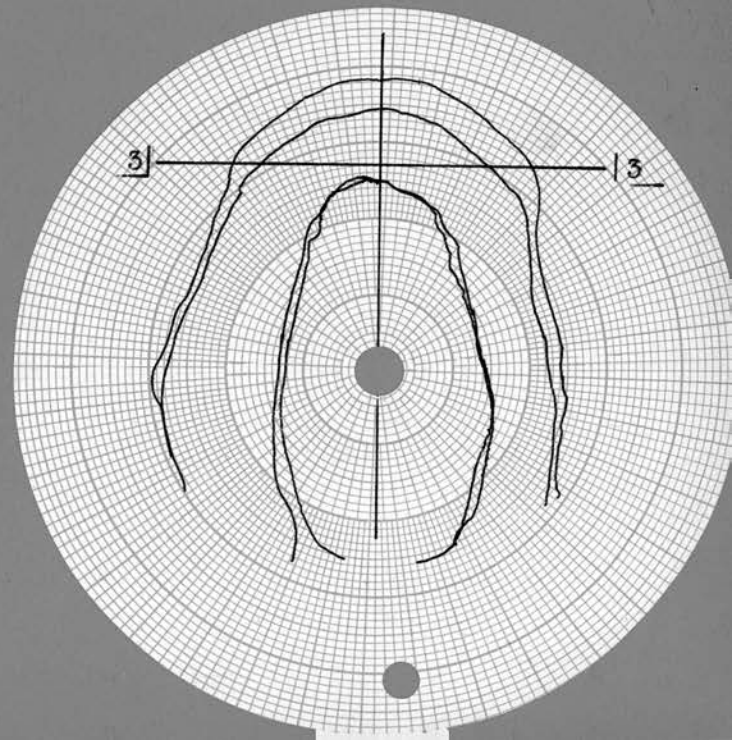


Fig. 30.

MEASUREMENTS OF POST-EXTRACTION CHANGES  
IN CORONAL TRACES THROUGH 4] (F30)

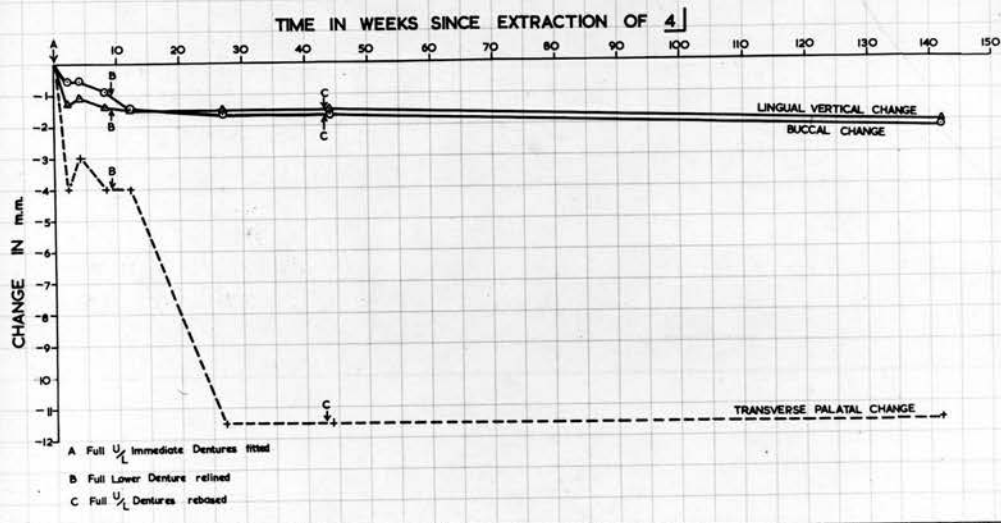


Table 11

MEASUREMENTS OF POST-EXTRACTION  
CHANGES IN CORONAL TRACES THROUGH  
4] (F.30)

| POSITION OF MEASUREMENT | Time in weeks since extraction of 4] |      |     |      |      |      |      |     |
|-------------------------|--------------------------------------|------|-----|------|------|------|------|-----|
|                         | 2                                    | 4    | 8   | 12   | 27   | 44   | 142  |     |
| BUCCAL                  | Upper                                | 0    | 0.7 | 0.8  | 1.5  | 1.8  | 2.0  | 2.2 |
|                         | Middle                               | 0.3  | 0.2 | 0.9  | 1.3  | 1.4  | 1.4  | 1.9 |
|                         | Lower                                | 1.3  | 0.7 | 1.0  | 1.5  | 1.6  | 1.5  | 2.4 |
| AVERAGE <sup>o</sup>    | 0.53                                 | 0.53 | 0.9 | 1.43 | 1.6  | 1.63 | 2.17 |     |
| LINGUAL VERTICAL +      | 1.3                                  | 1.1  | 1.4 | 1.45 | 1.5  | 1.5  | 2.0  |     |
| PALATAL *               | 4.0                                  | 3.0  | 4.0 | 4.0  | 11.5 | 11.5 | 11.5 |     |
| MEDIAN VERTICAL ø       | 0                                    | 0    | 0   | 0    | 0.5  | 1.0  | 1.1  |     |

<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

+ Measured at lingual gingival margin.

\* Horizontal extent of change across palate measured from lingual gingival margin. As the change in this case crosses the median plane the last 3 figures in this line represent half the palatal breadth in the plane of trace.

ø Vertical measurements in the median plane record further changes beyond the point where the full breadth of the palate is involved.

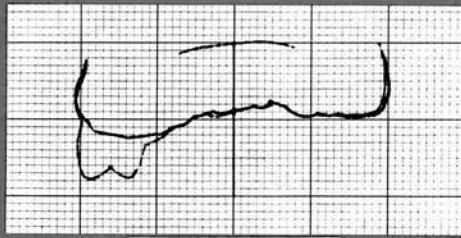
Average Ridge height 15 mm.

CORONAL TRACES  $\frac{4}{4}$  (F.30)

2 Weeks



12 Weeks



4 Weeks



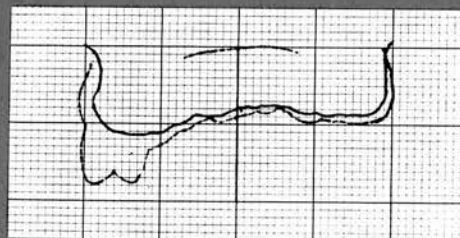
27 Weeks



8 Weeks



44 Weeks



142 Weeks

MEASUREMENTS OF POST-EXTRACTION CHANGES  
IN CORONAL TRACES THROUGH 5 (F 30)

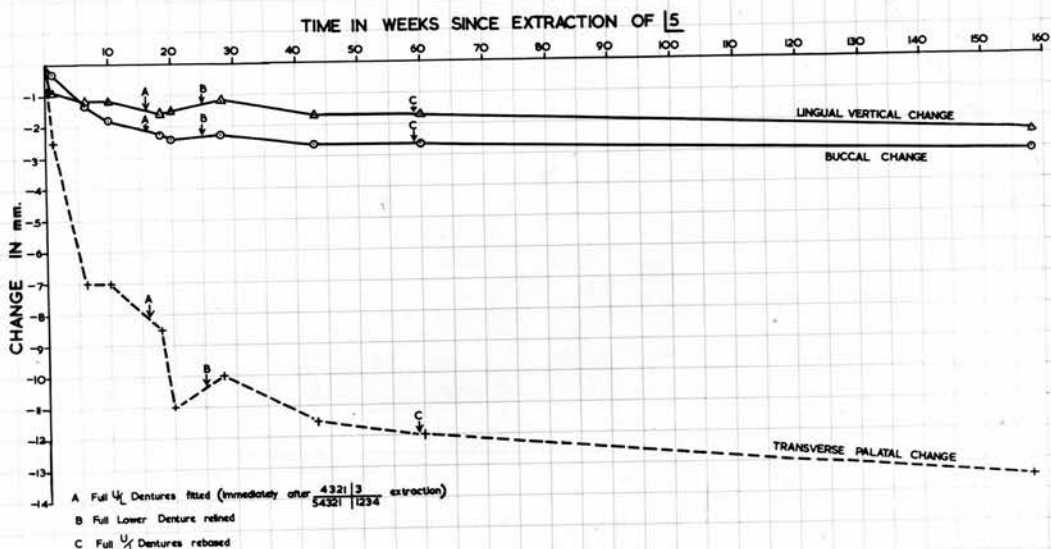


Table 12

MEASUREMENTS OF POST-EXTRACTION  
CHANGES IN CORONAL TRACES THROUGH  
5 (F.30)

| POSITION OF MEASUREMENT       | Time in weeks since extraction of <u>5</u> |     |     |      |      |      |      |      |      |
|-------------------------------|--|-----|-----|------|------|------|------|------|------|
|                               | 1  | 6   | 10  | 18   | 20   | 28   | 43   | 60   | 158  |
| Upper                         | 0  | 0.3 | 1.0 | 1.6  | 2.0  | 2.0  | 2.3  | 2.2  | 2.1  |
| Middle                        | 0.4  | 1.2 | 2.0 | 2.4  | 2.5  | 2.5  | 2.5  | 2.7  | 3.3  |
| BUCCAL Lower                  | 0.5  | 2.4 | 2.4 | 2.7  | 2.7  | 2.3  | 3.0  | 3.0  | 3.7  |
| AVERAGE <sup>o</sup>          | 0.3  | 1.3 | 1.8 | 2.23 | 2.4  | 2.27 | 2.6  | 2.63 | 3.03 |
| LINGUAL VERTICAL <sup>+</sup> | 0.9  | 1.2 | 1.2 | 1.6  | 1.5  | 1.2  | 1.7  | 1.7  | 2.4  |
| PALATAL*                      | 2.5  | 7.0 | 7.0 | 8.5  | 11.0 | 10.0 | 11.5 | 12.0 | 13.5 |

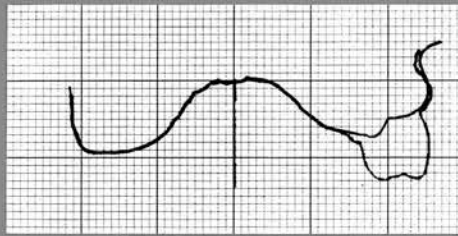
<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

<sup>+</sup> Measured at lingual gingival margin.

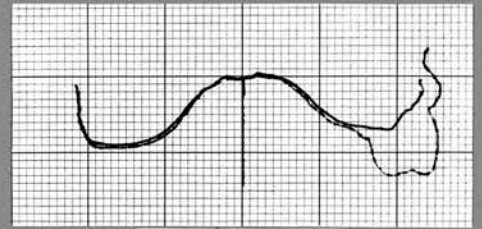
\* Horizontal extent of change across palate measured from lingual gingival margin.

Average Ridge Height 12 mm.

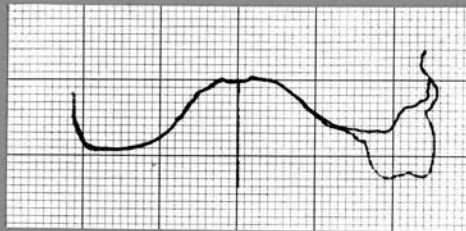
CORONAL TRACES 5 (F.30)



1 Week



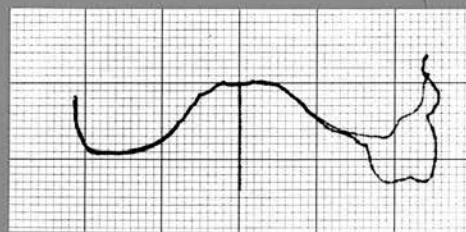
20 Weeks



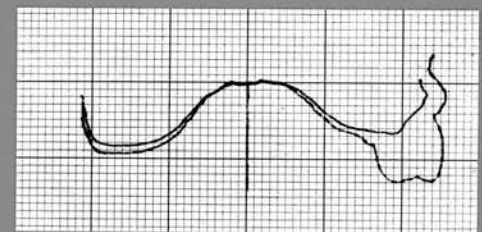
6 Weeks



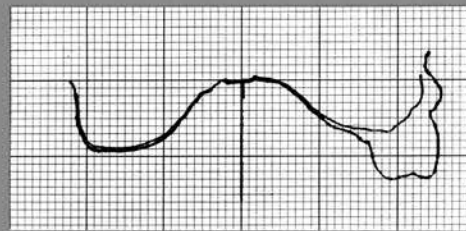
28 Weeks



10 Weeks



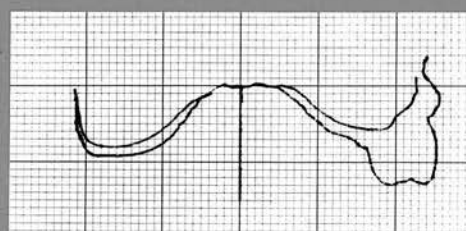
43 Weeks



18 Weeks



60 Weeks



158 Weeks

MEASUREMENTS OF POST-EXTRACTION CHANGES  
IN CORONAL TRACES THROUGH 6 (F 30)

TIME IN WEEKS SINCE EXTRACTION OF 6

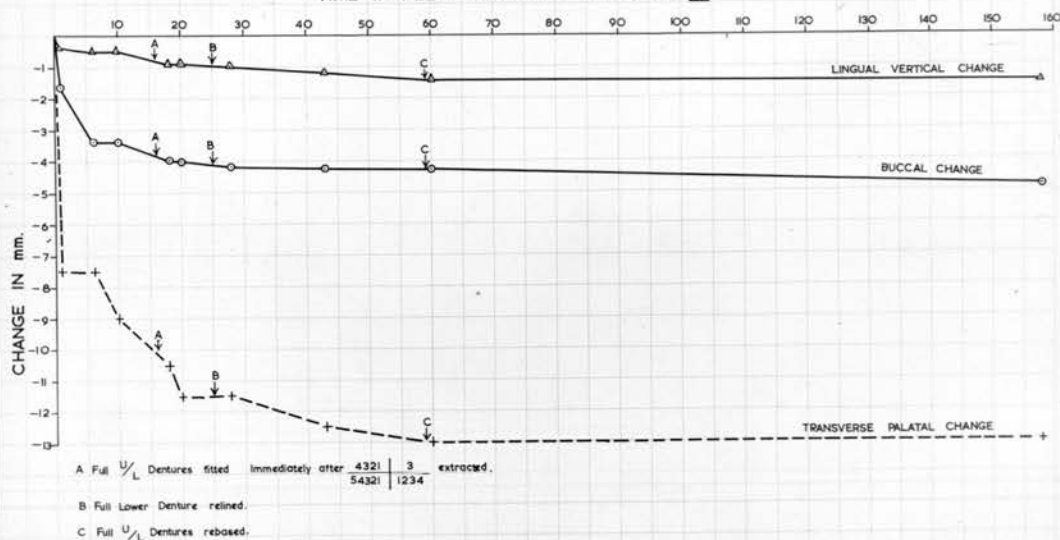


Table 13

| POSITION OF MEASUREMENT | MEASUREMENTS OF POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH <u>6</u> (F.30) |     |      |      |      |      |      |      |      |      |
|-------------------------|---|-----|------|------|------|------|------|------|------|------|
|                         | Time in weeks since extraction of <u>6</u>  |     |      |      |      |      |      |      |      |      |
|                         | 1   | 6   | 10   | 18   | 20   | 28   | 43   | 60   | 158  |      |
| BUCCAL                  | Upper   | 0.9 | 2.1  | 2.2  | 3.2  | 3.2  | 3.3  | 3.4  | 3.5  | 4.0  |
|                         | Middle  | 1.8 | 3.5  | 3.8  | 4.3  | 4.4  | 4.6  | 4.6  | 4.6  | 5.2  |
|                         | Lower   | 2.1 | 4.5  | 4.1  | 4.4  | 4.4  | 4.6  | 4.7  | 4.7  | 5.4  |
|                         | AVERAGE <sup>o</sup>  | 1.6 | 3.37 | 3.37 | 3.97 | 4.0  | 4.17 | 4.23 | 4.27 | 4.87 |
| LINGUAL VERTICAL +      | 0.4   | 0.5 | 0.5  | 0.9  | 0.9  | 1.0  | 1.2  | 1.4  | 1.5  |      |
| PALATAL *               | 7.5   | 7.5 | 9.0  | 10.5 | 11.5 | 11.5 | 12.5 | 13.0 | 13.0 |      |

<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

+ Measured at lingual gingival margin.

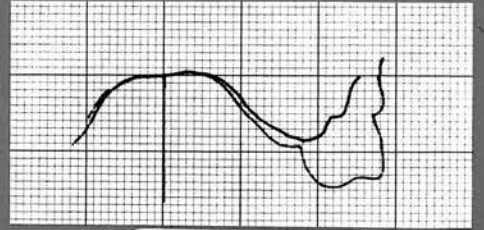
\* Horizontal extent of change across palate measured from lingual gingival margin.

Average Ridge Height 12 mm.

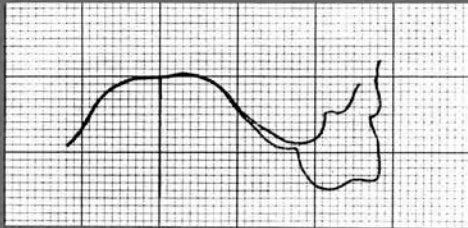
CORONAL TRACES [6 (F.30)



1 Week



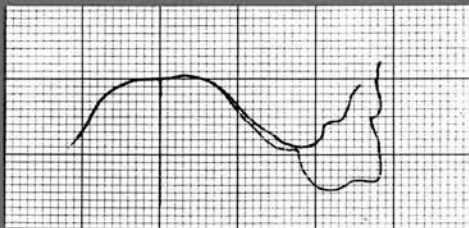
20 Weeks



6 Weeks



28 Weeks



10 Weeks



43 Weeks



18 Weeks



60 Weeks



158 Weeks

MEASUREMENTS OF POST EXTRACTION CHANGES  
IN CORONAL TRACES THROUGH 7] (F 30)

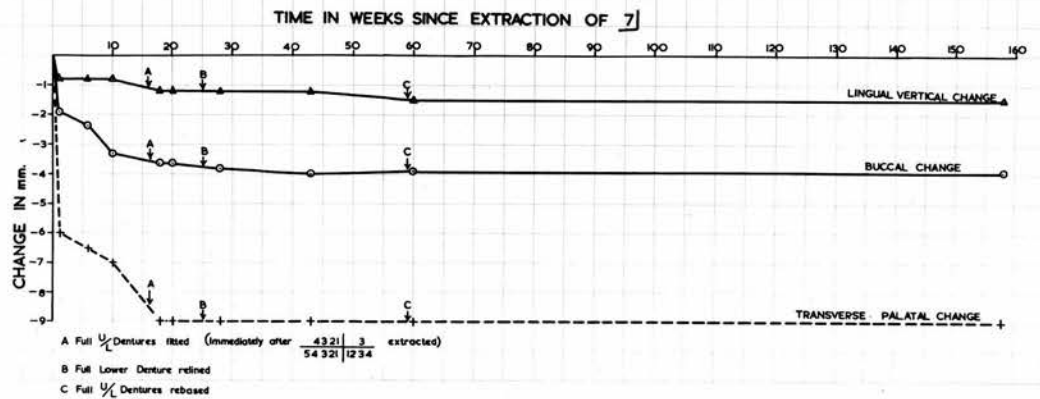


Table 14

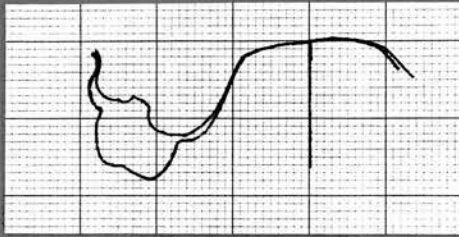
| POSITION OF MEASUREMENT | MEASUREMENTS OF POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 7] (F.30) |      |     |      |      |     |     |     |      |  |
|-------------------------|---|------|-----|------|------|-----|-----|-----|------|--|
|                         | Time in weeks since extraction of 7]  |      |     |      |      |     |     |     |      |  |
|                         | 1   | 6    | 10  | 18   | 20   | 28  | 43  | 60  | 158  |  |
| Upper                   | 0.5   | 0.9  | 2.2 | 2.4  | 2.5  | 2.7 | 2.8 | 3.0 | 3.0  |  |
| Middle                  | 1.2   | 1.8  | 2.8 | 3.4  | 3.3  | 3.5 | 3.7 | 3.8 | 3.8  |  |
| BUCCAL Lower            | 4.0   | 4.4  | 5.0 | 5.1  | 5.1  | 5.2 | 5.5 | 4.9 | 5.0  |  |
| AVERAGE <sup>o</sup>    | 1.9   | 2.37 | 3.3 | 3.63 | 3.63 | 3.8 | 4.0 | 3.9 | 3.93 |  |
| LINGUAL VERTICAL +      | 0.8   | 0.8  | 0.8 | 1.2  | 1.2  | 1.2 | 1.2 | 1.5 | 1.5  |  |
| PALATAL *               | 6.0   | 6.5  | 7.0 | 9.0  | 9.0  | 9.0 | 9.0 | 9.0 | 9.0  |  |

<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

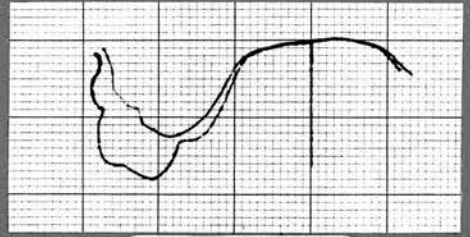
+ Measured at lingual gingival margin.

\* Horizontal extent of change across palate measured from lingual gingival margin.

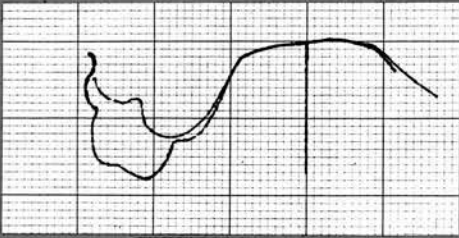
CORONAL TRACES 7 (F.30)



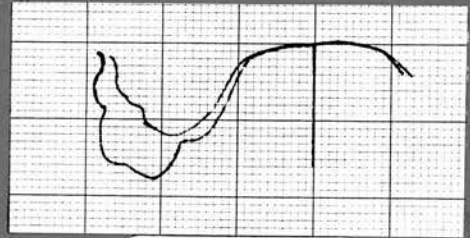
1 Week



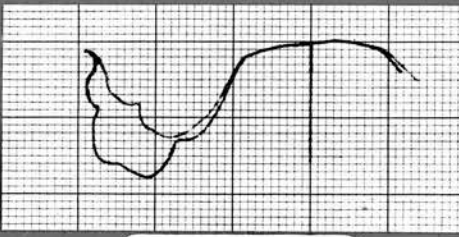
20 Weeks



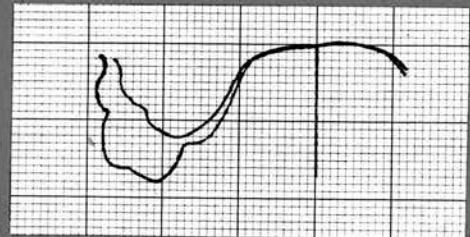
6 Weeks



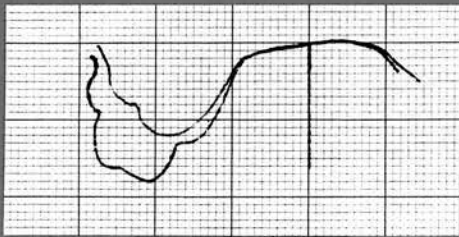
28 Weeks



10 Weeks



43 Weeks



18 Weeks



60 Weeks



158 Weeks

MEASUREMENTS OF POST-EXTRACTION CHANGES  
IN CORONAL TRACES THROUGH 8] (M.37)

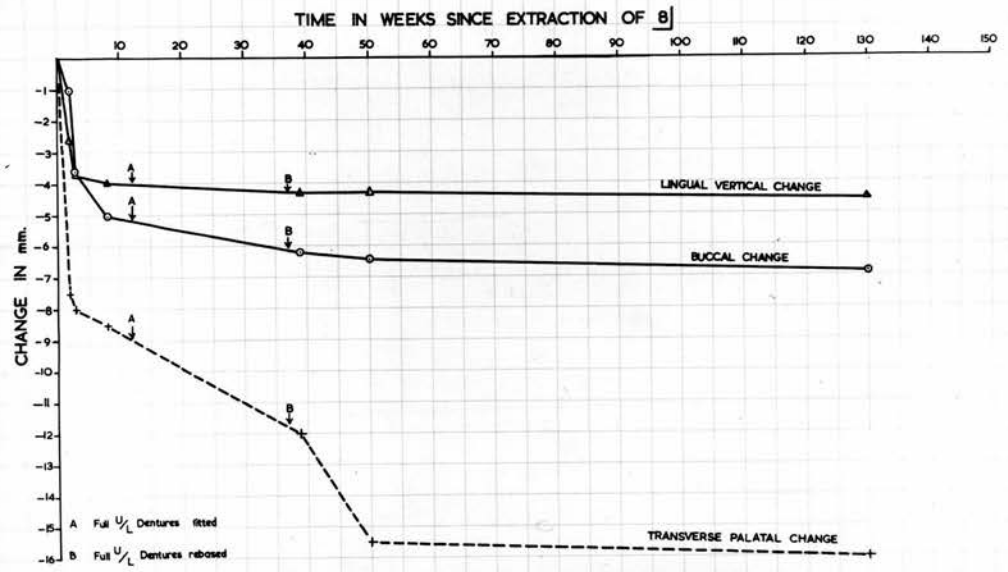


Table 15

| POSITION OF MEASUREMENT | MEASUREMENTS OF POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 8] (M.37) |     |      |      |      |      |
|-------------------------|---|-----|------|------|------|------|
|                         | Time in weeks since extraction of 8]  |     |      |      |      |      |
|                         | 2   | 3   | 8    | 39   | 50   | 130  |
|                         | mm  | mm  | mm   | mm   | mm   | mm   |
| Upper                   | 0   | 0   | 1.8  | 3.2  | 3.4  | 3.8  |
| Middle                  | 0.4   | 1.0 | 3.2  | 5.2  | 5.4  | 6.3  |
| BUCCAL Lower            | 2.7   | 9.8 | 10.1 | 10.2 | 10.5 | 10.5 |
| AVERAGE <sup>o</sup>    | 1.03  | 3.6 | 5.03 | 6.2  | 6.43 | 6.87 |
| LINGUAL VERTICAL +      | 2.6   | 3.7 | 4.0  | 4.3  | 4.3  | 4.5  |
| PALATAL *               | 7.5   | 8.0 | 8.5  | 12.0 | 15.5 | 16.0 |

<sup>o</sup> Average of upper middle and lower measurements of buccal change plotted on graph to nearest 0.05 mm.

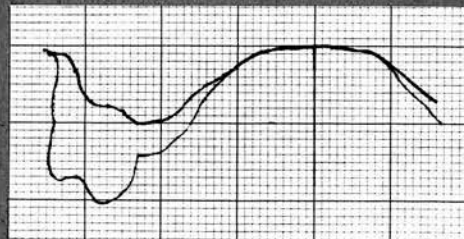
+ Measured at lingual gingival margin.

\* Horizontal extent of change across palate measured from lingual gingival margin.

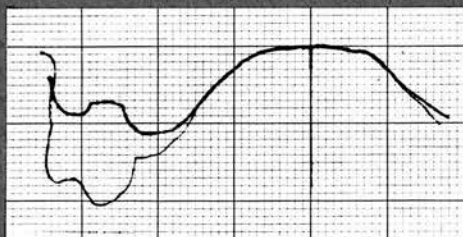
CORONAL TRACES 8 (M.37).



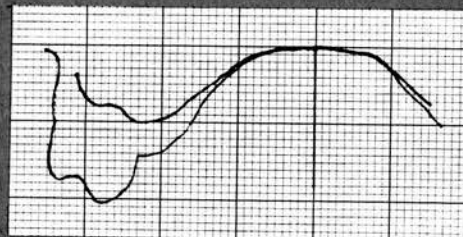
2 Weeks



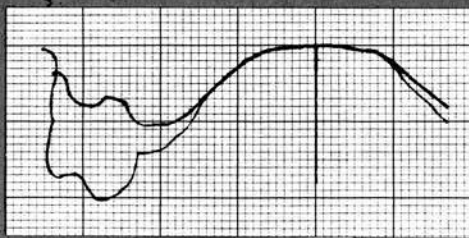
39 Weeks



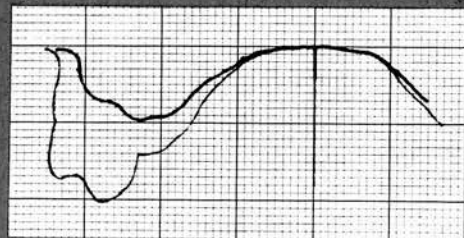
3 Weeks



50 Weeks



8 Weeks



130 Weeks

Fig. 35.

RESULTS OF THE INVESTIGATION.

The results of this investigation are chiefly embodied in the following tables of measurements, graphs and diagrams of the average post-extraction changes in the eight sections of the denture-bearing area which were studied.

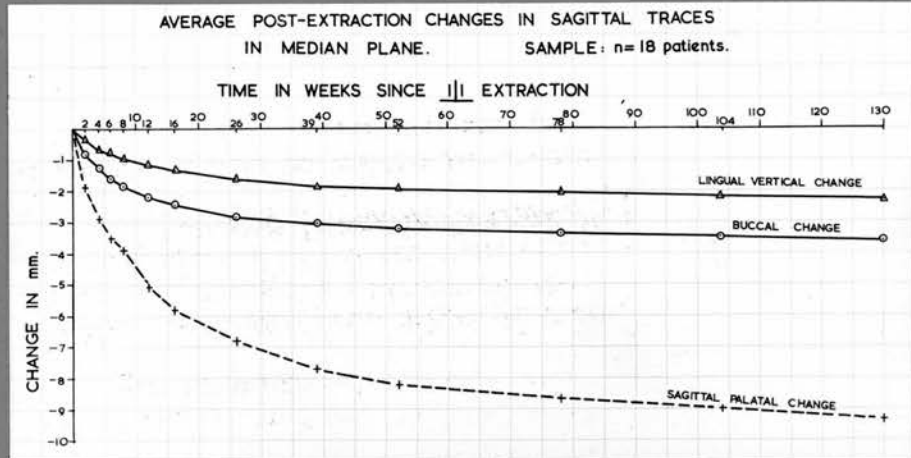


Table 16

AVERAGE POST-EXTRACTION CHANGES IN SAGITTAL TRACES IN MEDIAN PLANE.

SAMPLE: n = 18 patients.

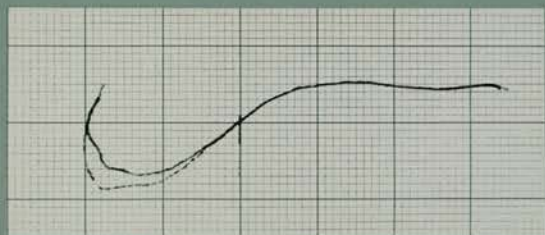
TIME IN WEEKS SINCE 1/1 EXTRACTION.

|                               | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39   | 52   | 78   | 104  | 130  |
|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
|                               | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   |
| BUCCAL <sup>o</sup>           | 0.80 | 1.25 | 1.60 | 1.85 | 2.20 | 2.40 | 2.80 | 3.05 | 3.20 | 3.35 | 3.50 | 3.60 |
| LINGUAL VERTICAL <sup>+</sup> | 0.35 | 0.65 | 0.80 | 0.95 | 1.15 | 1.30 | 1.60 | 1.85 | 1.95 | 2.05 | 2.20 | 2.30 |
| SAGITTAL PALATAL <sup>*</sup> | 1.90 | 2.90 | 3.50 | 3.90 | 5.05 | 5.80 | 6.80 | 7.70 | 8.20 | 8.65 | 9.00 | 9.35 |

<sup>o</sup> Mean of upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

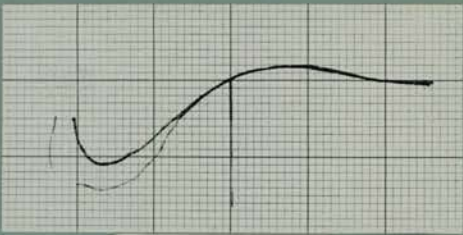
<sup>+</sup> At lingual gingival point.

<sup>\*</sup> Horizontal extent of change in palate measured from lingual gingival point.

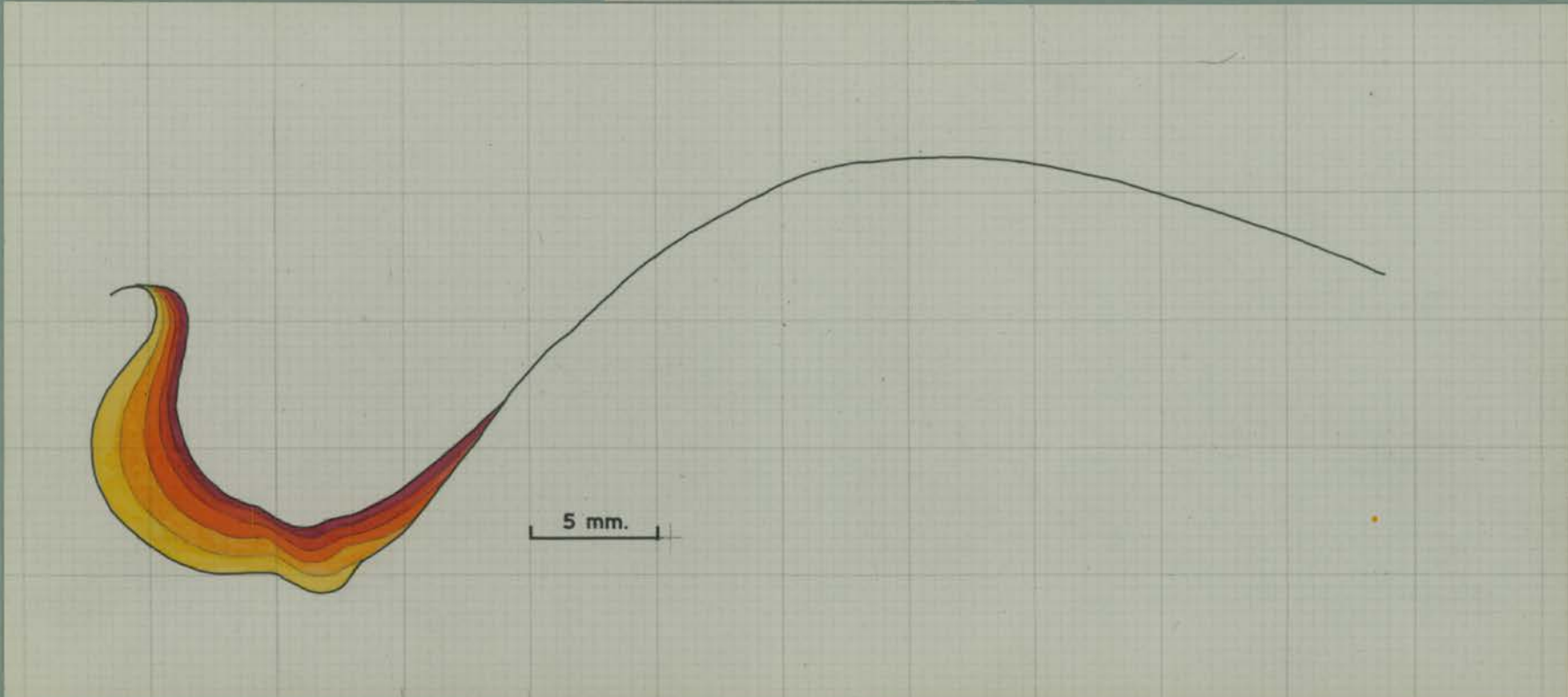
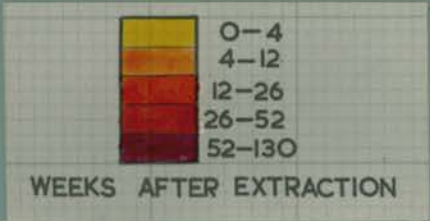


MINIMUM

MEDIAN



MAXIMUM



AVERAGE

Fig. 36.

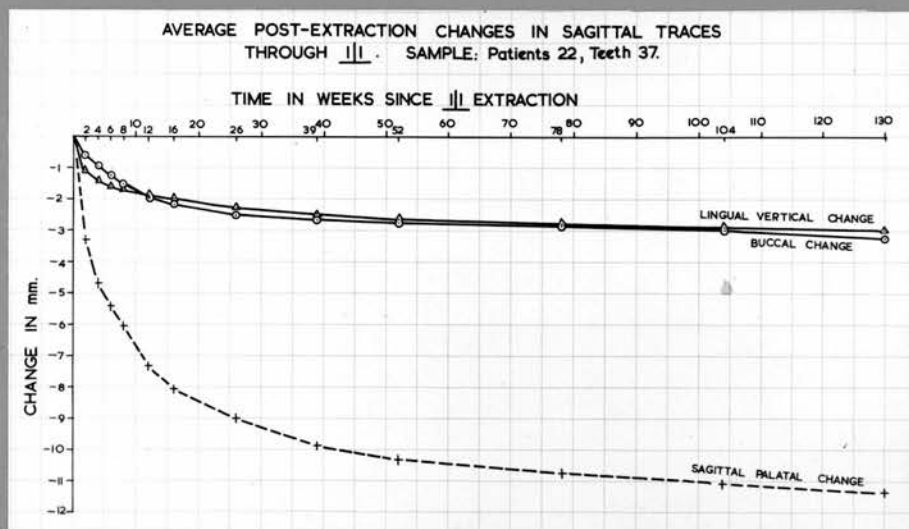


Table 17

AVERAGE POST-EXTRACTION CHANGES IN SAGITTAL TRACES THROUGH 1/1

SAMPLE: Patients 22, Teeth 37.

TIME IN WEEKS SINCE 1/1 EXTRACTION.

|                                  | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39   | 52    | 78    | 104   | 130   |
|----------------------------------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|
|                                  | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm    | mm    | mm    | mm    |
| BUCCAL <sup>o</sup>              | 0.60 | 0.95 | 1.25 | 1.55 | 1.95 | 2.20 | 2.50 | 2.65 | 2.75  | 2.85  | 3.00  | 3.25  |
| LINGUAL<br>VERTICAL <sup>+</sup> | 1.10 | 1.42 | 1.60 | 1.70 | 1.92 | 2.00 | 2.28 | 2.48 | 2.65  | 2.78  | 2.90  | 3.00  |
| SAGITTAL<br>PALATAL <sup>*</sup> | 3.30 | 4.70 | 5.40 | 6.05 | 7.35 | 8.05 | 9.00 | 9.85 | 10.30 | 10.75 | 11.10 | 11.35 |

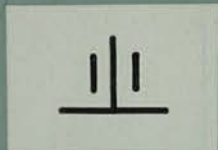
<sup>o</sup> Mean of upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

<sup>+</sup> At lingual gingival margin.

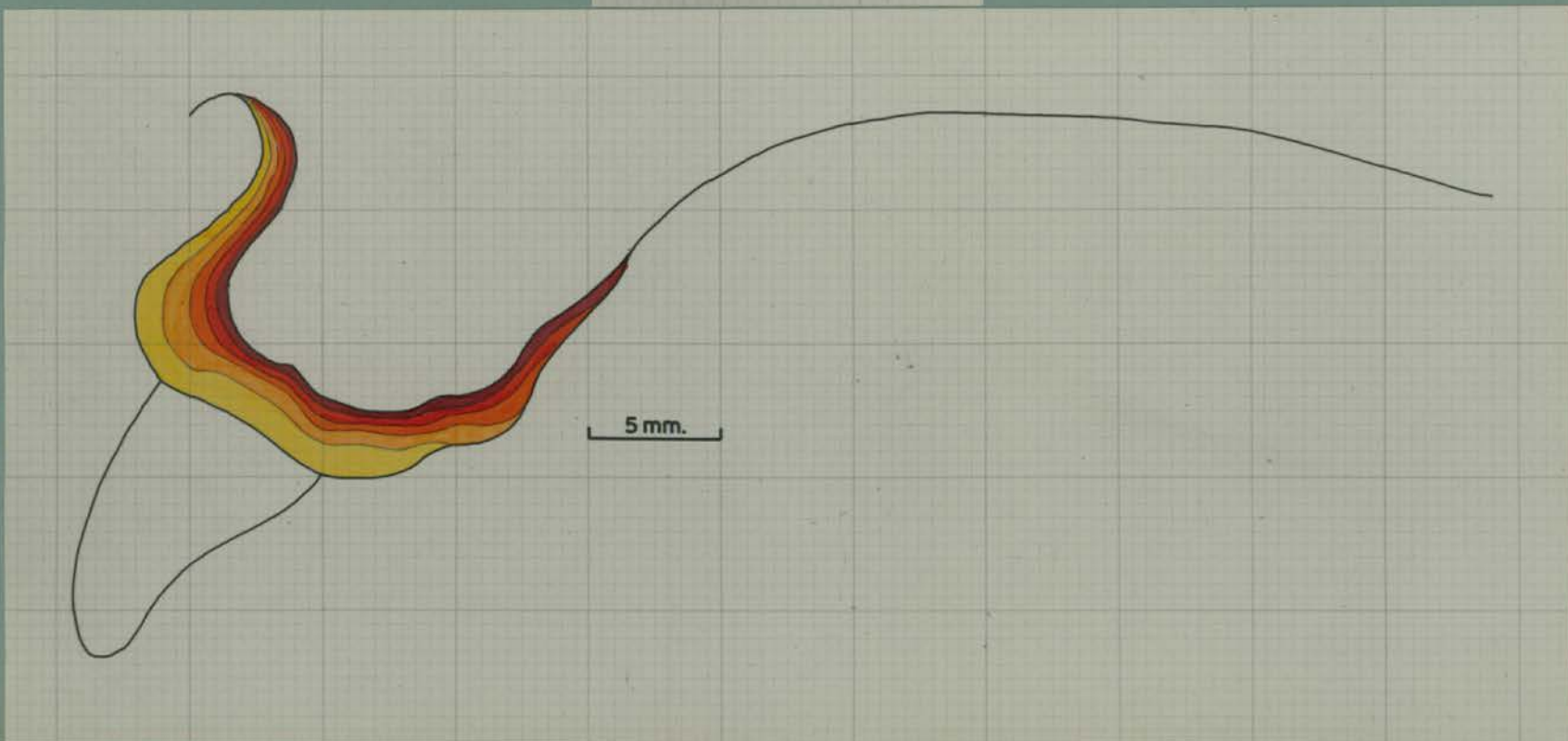
<sup>\*</sup> Horizontal extent of change in palate measured from lingual gingival margin.



MINIMUM



MAXIMUM



AVERAGE

FIG. 37.

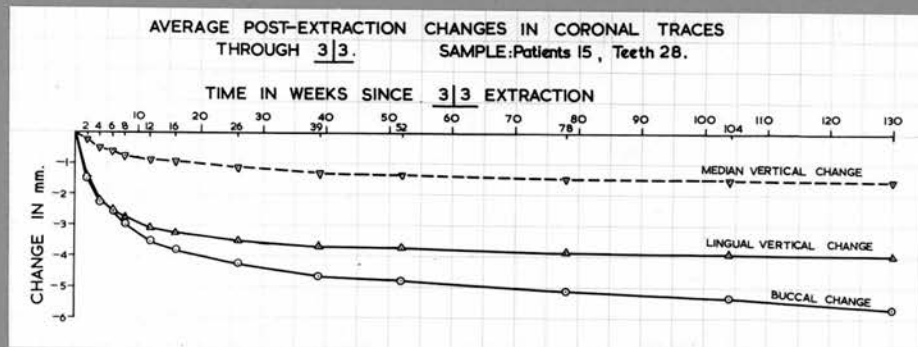


Table 18

AVERAGE POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 3/3  
SAMPLE: Patients 15, Teeth 28.  
TIME IN WEEKS SINCE 3/3 EXTRACTION.

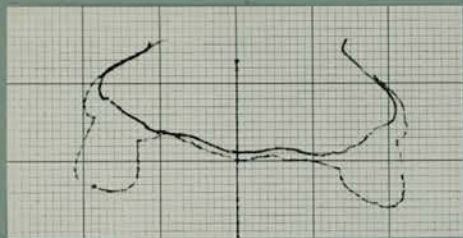
|                               | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39   | 52   | 78   | 104  | 130  |
|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
|                               | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   |
| BUCCAL <sup>o</sup>           | 1.50 | 2.30 | 2.60 | 3.00 | 3.55 | 3.85 | 4.25 | 4.65 | 4.80 | 5.10 | 5.30 | 5.65 |
| LINGUAL VERTICAL <sup>+</sup> | 1.40 | 2.20 | 2.55 | 2.75 | 3.10 | 3.25 | 3.50 | 3.70 | 3.75 | 3.85 | 3.90 | 3.95 |
| MEDIAN VERTICAL <sup>*</sup>  | 0.25 | 0.50 | 0.60 | 0.75 | 0.90 | 0.95 | 1.15 | 1.30 | 1.35 | 1.45 | 1.50 | 1.55 |

<sup>o</sup> Mean of right and left upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

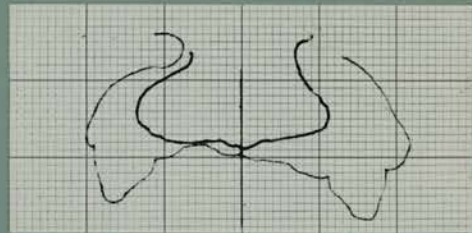
<sup>+</sup> At lingual gingival margin.

<sup>\*</sup> In median plane.

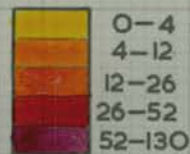
3/3



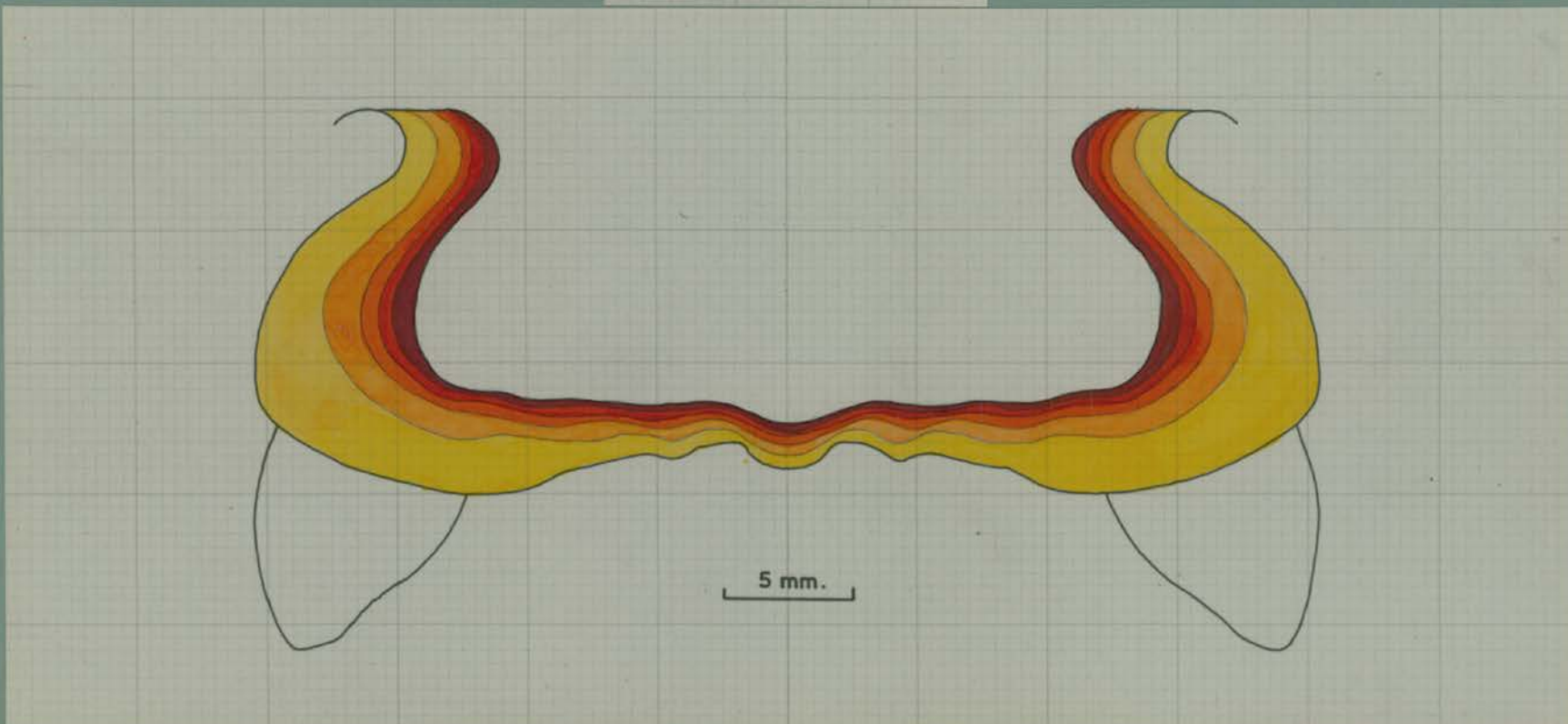
MINIMUM



MAXIMUM



WEEKS AFTER EXTRACTION



AVERAGE

Fig. 38.

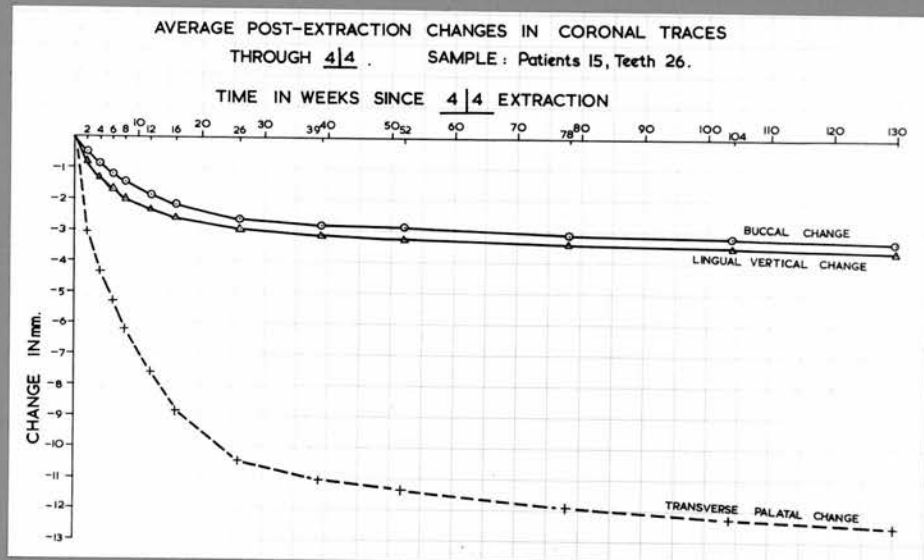


Table 19 .

AVERAGE POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 4/4.  
SAMPLE: Patients 15, Teeth 26.  
TIME IN WEEKS SINCE 4/4 EXTRACTION.

|                                    | 2    | 4    | 6    | 8    | 12   | 16   | 26    | 39    | 52    | 78    | 104   | 130   |
|------------------------------------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|
|                                    | mm   | mm   | mm   | mm   | mm   | mm   | mm    | mm    | mm    | mm    | mm    | mm    |
| BUCCAL <sup>o</sup>                | 0.50 | 0.85 | 1.20 | 1.45 | 1.90 | 2.20 | 2.65  | 2.85  | 2.90  | 3.10  | 3.20  | 3.35  |
| LINGUAL<br>VERTICAL <sup>+</sup>   | 0.80 | 1.35 | 1.70 | 2.00 | 2.35 | 2.60 | 2.95  | 3.15  | 3.25  | 3.40  | 3.50  | 3.60  |
| TRANSVERSE<br>PALATAL <sup>*</sup> | 3.05 | 4.35 | 5.30 | 6.20 | 7.60 | 8.85 | 10.45 | 11.05 | 11.35 | 11.90 | 12.25 | 12.50 |

<sup>o</sup> Mean of right and left upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

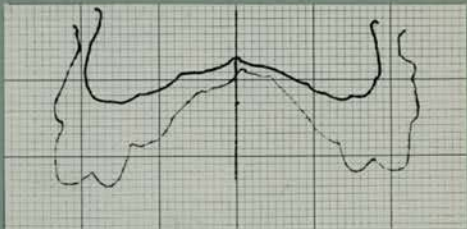
<sup>+</sup> At lingual gingival margin.

<sup>\*</sup> Horizontal extent of change across palate measured from lingual gingival margin.

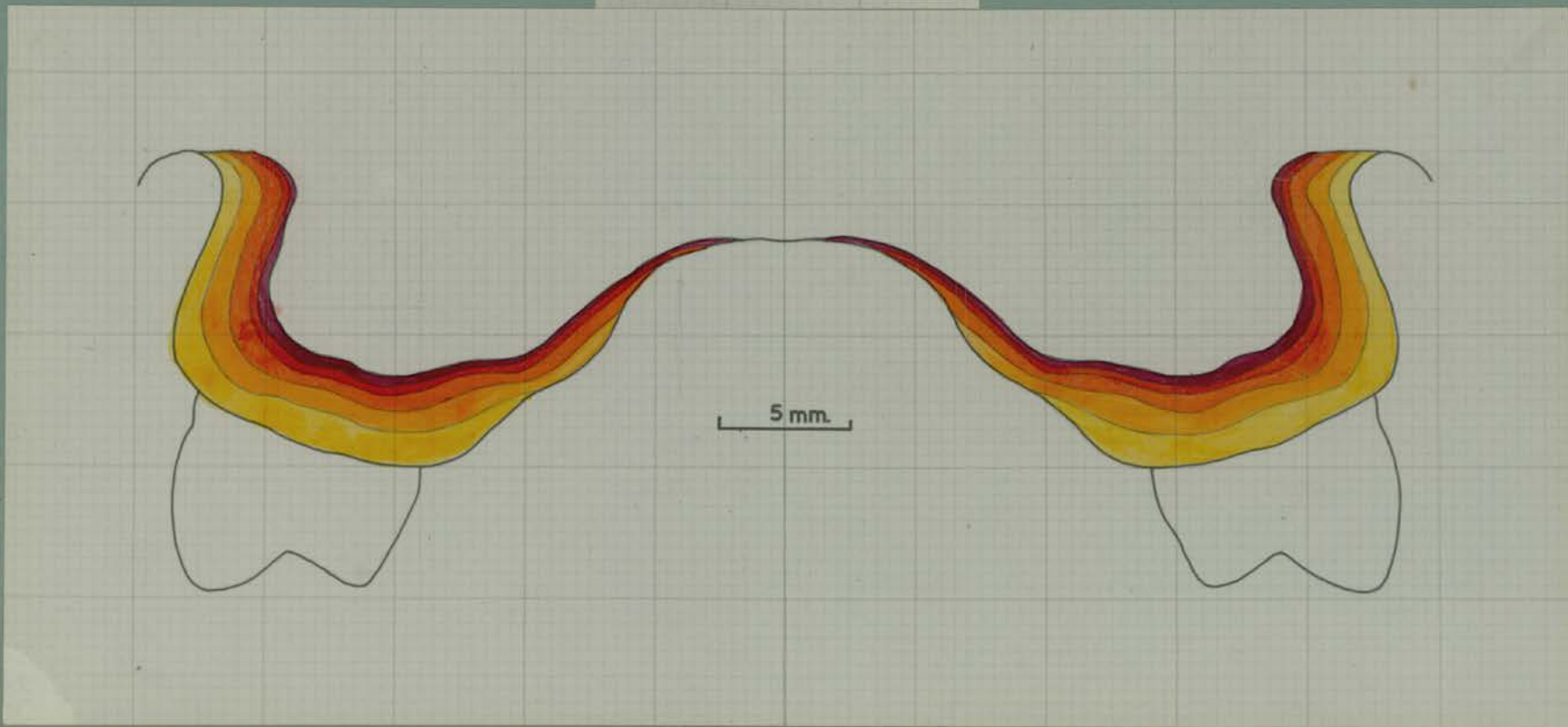
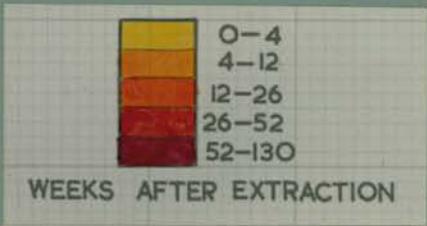


MINIMUM

4 | 4



MAXIMUM



AVERAGE

Fig. 39.

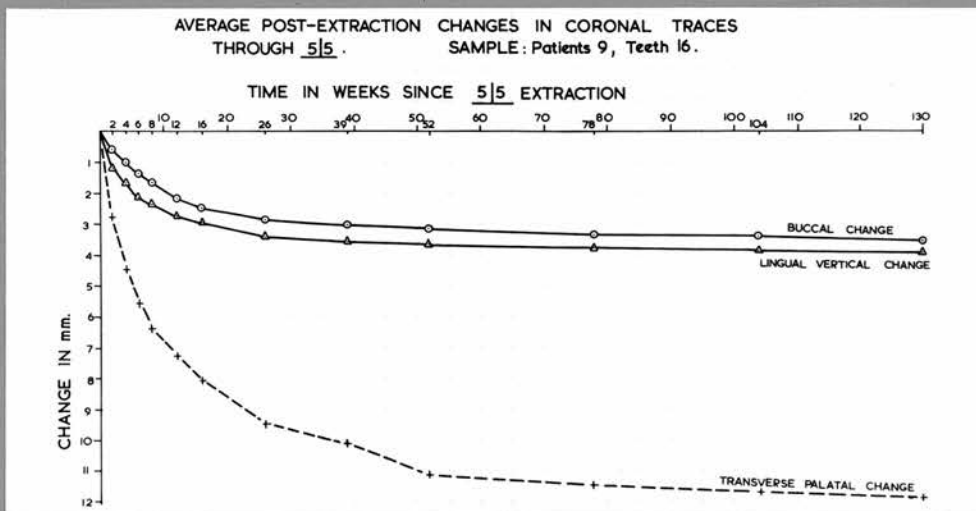


Table 20

AVERAGE POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 5/5.

SAMPLE: Patients 9, Teeth 16.

TIME IN WEEKS SINCE 5/5 EXTRACTION.

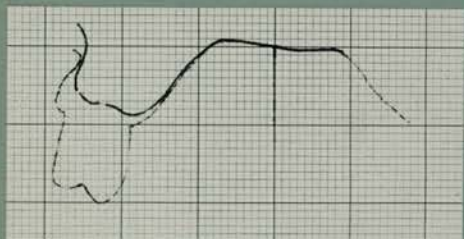
|                                 | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39    | 52    | 78    | 104   | 130   |
|---------------------------------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|
|                                 | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm    | mm    | mm    | mm    | mm    |
| BUCCAL <sup>o</sup>             | 0.60 | 1.00 | 1.35 | 1.65 | 2.15 | 2.45 | 2.85 | 3.00  | 3.15  | 3.30  | 3.40  | 3.55  |
| LINGUAL VERTICAL <sup>+</sup>   | 1.20 | 1.65 | 2.10 | 2.35 | 2.70 | 2.95 | 3.40 | 3.55  | 3.65  | 3.75  | 3.85  | 3.95  |
| TRANSVERSE PALATAL <sup>*</sup> | 2.75 | 4.45 | 5.55 | 6.35 | 7.25 | 8.05 | 9.45 | 10.10 | 11.11 | 11.45 | 11.70 | 11.90 |

<sup>o</sup> Mean of right and left upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

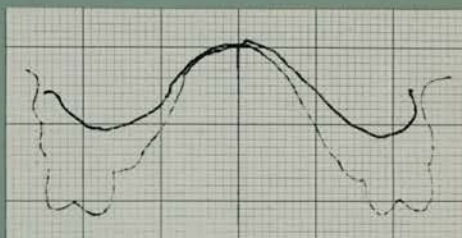
<sup>+</sup> At lingual gingival margin.

<sup>\*</sup> Horizontal extent of change across palate measured from lingual gingival margin.

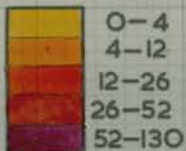
5 | 5



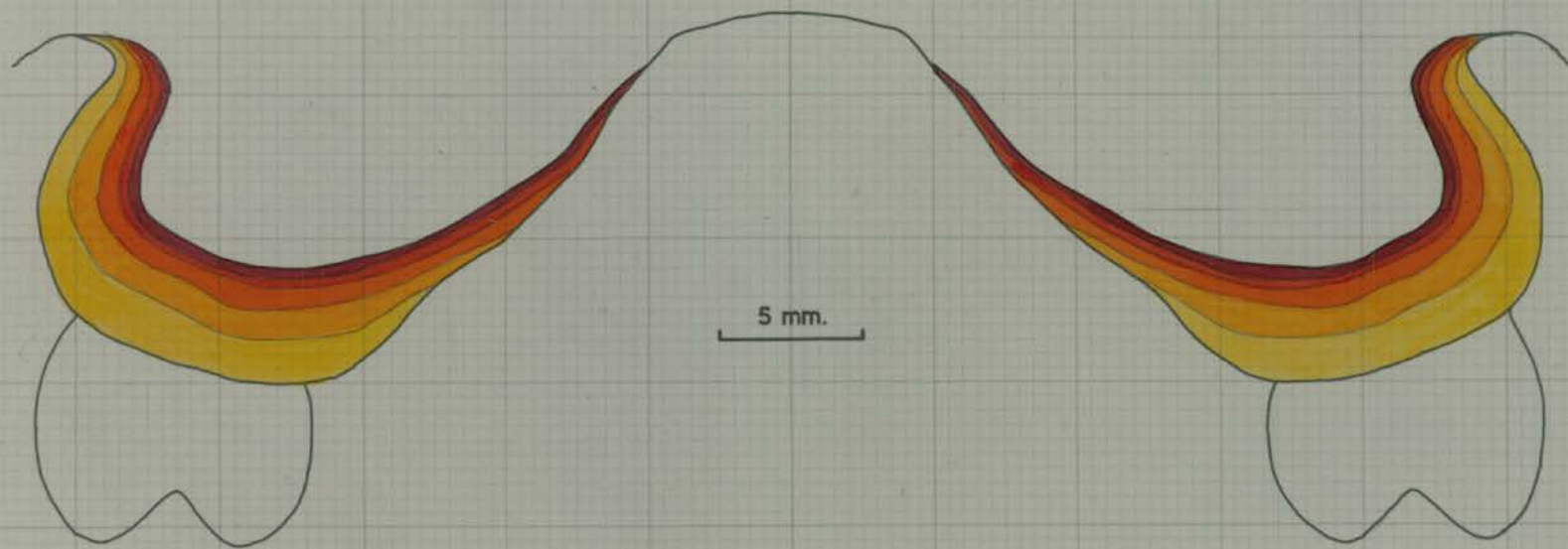
MINIMUM



MAXIMUM



WEEKS AFTER EXTRACTION



AVERAGE

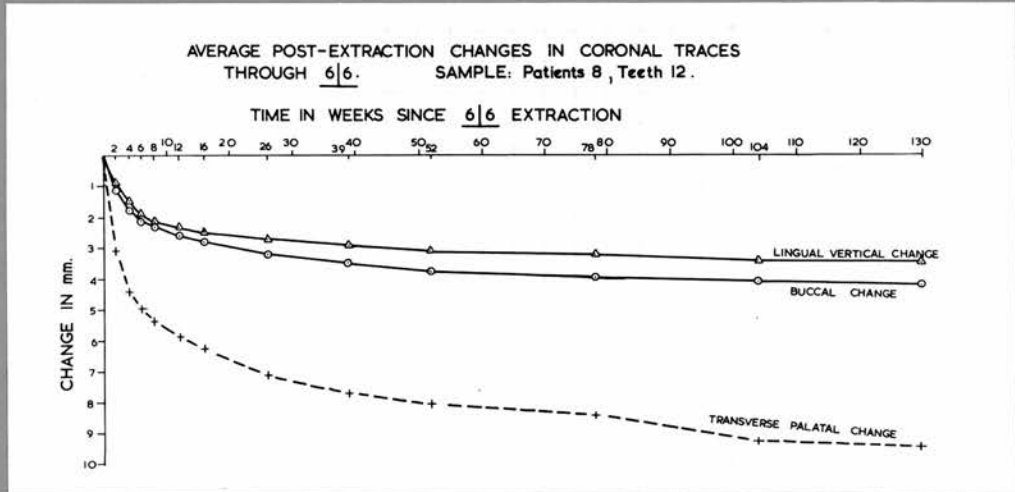


Table 21

AVERAGE POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 6/6.  
SAMPLE: Patients 8, Teeth 12.  
TIME IN WEEKS SINCE 6/6 EXTRACTION.

|                                 | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39   | 52   | 78   | 104  | 130  |
|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
|                                 | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   |
| BUCCAL <sup>o</sup>             | 1.10 | 1.75 | 2.10 | 2.30 | 2.60 | 2.80 | 3.20 | 3.45 | 3.75 | 3.95 | 4.10 | 4.20 |
| LINGUAL VERTICAL <sup>+</sup>   | 0.85 | 1.45 | 1.90 | 2.10 | 2.30 | 2.45 | 2.70 | 2.90 | 3.10 | 3.20 | 3.40 | 3.45 |
| TRANSVERSE PALATAL <sup>*</sup> | 3.05 | 4.40 | 4.95 | 5.35 | 5.85 | 6.25 | 7.10 | 7.70 | 8.05 | 8.40 | 9.25 | 9.45 |

<sup>o</sup> Mean of right and left upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

<sup>+</sup> At lingual gingival margin.

<sup>\*</sup> Horizontal extent of change across palate measured from lingual gingival margin.

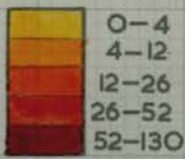
6 | 6



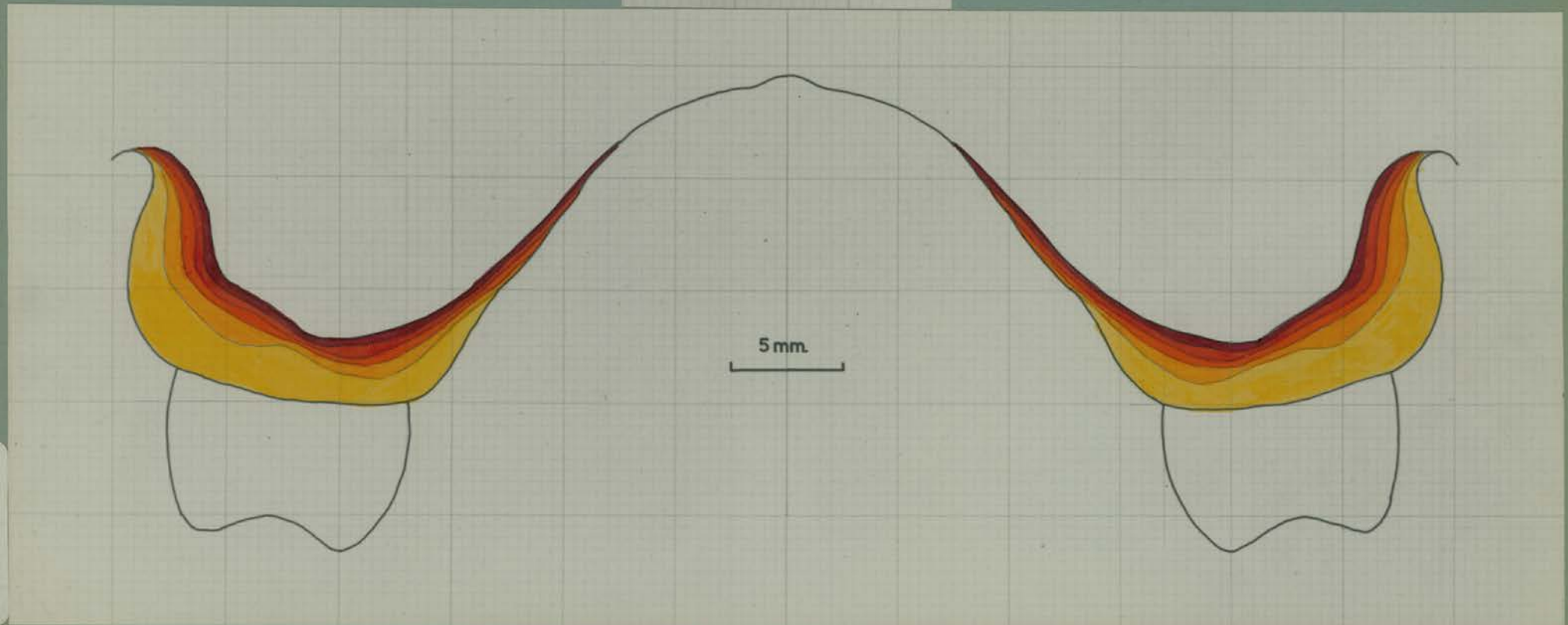
MINIMUM



MAXIMUM



WEEKS AFTER EXTRACTION



AVERAGE

Fig. 47.

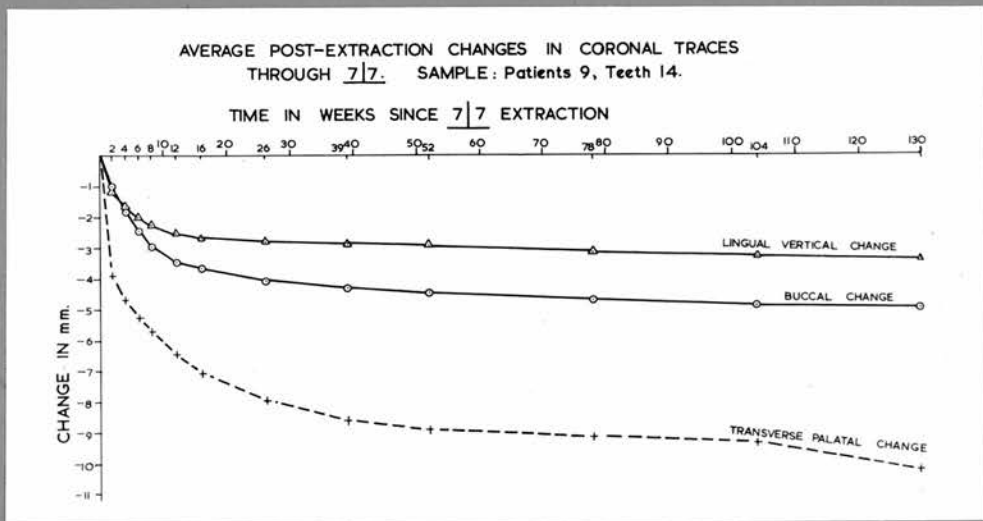


Table 22

AVERAGE POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 7/7.

SAMPLE: Patients 9, Teeth 14.

TIME IN WEEKS SINCE 7/7 EXTRACTION.

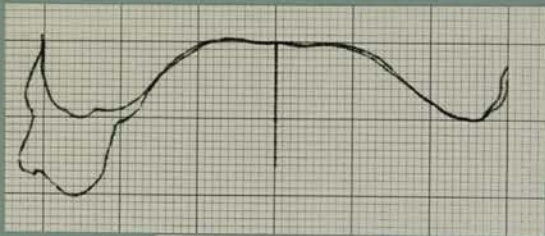
|                                 | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39   | 52   | 78   | 104  | 130   |
|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|-------|
|                                 | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm    |
| BUCCAL <sup>o</sup>             | 1.00 | 1.80 | 2.45 | 2.95 | 3.45 | 3.65 | 4.05 | 4.30 | 4.45 | 4.70 | 4.90 | 5.00  |
| LINGUAL VERTICAL <sup>+</sup>   | 1.20 | 1.65 | 2.00 | 2.25 | 2.50 | 2.65 | 2.80 | 2.90 | 2.95 | 3.15 | 3.30 | 3.40  |
| TRANSVERSE PALATAL <sup>*</sup> | 3.90 | 4.70 | 5.25 | 5.70 | 6.45 | 7.05 | 7.95 | 8.60 | 8.90 | 9.15 | 9.35 | 10.25 |

<sup>o</sup> Mean of right and left upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

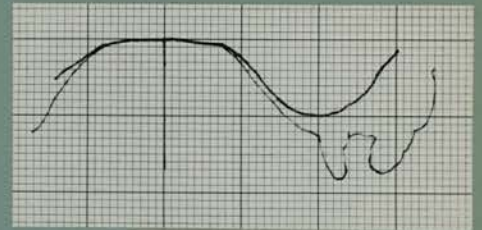
<sup>+</sup> At lingual gingival margin.

<sup>\*</sup> Horizontal extent of change across palate measured from lingual gingival margin.

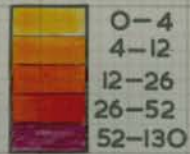
7/7



MINIMUM



MAXIMUM



0-4

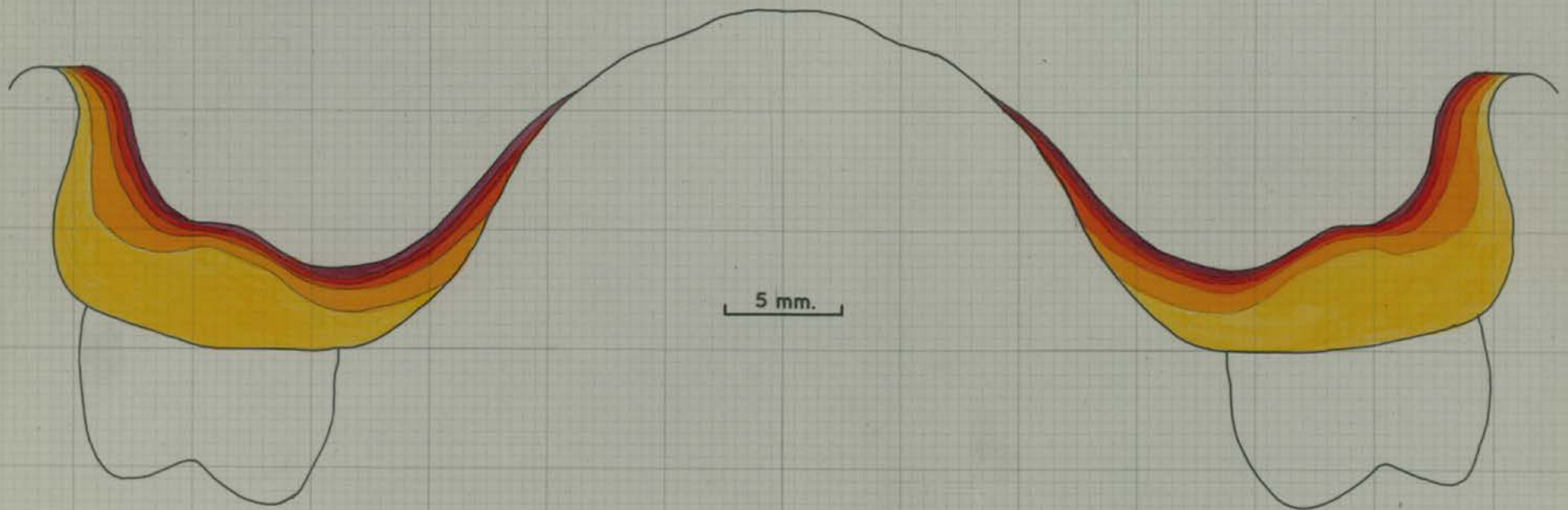
4-12

12-26

26-52

52-130

WEEKS AFTER EXTRACTION



AVERAGE

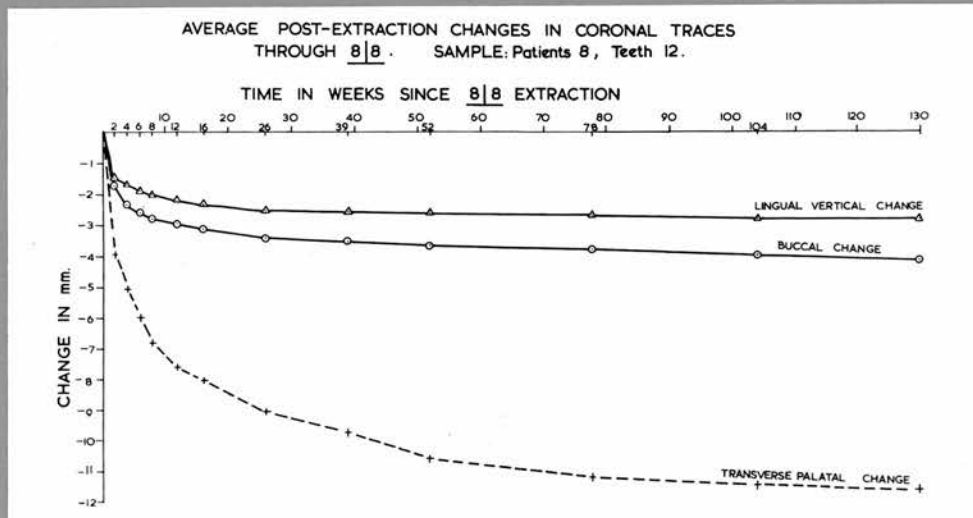


Table 23

AVERAGE POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 8|8.

SAMPLE: Patients 8, Teeth 12.

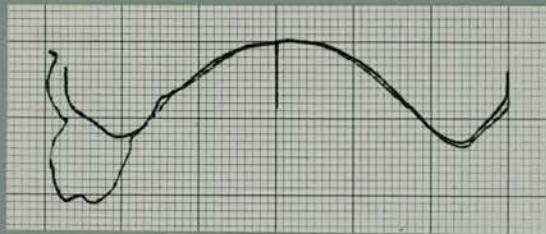
TIME IN WEEKS SINCE 8|8 EXTRACTION.

|                                 | 2    | 4    | 6    | 8    | 12   | 16   | 26   | 39   | 52    | 78    | 104   | 130   |
|---------------------------------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|
|                                 | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm   | mm    | mm    | mm    | mm    |
| BUCCAL <sup>o</sup>             | 1.70 | 2.35 | 2.60 | 2.80 | 2.95 | 3.10 | 3.40 | 3.55 | 3.65  | 3.80  | 4.00  | 4.20  |
| LINGUAL VERTICAL <sup>+</sup>   | 1.45 | 1.65 | 1.85 | 2.00 | 2.20 | 2.30 | 2.50 | 2.55 | 2.60  | 2.70  | 2.80  | 2.85  |
| TRANSVERSE PALATAL <sup>*</sup> | 3.95 | 5.05 | 6.00 | 6.85 | 7.60 | 8.05 | 9.05 | 9.75 | 10.60 | 11.20 | 11.45 | 11.65 |

<sup>o</sup> Mean of right and left upper, middle and lower measurements of post-extraction change at buccal surface of alveolar ridge.

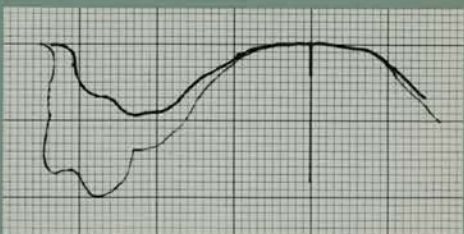
<sup>+</sup> At lingual gingival margin.

<sup>\*</sup> Horizontal extent of change across palate measured from lingual gingival margin.

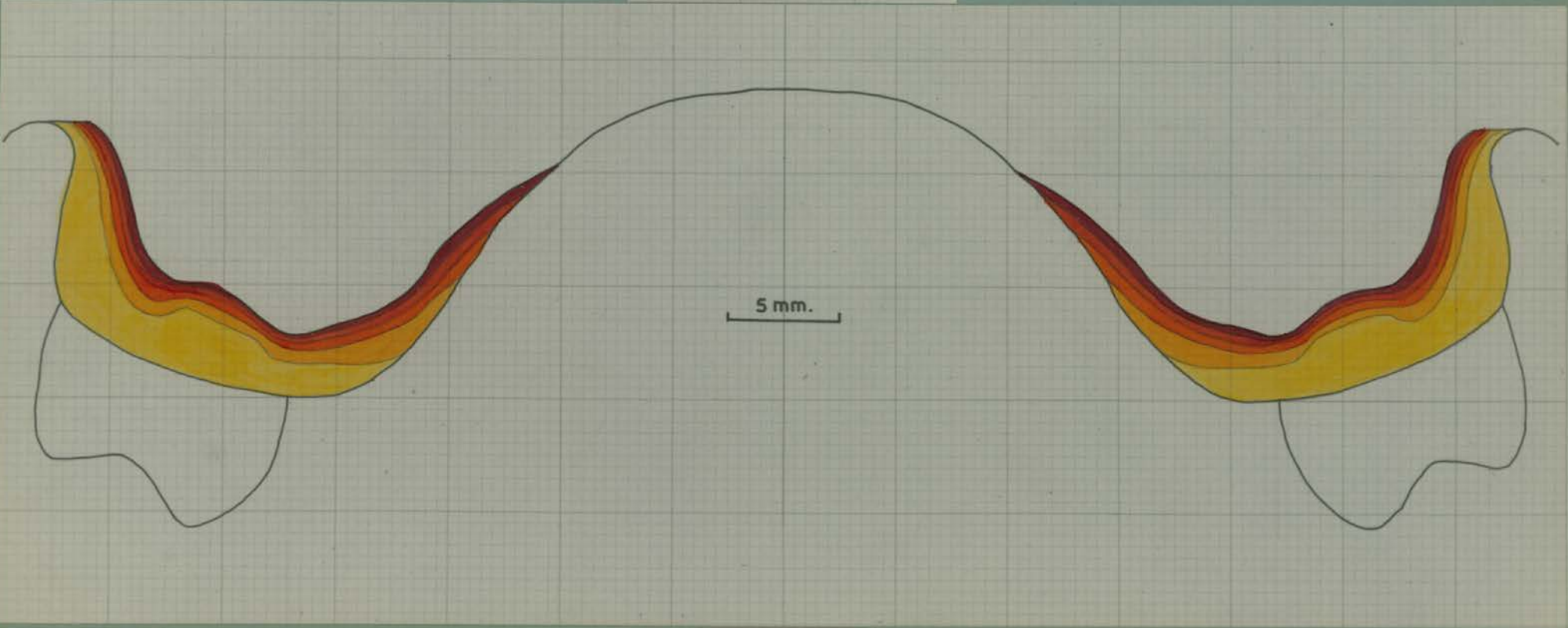
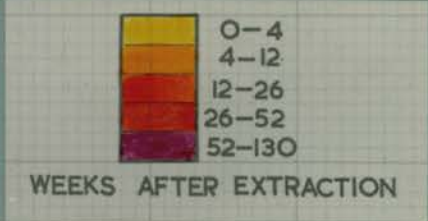


MINIMUM

8 | 8



MAXIMUM



AVERAGE

Fig. 43.

FURTHER OBSERVATIONS & DISCUSSION.1. COLLAPSE OF GINGIVAL MARGINS.

General observations showed that in every case the buccal and lingual gingival margins collapsed towards the sockets when teeth were extracted. This collapse was encouraged by pressure of the operator's fingers at the time of extraction and had the effect of reducing the buccolingual diameter of the extraction wounds. The amount of collapse and the effect on measurements of post-extraction changes appeared to vary considerably between extractions. In the majority of cases the collapse of the lingual gingival margin was reflected by a dip in the graph of lingual vertical change shortly after extraction and thereafter the change proceeded more slowly. The collapse of the buccal gingival margins produced similar dips in the graphs of buccal change in cases where it was sufficiently extensive to involve the lower buccal measurements.

In the median plane the points at which the lingual vertical measurements were made did not lie on gingival margins and consequently the measurements were not affected by marginal collapse to the same extent as in other regions. Thus the first part of the curve of average lingual vertical change in the median plane, showed a more gentle slope, than in other regions and the percentage of lingual vertical change in the median plane four weeks after extraction of the central incisors, was also less than in other regions

Discussion

The depth of periodontal pockets and the health of the marginal gingivae were not assessed prior to the extraction of the teeth as many of the patients were in pain, but it seems reasonable to assume that differences in the extent of the free gingivae accounted for some of the variations in the gingival collapse. Different degrees of trauma during extractions were also likely to have contributed to the variations observed.

In some graphs of post-extraction changes there appeared to be a relationship between the amount of gingival collapse and the total change at the end of the study but in others there was not and no conclusions could be drawn.

## 2. CHANGES IN SURFACE FORM WITHIN THE MARGINS OF EXTRACTION WOUNDS.

No measurements were made within the margins of the extraction wounds but it was evident from general observation of the traces that there was a good deal of variation in the levels to which the blood clot filled the sockets. In cases where incomplete filling of the socket or early breakdown of the surface of the clot had occurred the concave surface of the wound was apparent in the early post-extraction traces but as healing progressed the concavity became less obvious. This was chiefly due to shrinkage at the margins of the wound but partly to proliferative changes within it. (Fig. 44. ) Lisowski (1944) took measurements within the margins of extraction wounds and also observed proliferative changes.

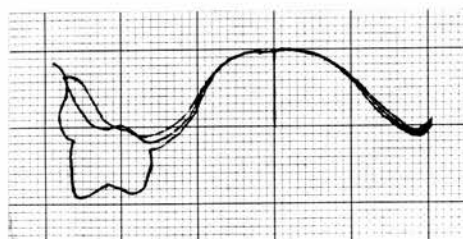


Fig. 44.

Traces at 3 weeks and 14 weeks after extraction of 6/ superimposed on pre-extraction trace to illustrate changes associated with wound healing.

When dentures were fitted after the wound surface had healed but before the depression in the mucosa was obliterated, the presence of the dentures preserved the hollowed contour of the wounds.

In the majority of wounds covered by immediate prosthesis, the blood clot completely filled the sockets. Depressions at the sites of the wounds were shallow or absent except in a few cases where infection had supervened. It will be remembered that the plaster teeth had been removed flush with the "mucosal" surface of the casts on which the immediate dentures were processed. These denture bases did not therefore extend into extraction wounds where surface breakdown of the clot had occurred and the depressions disappeared. Thus the contour of the residual ridges under immediate dentures was smoother than under prosthesis which were fitted after healing. Examples of traces of wounds covered by immediate dentures are shown on pages 131, 133 & 135 and wounds covered by dentures after healing are shown on pages 137, 139, 141 & 143. The times at which the dentures were fitted or relined are indicated by arrows on the graphs accompanying the traces.

#### Discussion.

In connection with these observations the following practical point arises. Where fitting of dentures is contemplated before depressions at the sites of extraction wounds have disappeared, it may be wise to fill the depressions on the casts with plaster of Paris, before processing the dentures, so that their fitting surfaces will not perpetuate the irregularities on the residual ridges.

### 3. CHANGES IN POSITION AND SHAPE OF THE INCISIVE PAPILLA.

By means of the vertical section tracing instrument measurements were made horizontally in the median plane from the posterior border of the incisive papilla to the R. plane on the pre-extraction and last post-extraction casts of the 18 patients in the median plane sample, who had both central incisors extracted. In every case the measurement on the post-extraction cast was greater than the pre-extraction measurement and the difference represented the forward movement in the horizontal plane of the posterior border of the incisive papilla  $2\frac{1}{2}$  years or more after the extraction of both central incisors.

The mean horizontal forward movement observed in the sample was 1.6 mm. and the range of movement 0.6 to 2.7 mm.

Similar measurements were made in four patients who had one central incisor missing prior to the start of the study and, for this reason, had been excluded from the sample of tracings in the median plane. The mean forward movement in these patients was 0.8 mm. and the range 0.3 mm. to 1.4 mm.. In this group of patients, drifting of the remaining central incisor had caused a deviation of the incisive papilla towards the gap. On extraction of the remaining incisor the papilla returned to the median plane in every case. It is possible that this movement, together with changes associated with the previous extractions, was responsible for the reduced forward movement observed in these cases, but conclusions could not be drawn from such a small sample.

On the pre-extraction and last post-extraction casts of the 18 patients in the median plane sample, who had both central incisors extracted during the study, the measurements between the points described were repeated by stepping sharp pointed calipers along the "mucosal" surface, in the median plane. The mean forward movement of the posterior border of the papilla in these measurements was 0.6 mm. and the range was 0.0 to 2.0 mm.

Measurements of the vertical movement of the incisive papilla per se. were not made but, as the lingual vertical point in the median plane lay on or near its anterior border and the median vertical measurement on the canine trace was on or near its posterior border an indication of the upward movement of the papilla was obtained from these measurements. On this basis the average vertical movement of the anterior part of the papilla  $2\frac{1}{2}$  years after the extraction of both central incisors was 2.3 mm. and the range 1.3 mm. to 4.0 mm. The average vertical movement of the posterior part was 1.55 mm. with a range of 0.1 mm. to 3.3 mm.

A change in the shape of the incisive papilla was observed in every case following the extraction of maxillary central incisors, and it was recognised that this may have partly contributed to the measurements of post-extraction movement.

In most cases the change was towards a more circular outline shape. In some cases the size of the papilla diminished after extraction of the teeth and in others an increase in size was observed (Fig. 46 ).

Fig. 45. Top:- Pre-extraction cast (M.20).

Bottom:- The natural teeth positioned, by means of a palatal register, on a duplicate of the last post-extraction cast (M.20). This illustrates the buccal morphological change relative to the natural teeth 158 weeks after extraction.

Fig. 46. Another view of the same casts to show the post-extraction changes in incisive papilla and rugae relative to the teeth.

Right:- Pre-extraction cast.

Left:- Post-extraction cast.

Fig. 45.

Fig. 46.

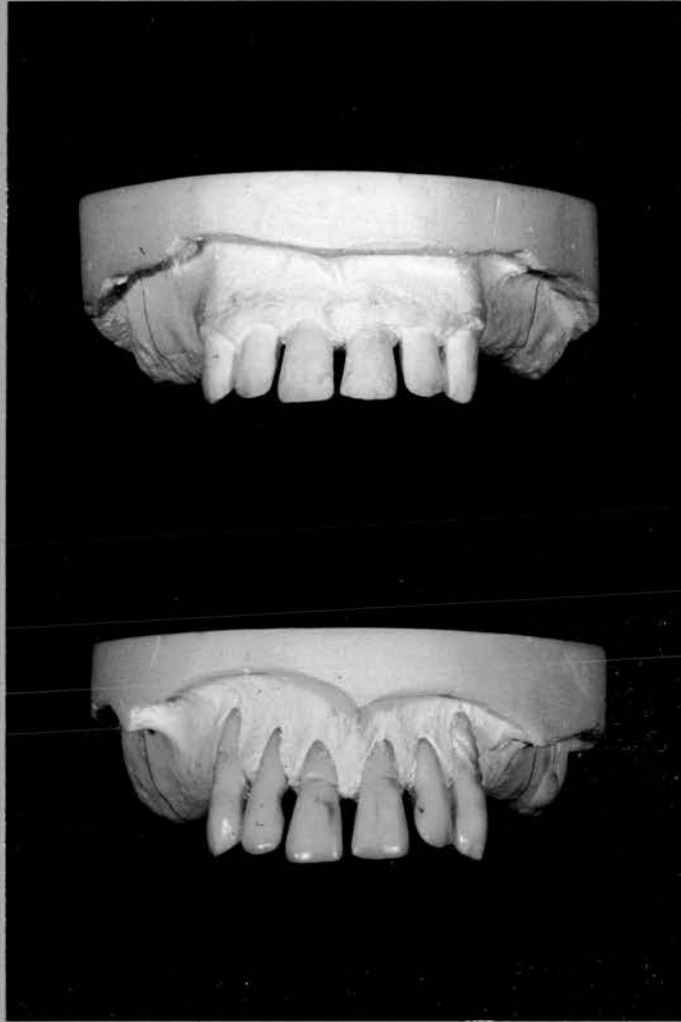


Fig. 45.



Fig. 46.

Discussion.

In every one of the 18 patients in the median plane sample the forward movement of the posterior border of the incisive papilla was greater when measured in the horizontal plane than when measured along the surface of the cast. This suggested the papilla was carried forward chiefly by a "hinge like" movement of the mucosa concomitant with the underlying bony change. Examination of the traces tended to support this view.

In four of the patients the pre- and post-extraction measurements along the surface of the casts were identical, and in seven, increases of less than 0.7 mm. were observed. These were within the range of error of the measurements. In the remainder however the distances between the R points and the posterior borders of the incisive papillae measured on the surface of the casts showed increases between 1.0 and 2.0 mms. Thus it appeared that movement on the mucosal surface took place in some patients in addition to the general change in form. It is possible that changes in the shape of the papilla, caused by denture trauma or scar tissue contraction in the adjacent sockets, may have been partly responsible for this movement.

It is of interest to note that Harper's (1948) conclusion that the incisive papilla did not change position following the extraction of teeth, was based on caliper measurements on the surface of casts.

From the vertical measurements it was evident that the

upward movement of the papilla was greater than its forward movement and since Harper used the level of the papilla to define the plane from which he measured post-extraction changes it is not surprising that some of his measurements apparently showed increases in the height of the residual ridges following the extraction of teeth.

#### Conclusion.

A change in the position of the incisive papilla relative to the stable area of the palate was observed, following the extraction of maxillary central incisors, in every patient in the sample. It is therefore concluded that this change commonly accompanies the extraction of maxillary central incisors.

It is possible that changes in the shape of the incisive papilla also commonly accompany the extraction of maxillary incisors but the changes were assessed only by general observation and no measurements were made.

#### 4. CHANGES IN POSITION AND SHAPE OF THE RUGAE.

Changes in the position and shape of the rugae following the extraction of anterior teeth were not specifically studied but, from general observation of the traces and comparative caliper measurements of the casts (used in the location of M, R and lateral points) it was evident that such changes took place. In general terms the changes appeared to be as follows:-

Along the whole length of the first pair of primary rugae a forward and upward movement occurred usually within 12 weeks after the extraction of the anterior teeth.

A similar but less marked forward and upward movement of the second pair of primary rugae was observed in the majority of cases but in some, the movement was confined to the lateral parts of the rugae and did not affect their terminations near the median plane. In addition to the forward and upward movements, the lateral ends of the second pair of rugae appeared to move laterally. Changes in position of the second pair of primary rugae occurred later than in the first pair but were usually evident by the 26th post-extraction week.

In four cases (M12, M16, F17, M20) small changes were observed after the first post-extraction year near the medial ends of the third pair of primary rugae and in these cases the R point was located in the median plane immediately behind the fourth pair of rugae. In none of the patients was change observed at the R point during the period of the

study. In some cases the lateral ends of the third and fourth pairs of primary rugae were observed to move upwards and laterally especially when the rugae were long.

In some of the patients, after dentures were fitted, the rugae became less prominent. The first pair of rugae were chiefly affected and sometimes could not be detected on the casts one year after extraction of the anterior teeth. Flattening of the second and third pairs of rugae was also observed but usually to a lesser extent.

#### Discussion.

The measurements of palatal change in the central incisor, canine and premolar regions were affected by movements of the rugae. The lines of the pre- and post-extraction traces often coincided at a point where a ruga was present and the measurement of palatal change did not increase until the change was sufficiently large to disengage the ruga outline of the post-extraction trace from that of the pre-extraction trace, thus short plateaux occurred in the individual graphs of palatal change. In some cases the forward and outward movement of the rugae led to a decrease of the palatal change measurement at a given point.

Similar decreases sometimes occurred in the measurements of vertical change where the post-extraction movement of the lateral ends of the rugae brought them into the line of the measurements.

Rugae movement was also responsible for the apparent differences between the palatal parts of pre- and post-

extraction coronal traces through the first premolars.

The post-extraction changes in the positions of the rugae relative to their pre-extraction positions appeared to be part and parcel of a general unfolding of the anterior and lateral parts of the palatal mucosa associated with the ridge resorption, rather than a change in their positions relative to each other within the mucosal surface. Thus apart from a flattening and occasional disappearance of the first primary rugae, the general appearance of the rugae pattern was not much altered by the extraction of teeth. Where flattening of the rugae was observed it may possibly have been caused by denture trauma or scar tissue contraction in the extraction wounds.

### 5. TATTOO SPOT STUDY.

In 8 of the 25 patients in the sample, tattoo spots were placed near the gingival margins on the buccal and lingual sides of the teeth before extraction. One buccal and one lingual spot was placed at each tooth position. 110 spots in all were tattooed by the observer.

The buccal spots were placed directly above and 2 mm. away from the centre of the buccal gingival margins of the teeth to be extracted. The lingual spots were 1 mm. above the centres of the lingual gingival margins.

The spots were usually tattooed while the patients were under general anaesthesia prior to extraction of the teeth. The position of a spot was marked on the mucosa with dividers and a hypodermic needle (gauge 26) filled with Indian ink, was inserted and the stylet, which was half withdrawn before insertion, was depressed. The needle was then removed.

The positions of the spots were checked and transferred to the pre-extraction casts by measurement.

At each subsequent visit of the patient the tattoo spots were located and marked on the mucosa with a sharp indelible pencil before the post-extraction impressions were taken. On removal of the impressions from the mouth the indelible pencil marks, though smudged, could be clearly seen. Short lengths of 0.3 mm. diameter stainless steel wire were stuck into the alginate impressions at the centres of the darkest parts of the smudged pencil dots.

When the impressions were cast the wires remained embedded in the casts and the protruding ends were cut off. Thus the positions of the tattoo spots were located on the casts (Fig. 22 ). The pre-extraction and last post-extraction casts of each of the tattooed patients were positioned in turn on the horizontal tracing instrument and the pre- and post-extraction positions of the spots were plotted on polar graph paper within the buccal outline of the pre-extraction casts (Figs. 47 & 48 ).

Circles were drawn round the pre-extraction positions of the spots and arrows were used to indicate the positions of the spots on the last post-extraction casts. Spots which disappeared before the end of the study were marked with a cross.

The technique was not considered to be sufficiently accurate to warrant detailed measurements of the spots throughout the period of study, but it was evident, from general observation, that the buccolingual distance between pairs of spots was reduced by the healing and resorptive processes which followed the extraction of the teeth.

#### Discussion.

The movements of the tattoo spots seemed to indicate that the greatest reduction in mucosal surface area, during the period of study, took place in the areas of extraction wounds. Thus scar tissue contraction in these areas may have contributed to the changes in the positions of the rugae which were observed.

TATTOO SPOT STUDY.

Figs. 47 & 48.

Records of pre- and post-extraction positions of spots tattooed near buccal and lingual gingival margins. The pre-extraction positions of the spots are circled and the post-extraction positions are indicated with arrows. Crosses mark spots which disappeared during the study.

Figs. 47 & 48.

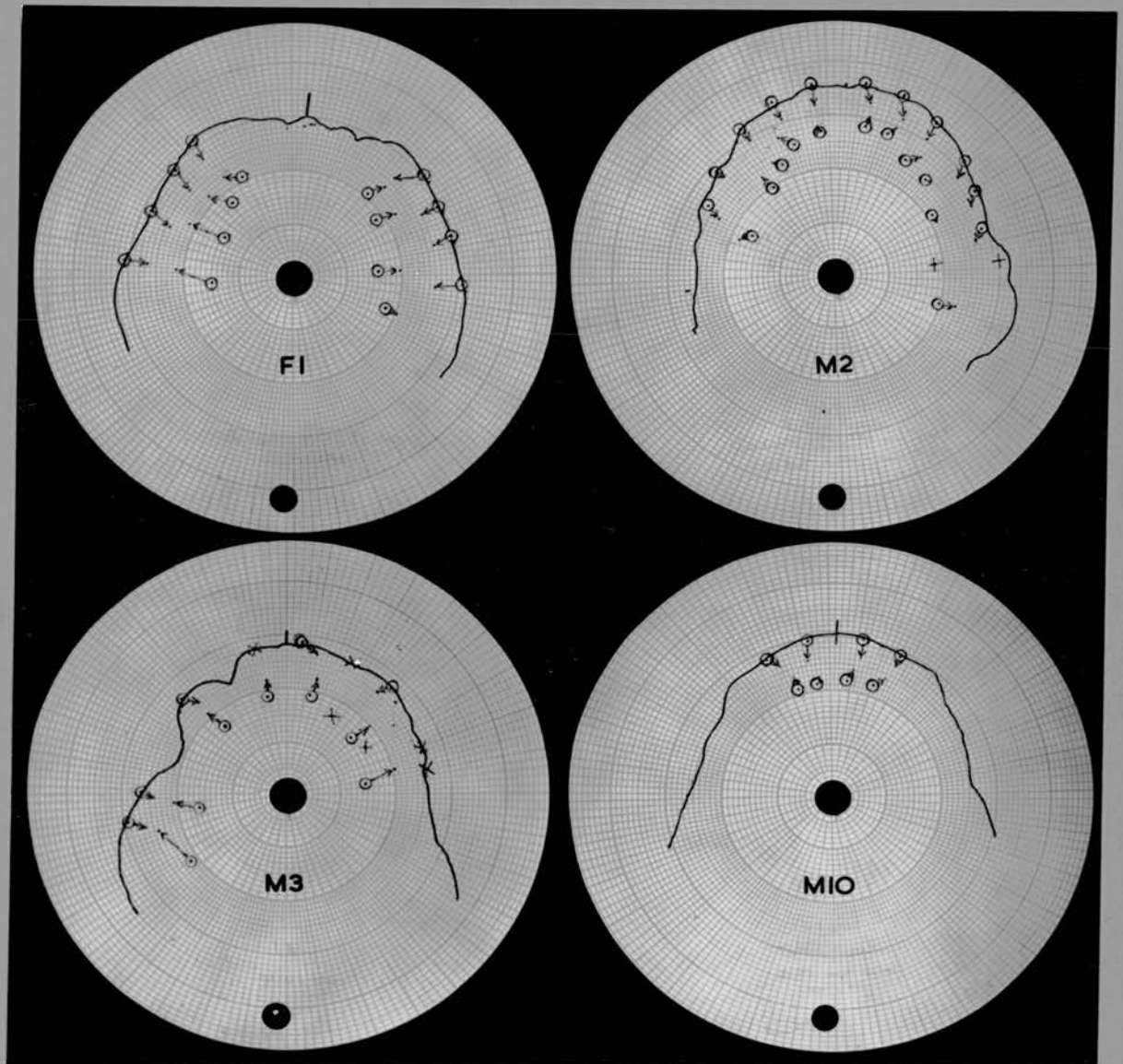


Fig. 47.

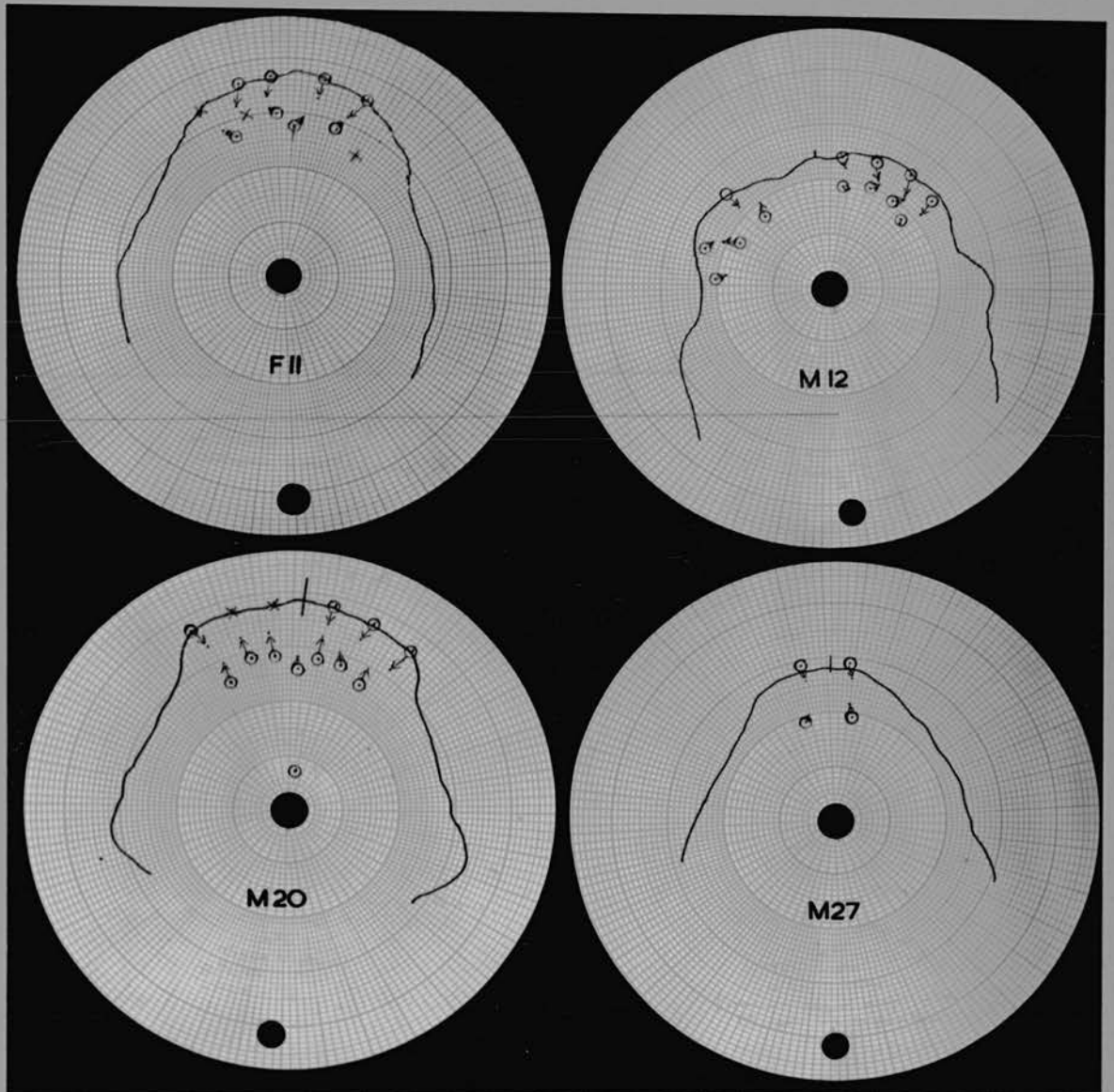


Fig. 48.

## 6. OBSERVATIONS ON HORIZONTAL SECTION TRACES.

Tracings were made with the horizontal tracing instrument through the alveolar processes of the pre-extraction and last post-extraction casts of each series. The tracings were parallel to the "occlusal plane" of the pre-extraction casts and about the level of the mid-buccal points in the second premolar region. Lingual and buccal contours of each pair of casts were traced on the same piece of polar graph paper and the plane of the tracing was identical for each pair. Traces from the 25 patients in the sample are shown in Figs. 49 & 50. The section outline of the residual ridge of the last post-extraction cast of each series has been shaded and lines indicate the positions of the R and M planes.

As the plane of the section traced was fixed but the ridge height varied in different areas there was a considerable variation in the points at which the horizontal tracing intersected the lines of the vertical tracings. Thus the changes observed in horizontal traces were not directly comparable with the post-extraction measurements of the vertical traces. In many cases the buccal outline of the pre-extraction horizontal trace stopped short in the second or third molar region as the plane of the tracing entered the buccal sulcus. In one case (F.14) there was marked asymmetry and it was necessary to trace opposite sides of the casts at different levels. The large variation in amounts of change between patients and between different areas in the same patient was clearly shown by the horizontal

Three of the patients were partially edentulous at the end of the study (M10, M26 & M28) and little or no change, in the plane of the trace, was observed where teeth were present. The amount of change during the period of this study was noticeably less in areas where teeth had been lost prior to the start of the study. With the exception of F.1 such areas were present in every case. The changes observed in the vertical section traces of F.30 were about average and details of the horizontal traces of this patient are given (Fig. 51).

The horizontal traces passed through areas which had been excluded from the study for various reasons (page 41) In areas where exclusion was due to surgical intervention, other than simple forceps extraction, the change appeared to be increased (e.g. M.12 /67 fracture and removal of buccal plate M.18 6/ roots removed surgically).

The apparently large buccal change in M.37 was chiefly due to the subsidence of a swelling which led to the exclusion of many teeth.

It was evident from examination of the casts that the posterior border of the maxillary tuberosity was subject to atrophic changes following the extraction of the last molars. Such changes are illustrated in the horizontal traces where it was possible to extend the pre-extraction lines to the postero-lateral border of the maxillary tuberosity (F. 5, 6, 15, 17, 32 & M.28).

The forward movement of the posterior border of the tuberosity together with the buccal change following the extraction of the anterior teeth reduced the antero-posterior length of the residual alveolar ridges.

SUPERIMPOSED  
HORIZONTAL TRACES  
OF PRE-EXTRACTION AND  
LAST POST-EXTRACTION  
CASTS OF EACH SERIES.

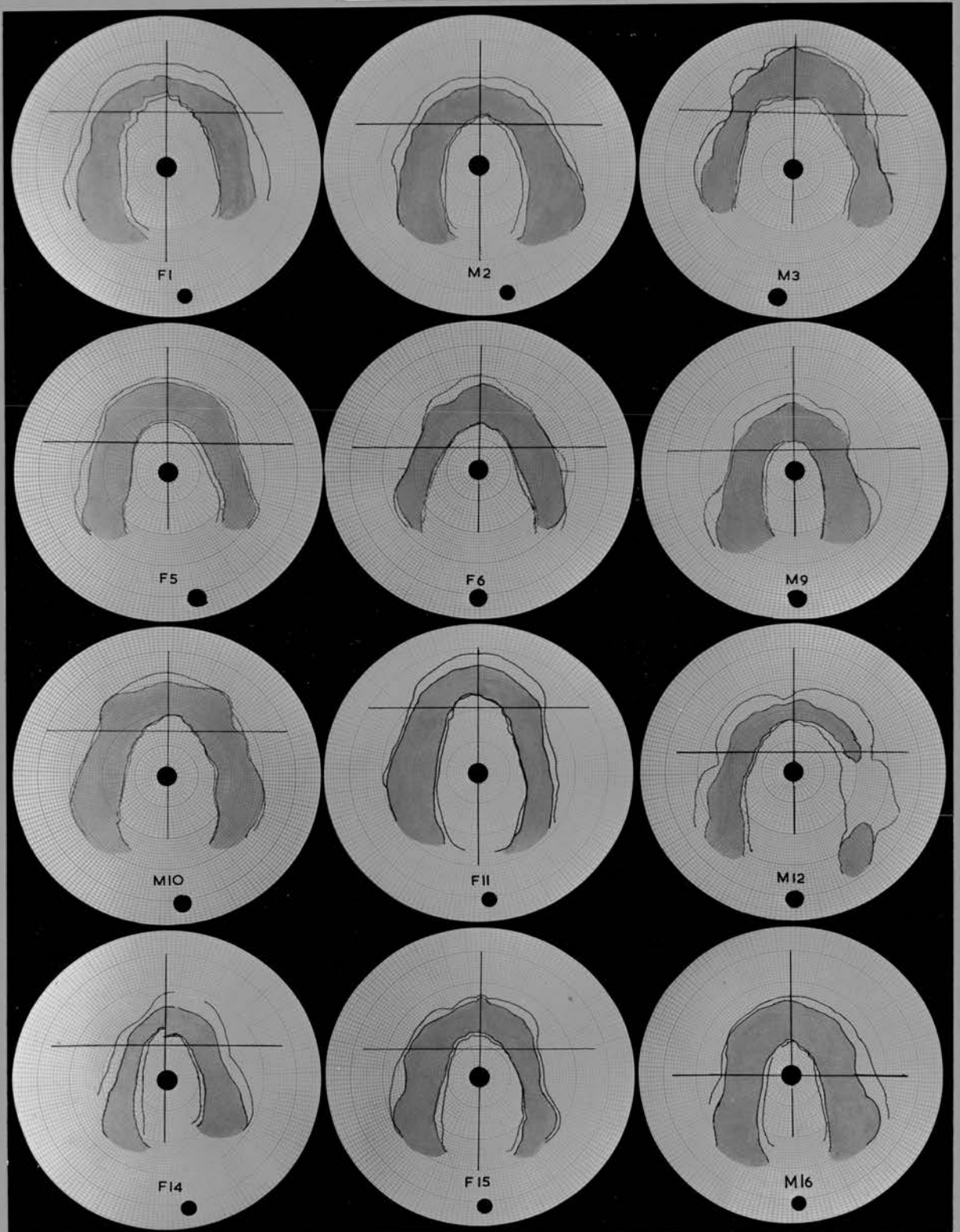


Fig. 49.

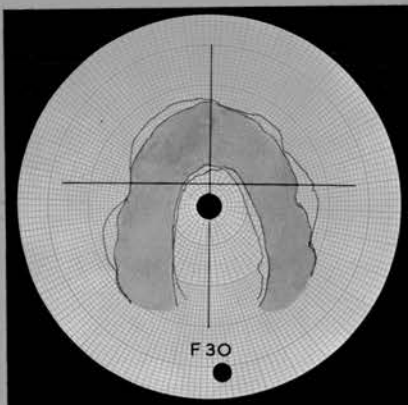
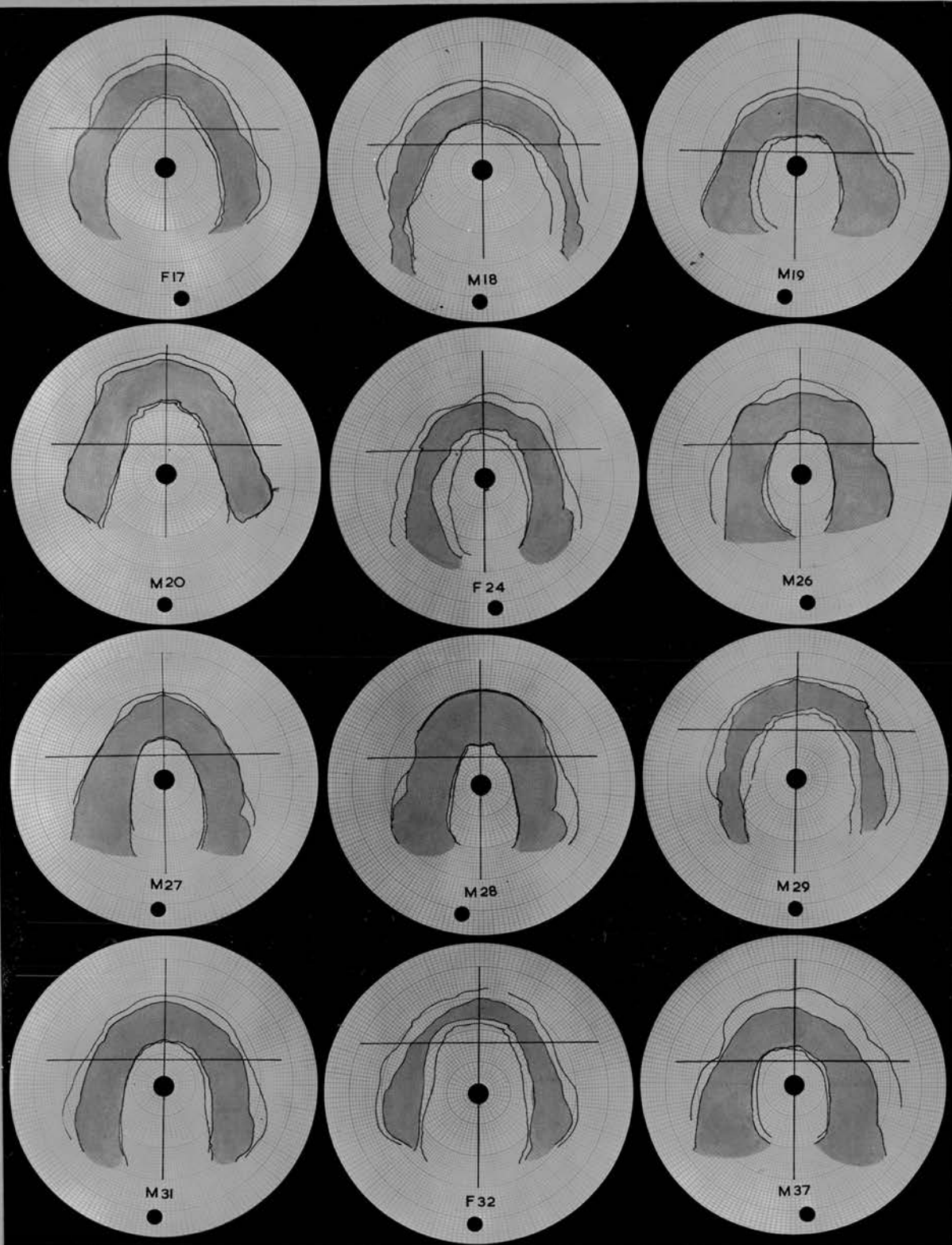
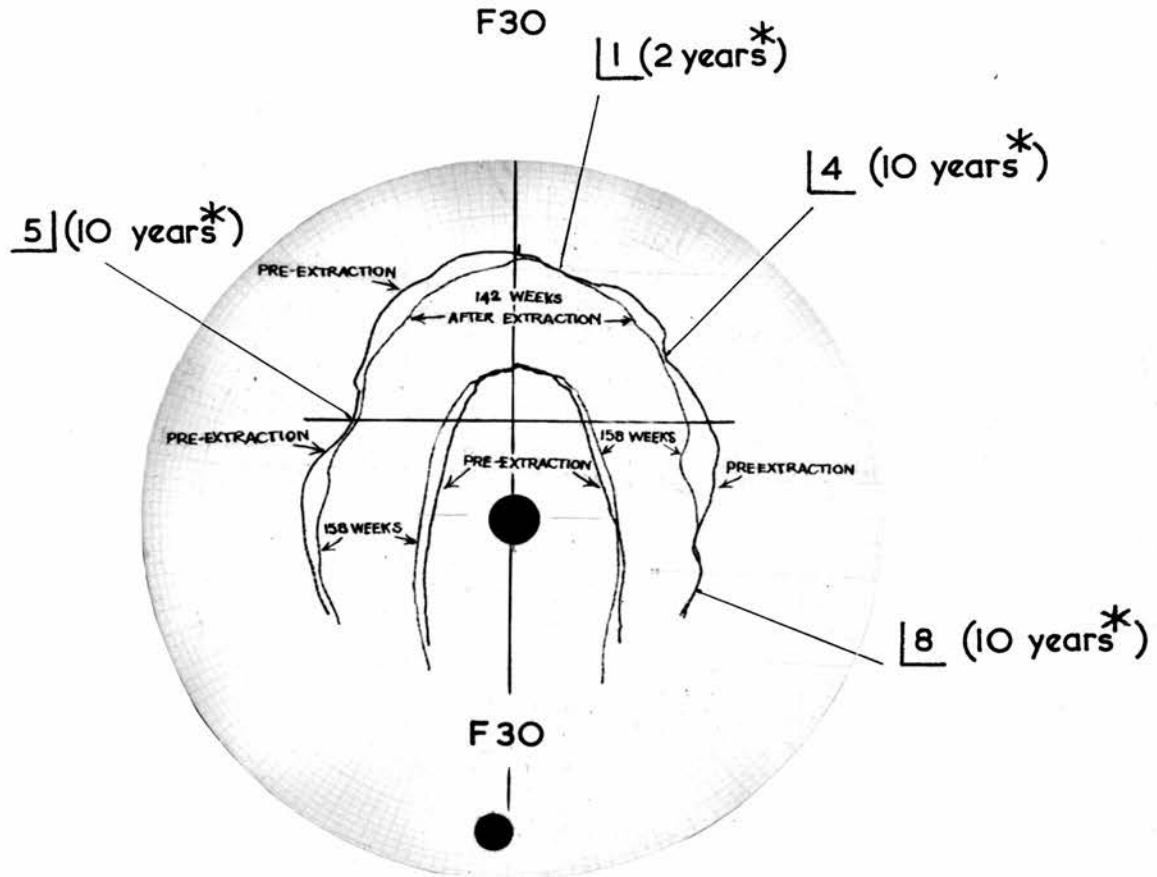


Fig. 50.

PRE- and POST-EXTRACTION  
HORIZONTAL SECTION TRACES



\*Teeth extracted prior to start of study.  
The times between the extractions and the  
start of the study are shown in brackets.

Fig. 51.

Widening of the palatal contour in the planes of the traces following the extraction of teeth is clearly illustrated by the horizontal traces as is the reduction in bucco-lingual width of the residual alveolar ridges.

#### Discussion.

It is generally accepted that a prosthesis should support the lips and cheeks in the positions which they occupied prior to extraction of the teeth. Thus the buccal space between pre- and post-extraction traces represents the approximate thickness of the buccal flanges of denture prostheses in the sections traced. It is evident that there should be a direct relationship between the thickness of the denture flange and the amount of buccal change, in order to support the lips and cheeks. Therefore the practice of making upper dentures with a standard thickness of flange is contraindicated.

As a general rule more change occurred buccally than lingually in the sections traced so that the radius of the curve of the residual ridge appeared to be less than before extraction of the teeth. Thus, if the artificial teeth are set directly under the residual ridge, they are likely to lie in a narrower arch, of shorter radius, than their natural counterparts.

7. AVERAGE AND RANGE OF CHANGES  $2\frac{1}{2}$  YEARS AFTER EXTRACTIONS.

In every series of traces examined reduction in the height and buccal contour of the residual alveolar ridges was observed at the positions of measurement following the extraction of the maxillary teeth. In every patient in the sample the greatest amount of change at the positions of measurement was observed  $2\frac{1}{2}$  years or more after extraction of the teeth and the greatest range of changes, between patients, was also observed at this period. The following table shows the range and average of the changes  $2\frac{1}{2}$  years after extraction of the maxillary teeth.

TABLE 24

AVERAGE MEASUREMENTS AND RANGE OF CHANGES OBSERVED 2½ YEARS AFTER THE EXTRACTION OF TEETH IN THE EIGHT REGIONS OF THE MAXILLARY DENTURE BEARING AREA WHICH WERE INVESTIGATED.

| No. of patients | REGION       | BUCCAL CHANGES |      |      | LINGUAL VERTICAL CHANGES |      |      | PALATAL CHANGES |      |      |
|-----------------|--------------|----------------|------|------|--------------------------|------|------|-----------------|------|------|
|                 |              | Av.            | Min. | Max. | Av.                      | Min. | Max. | Av.             | Min. | Max. |
| 18              | Median Plane | 3.60           | 1.2  | 5.8  | 2.30                     | 1.3  | 4.0  | 9.35            | 7.3  | 14.7 |
| 22              | <u>1 / 1</u> | 3.25           | 1.3  | 5.1  | 3.00                     | 1.6  | 4.2  | 11.35           | 6.9  | 18.9 |
| 15              | <u>3 / 3</u> | 5.65           | 2.4  | 9.1  | 3.95                     | 2.7  | 5.5  | *1.55           | *0.1 | *3.3 |
| 15              | <u>4 / 4</u> | 3.35           | 1.4  | 5.4  | 3.60                     | 1.7  | 6.1  | 12.50           | 4.00 | *2.0 |
| 9               | <u>5 / 5</u> | 3.55           | 1.7  | 5.3  | 3.95                     | 2.2  | 6.5  | 11.90           | 8.8  | 14.7 |
| 8               | <u>6 / 6</u> | 4.20           | 2.0  | 6.3  | 3.45                     | 1.5  | 6.2  | 9.45            | 4.5  | 13.5 |
| 9               | <u>7 / 7</u> | 5.00           | 1.9  | 6.8  | 3.40                     | 1.5  | 6.2  | 10.25           | 4.5  | 14.5 |
| 8               | <u>8 / 8</u> | 4.20           | 3.3  | 7.0  | 2.85                     | 0.6  | 4.6  | 11.65           | 2.5  | 17.3 |

\* Median vertical measurement - post-extraction change crossed the median plane.

### Discussion.

#### (a) Range

It is apparent that even in the small samples studied differences of 4 mm. were not uncommon between patients showing the greatest and least buccal and lingual vertical changes. It is possible that the range would have been considerably greater in larger samples studied over longer periods, and in samples where a variety of methods were employed for the extraction of the teeth.

#### (b) Average Buccal Changes

Two and a half years after extraction the average buccal changes in the median plane, central incisor and premolar samples were similar and were about 3.5 mm. The fact that the median plane tracings did not cross tooth sockets but passed between the central incisors had no noticeable effect on the average buccal change in the median plane.

The angle between the alveolar ridge and the coronal tracings through the canines was thought to be chiefly responsible for the increased average buccal measurement in this region, for, in the horizontal section traces, little difference was observed between the amount of buccal changes, radial to the curve of the alveolar ridge, in the incisor, canine and premolar regions.

The average buccal changes in the molar traces 2½ years after extraction were between 4 and 5 mm. The greater average change observed in these traces may have been a characteristic of the samples but it seems reasonable to expect the post-extraction changes to be greater in this region and in some measure related to the size of the

(c) Average Lingual Vertical Changes.

Apart from the lesser average change in the median plane which has been discussed, the average lingual vertical changes in the other regions appeared to be fairly uniform and roughly between 3 and 4 mm. The average change in the last molar region was low but this might have been due to chance. It was apparent that the average changes in this region within one month of tooth extraction were as great as elsewhere consequently the average change at this period represented a higher percentage of the smaller average change  $2\frac{1}{2}$  years after extraction (Table 25 ).

In some cases there was a small initial collapse of the lingual gingival margin in the third molar region and thereafter little or no increase of the lingual vertical change took place (Fig. 9, p. 73). A fibrous hyperplasia of the gingivae round the last molars was observed clinically in these patients prior to extraction and the fibrous tissue appeared to persist after extraction. Thus, at the end of the study, the "maxillary tuberosities" appeared to be large and fibrous but there was no evidence that growth had taken place in the region during the post-extraction period. In the patient with minimum change in the third molar traces (Fig. 43 minimum) there was a hyperplastic pad of soft tissue at the distal gingival margin which collapsed anteriorly on the extraction of the tooth and, as scar tissue contraction and resorptive change occurred, it gradually moved into the plane of the trace. The small measurements of this case contributed to the reduction in the average change.

(d) Palatal Changes.

In the coronal plane passing through the canine teeth the palatal change crossed the mid-line in every case and thus median vertical measurements were given to indicate its extent. In 7 of the 15 patients the palatal change in the first premolar traces was observed to cross the median plane before the study terminated. It appeared, from inspection of the casts that, whether or not the change crossed the median plane depended on the antero-posterior position of the first premolars. Where the maxillary dental arch was flattened antero-posteriorly in the region of the anterior teeth the coronal trace through the first premolars crossed the alveolar process posterior to the central incisors in the median plane, but where the anterior part of the dental arch was acutely curved or V-shaped the first premolars were more distally placed and the coronal trace lay posterior to the alveolar process in the median plane. In the former case the palatal change crossed the median plane and in the latter it did not.

Large variations in the extent of palatal changes were observed between individuals but on average, the area of the palate which was subject to change, during the course of this study, can be roughly defined as the area of the palate lateral to a line on its surface about one centimetre (measured in the horizontal plane) from the lingual gingival margins of the teeth.

### 8. THE STABLE AREA OF THE PALATE.

As the atrophy of the alveolar ridge progressed following the extraction of maxillary teeth, changes in the contour of the anterior and lateral parts of the hard palate occurred in every case. The palate appeared to open, rather like a flower, the mucosa covering the lingual surface of alveolar process moved upwards and outwards as the atrophy continued and the area of palatal change extended towards the centre of the palate until only a relatively small median "stable area" remained unchanged.

The average extent of the stable area  $2\frac{1}{2}$  years after extraction of the teeth in the sample is shown in the diagram (Fig. 52 ). The relevant measurements from which the diagram was constructed are to be found in the Tables on pages 124 and 186.

The areas in which no change occurred during the course of this study, were painted on the pre-extraction casts of the patients with the minimum and maximum palatal changes  $2\frac{1}{2}$  years after extraction of the remaining teeth (Fig. 53 ) Both the patients illustrated had teeth missing prior to the start of this study and it seems reasonable to assume that, in the period following their loss, changes took place within the areas which later remained stable.

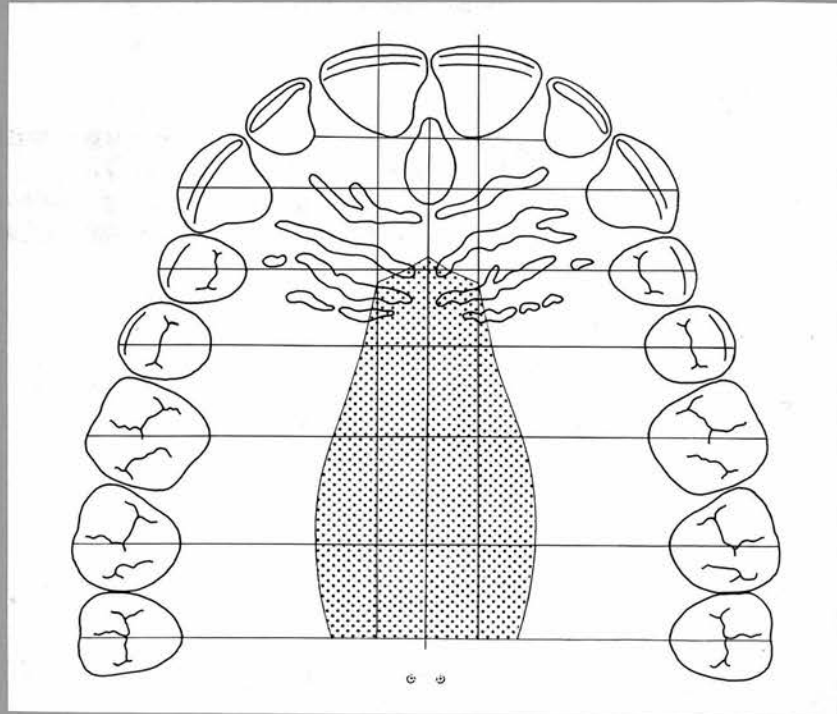
## THE STABLE AREA OF THE PALATE.

Fig. 52. Diagram constructed from average measurements of the whole sample (Scale x 1.7). The average area unaffected by post-extraction changes at 130 weeks after extraction of the teeth is stippled.

Fig. 53. The pre-extraction casts of the patients with the greatest (left) and the least (right) post-extraction change in the palate at 130 weeks. The black areas represent the parts of the palate unaffected by post-extraction change during the period of study but presumably changes had already occurred in the areas where teeth had previously been lost.

Fig. 52.

Fig. 53.



Discussion.

The "average patient" and the "average stable area of the palate" exist only on paper but nevertheless provide approximate baselines from which deviations can be assessed. The "minimum" and "maximum" casts showed prolongations of the stable area towards the regions where teeth had been lost prior to the start of the study. If these prolongations were discounted, on the grounds that they represented areas where change had taken place at the time of the previous extractions, it seemed that only a relatively small median area of the palate remained unaffected by change following the extraction of the teeth. Clinically it corresponded to the median area where the soft tissue covering of the palatine process of the maxilla is thin. Its boundaries were approximately defined as follows:-

Anterior:- A coronal plane through the first premolars.

Posterior:- A coronal plane through the third molars

(this is an arbitrary boundary as soft palate movement affected the surface form of the mucosa posterior to this).

Lateral:- Antero-posterior lines running roughly parallel to the dental arch starting anteriorly about 5 mm. to the right and left of the median plane.

At the end of the study the palatal change was still progressing slowly. Further diminution of the stable area is therefore to be expected in studies covering a longer period than two and a half years.

### 9. RATE OF POST-EXTRACTION CHANGES.

Examination of 312 graphs which were constructed to study the post-extraction changes in the 25 individuals in the sample showed a rapid change in every case shortly after extraction and a general trend towards decrease in the rate of change as the post-extraction time increased. This trend was reflected in the smooth curves of average post-extraction changes (pages 145-160). The curves of individual graphs, however, were seldom smooth and phases of increased and decreased rate of change were observed more than three months after extraction although the general trend towards a decrease in the rate of change continued with the lengthening of the post-extraction period.

These phases occurred at different post-extraction intervals in different patients and tended to cancel each other so that the curves of average change were smooth.

The time intervals between the points on the individual graphs were not short enough to establish whether the rate of change was characteristically phasic but it is possible that resting phases followed by phases of more rapid change, which were too small to be detected by the method employed, may have occurred characteristically.

An assessment of the average rate of change in the samples was made by expressing the average changes in each region, at 4, 12, 26 and 52 weeks after extraction, as percentages of the average changes observed  $2\frac{1}{2}$  years after extraction. The figures are shown in the following Tables.

TABLE 25.

AVERAGE BUCCAL CHANGES AT VARIOUS POST-EXTRACTION PERIODS EXPRESSED AS PERCENTAGES OF THE AVERAGE BUCCAL CHANGES OBSERVED  $2\frac{1}{2}$  YEARS AFTER EXTRACTION OF TEETH IN THE EIGHT REGIONS OF THE MAXILLARY DENTURE BEARING AREA WHICH WERE INVESTIGATED.

| REGION       | % of AVERAGE CHANGE AT $2\frac{1}{2}$ YEARS.<br>Time in weeks since extractions. |      |      |      |
|--------------|--|------|------|------|
|              | 4  | 12   | 26   | 52   |
| Median plane | 34.7   | 61.1 | 77.7 | 88.8 |
| <u>1 / 1</u> | 29.2   | 60.0 | 76.9 | 84.6 |
| <u>3 / 3</u> | 42.5   | 62.8 | 75.2 | 85.0 |
| <u>4 / 4</u> | 25.4   | 56.7 | 79.1 | 86.6 |
| <u>5 / 5</u> | 28.2   | 60.6 | 80.3 | 88.7 |
| <u>6 / 6</u> | 41.7   | 61.9 | 76.2 | 89.3 |
| <u>7 / 7</u> | 36.0   | 69.0 | 81.0 | 89.0 |
| <u>8 / 8</u> | 56.0   | 70.2 | 81.0 | 87.0 |

TABLE 26.

AVERAGE LINGUAL VERTICAL CHANGES AT VARIOUS POST-EXTRACTION PERIODS EXPRESSED AS PERCENTAGES OF THE AVERAGE LINGUAL VERTICAL CHANGES OBSERVED  $2\frac{1}{2}$  YEARS AFTER EXTRACTION OF TEETH IN THE EIGHT REGIONS OF THE MAXILLARY DENTURE BEARING AREA WHICH WERE INVESTIGATED.

| REGION       | % of AVERAGE CHANGE AT $2\frac{1}{2}$ YEARS.<br>Time in weeks since extractions. |      |      |      |
|--------------|--|------|------|------|
|              | 4  | 12   | 26   | 52   |
| Median plane | 28.3   | 50.0 | 69.6 | 84.8 |
| <u>1 / 1</u> | 36.7   | 64.0 | 76.0 | 88.3 |
| <u>3 / 3</u> | 55.7   | 78.5 | 88.6 | 95.0 |
| <u>4 / 4</u> | 37.5   | 65.3 | 81.9 | 90.3 |
| <u>5 / 5</u> | 41.8   | 68.4 | 86.1 | 92.4 |
| <u>6 / 6</u> | 42.0   | 66.6 | 78.3 | 89.9 |
| <u>7 / 7</u> | 48.5   | 73.5 | 82.4 | 86.7 |
| <u>8 / 8</u> | 57.9   | 77.2 | 87.7 | 91.2 |

TABLE 27.

AVERAGE PALATAL CHANGES AT VARIOUS POST-EXTRACTION PERIODS EXPRESSED AS PERCENTAGES OF THE AVERAGE PALATAL CHANGES OBSERVED 2½ YEARS AFTER EXTRACTION OF TEETH IN THE EIGHT REGIONS OF THE MAXILLARY DENTURE BEARING AREA WHICH WERE INVESTIGATED.

% of AVERAGE CHANGE AT 2½ YEARS.  
Time in weeks since extractions.

| REGION       | 4     | 12    | 26    | 52    |
|--------------|-------|-------|-------|-------|
| Median plane | 31.0  | 54.9  | 72.7  | 87.7  |
| <u>1 / 1</u> | 41.4  | 64.8  | 79.3  | 90.7  |
| <u>3 / 3</u> | 32.3* | 58.0* | 74.2* | 87.1* |
| <u>4 / 4</u> | 34.8  | 60.8  | 83.6  | 90.8  |
| <u>5 / 5</u> | 37.4  | 60.9  | 79.4  | 93.3  |
| <u>6 / 6</u> | 46.6  | 61.9  | 75.1  | 85.2  |
| <u>7 / 7</u> | 45.8  | 62.9  | 77.6  | 86.8  |
| <u>8 / 8</u> | 43.3  | 67.8  | 77.7  | 91.0  |

\* Median vertical - change crossed the median plane.

#### Discussion.

It is evident that the average rates of change in a given post-extraction time varied considerably between different points of measurement in the same region and between regions. Much greater variations in the rates of change were observed between individuals.

Nevertheless the tables show quite clearly that the change was most rapid in the first post-extraction month and the rate of change diminished as the post-extraction time lengthened so that, on average, only about 10% of the change took place between the 52nd and 130th post-extraction weeks. Within the limits of the samples in

the sections of the maxillary denture bearing area which were studied the rate of change may be expressed in very general terms by the following approximate modal values.

40% by the end of the first post-extraction month.

65% " " " " " third " " month.

80% " " " " " sixth " " month.

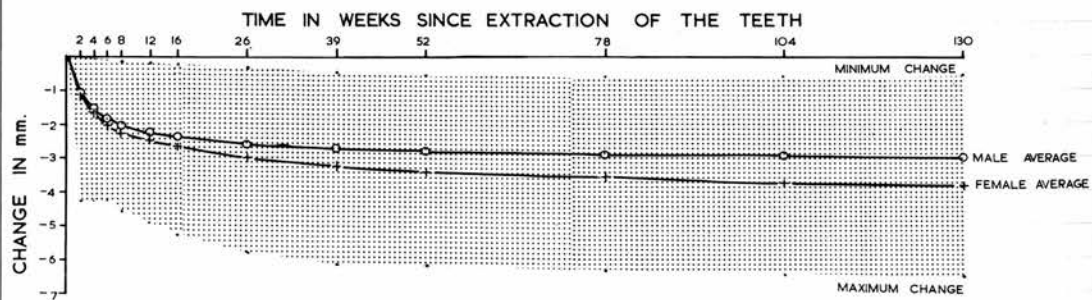
90% " " " " " first " " year.

10. POST-EXTRACTION CHANGES IN MALES AND FEMALES.

The tables and graphs on pages 199 - 200 show the average lingual vertical changes and average buccal changes of the 8 regions traced in males and females. The range of lingual vertical and buccal changes in the whole sample is also shown.

The average post-extraction changes over the eight regions appeared to be slightly less in males than in females but in view of the small sample and the large range of the observed changes the difference is obviously not significant.

RANGE AND AVERAGE LINGUAL VERTICAL POST-EXTRACTION CHANGES IN THE 8 REGIONS TRACED IN MALES AND FEMALES.



TABLE

AVERAGE LINGUAL VERTICAL CHANGES IN THE EIGHT REGIONS TRACED IN MALES AND FEMALES AND RANGE OF LINGUAL VERTICAL CHANGES IN THE WHOLE SAMPLE (n = 25)

| Weeks since extractions | Lingual Vertical Changes |                | Range of changes in the whole sample. |                |
|-------------------------|--------------------------|----------------|---------------------------------------|----------------|
|                         | Males<br>mm.             | Females<br>mm. | Minimum<br>mm.                        | Maximum<br>mm. |
| 2                       | 1.06                     | 1.13           | 0.00                                  | 4.25           |
| 4                       | 1.54                     | 1.62           | 0.06                                  | 4.25           |
| 6                       | 1.82                     | 2.02           | 0.09                                  | 4.25           |
| 8                       | 2.02                     | 2.22           | 0.12                                  | 4.55           |
| 12                      | 2.26                     | 2.48           | 0.18                                  | 4.91           |
| 16                      | 2.34                     | 2.66           | 0.22                                  | 5.25           |
| 26                      | 2.60                     | 3.00           | 0.33                                  | 5.78           |
| 39                      | 2.72                     | 3.24           | 0.49                                  | 6.12           |
| 52                      | 2.81                     | 3.40           | 0.55                                  | 6.19           |
| 78                      | 2.91                     | 3.58           | 0.60                                  | 6.34           |
| 104                     | 2.96                     | 3.77           | 0.60                                  | 6.45           |
| 130                     | 3.03                     | 3.86           | 0.60                                  | 6.54           |

RANGE AND AVERAGE BUCCAL POST-EXTRACTION CHANGES IN  
THE 8 REGIONS TRACED IN MALES AND FEMALES

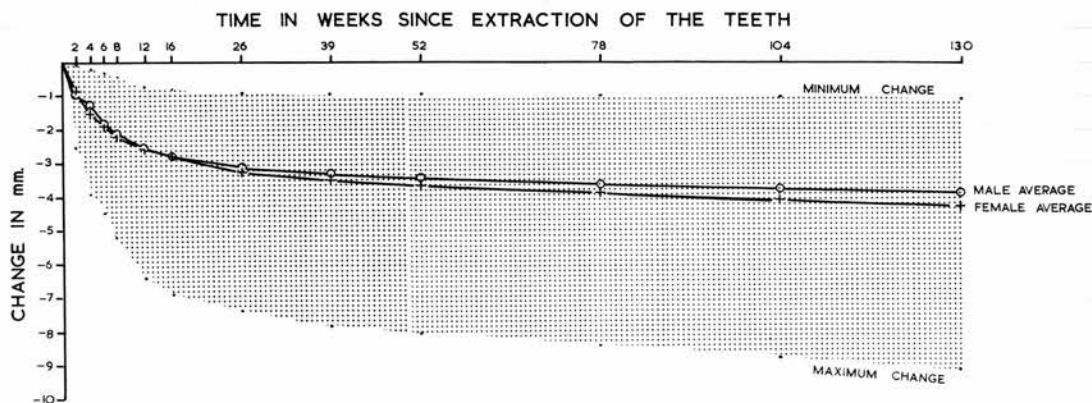


TABLE 29.

AVERAGE BUCCAL CHANGES IN THE EIGHT REGIONS TRACED IN MALES  
AND FEMALES AND RANGE OF BUCCAL CHANGES IN THE WHOLE SAMPLE.

| Weeks since<br>extractions | Buccal Changes |                | Range of changes in<br>the whole sample. |                |
|----------------------------|----------------|----------------|--|----------------|
|                            | Males<br>mm.   | Females<br>mm. | Minimum<br>mm.                           | Maximum<br>mm. |
| 2                          | 0.87           | 0.96           | 0.07                                     | 2.50           |
| 4                          | 1.52           | 1.23           | 0.21                                     | 3.89           |
| 6                          | 1.90           | 1.82           | 0.33                                     | 4.45           |
| 8                          | 2.21           | 2.12           | 0.42                                     | 5.20           |
| 12                         | 2.57           | 2.55           | 0.75                                     | 6.40           |
| 16                         | 2.82           | 2.82           | 0.84                                     | 6.88           |
| 26                         | 3.13           | 3.26           | 0.91                                     | 7.35           |
| 39                         | 3.31           | 3.50           | 0.94                                     | 7.82           |
| 52                         | 3.46           | 3.69           | 0.97                                     | 8.02           |
| 78                         | 3.62           | 3.89           | 1.00                                     | 8.40           |
| 104                        | 3.75           | 4.08           | 1.05                                     | 8.75           |
| 130                        | 3.86           | 4.26           | 1.10                                     | 9.10           |

11. GENERAL OBSERVATIONS ON MORPHOLOGICAL CHANGES  
ASSOCIATED WITH DENTURE WEARING.

The times at which dentures were fitted and relined were marked on all the individual graphs of post-extraction changes (pages 128 - 142 ). In the majority of cases the graphs showed no appreciable deflection after dentures were fitted or relined and in this respect the observation of Atwood (1957) is confirmed, but it is a matter of common clinical experience that the "settling" of new dentures takes place chiefly during the first two weeks of wear and the time intervals between the points on the graphs were not short enough to detect changes which may have occurred during that period.

In cases where deflections in the graphs were observed about the time dentures were fitted or relined, the changes could not be attributed to the presence of the dentures with any degree of confidence as other factors might have caused them.

In four patients, after the upper denture was relined, a marked increase in the extent of palatal change was observed in the first and second molar traces without corresponding increases in the lingual vertical or buccal changes. It is possible that the Zinc Oxide eugenol impression paste used in the relining of the dentures in these cases may have compressed the comparatively thick layer of soft tissue between the palatine and alveolar processes in the molar region. The extent of the change in these cases was sufficiently marked to produce late deflections in the average curves of palatal change (pages 155 & 157). A trace from one of the patients, 3 weeks after the relining of the

Occasional upward deviations in the graphs were seen when lower dentures were relined. These might possibly have been due to adaptive changes in the maxillary denture bearing area caused by a slight change in occlusion associated with relining of the lower dentures, but in the absence of a control, attributing such changes to the presence of dentures is purely conjectural.

#### Discussion.

Every effort was made in this study to reduce the effects of denture wearing on the surface form of the denture bearing area (page 44 ). Although changes may have occurred which were specifically produced by the presence of the dentures, they clearly could not be isolated from the other factors responsible for the changes. The material was unsuitable for the investigation of the biological mechanisms which were responsible for the changes and no attempt was made to study them.

## 12. POST-EXTRACTION CHANGES IN PATIENTS WITH IMMEDIATE DENTURES.

The average buccal and lingual vertical post-extraction changes in the central incisor and canine regions in patients with dentures fitted immediately after extraction were compared with the average post-extraction changes in patients who had dentures fitted from 14 to 52 weeks after the extraction of central incisors and canines.

The data from this study is shown on pages 204-207.

After the first post-extraction month the buccal changes and the vertical changes at the lingual gingival margins in the plane of the traces were less in patients with immediate dentures than in patients with ordinary dentures (i.e. dentures fitted after healing of the extraction wounds).

The greatest difference was observed between the average vertical changes at the lingual gingival margins of the canine traces. These figures were tested but were not found to be statistically significant.

RANGE & AVERAGE BUCCAL POST-EXTRACTION CHANGES IN SAGITTAL TRACES THROUGH  $\frac{1}{1}$ .  
 (A) PATIENTS WITH IMMEDIATE DENTURES n=12 (B) PATIENTS WITH DENTURES FITTED AFTER HEALING n=10.

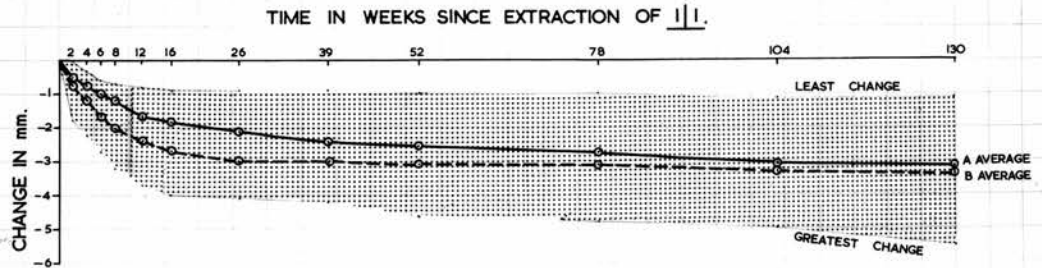


TABLE 30.

RANGE & AVERAGE BUCCAL POST-EXTRACTION CHANGES IN SAGITTAL TRACES THROUGH  $\frac{1}{1}$  OF 12 PATIENTS WITH IMMEDIATE DENTURES AND 10 PATIENTS WITH DENTURES FITTED AFTER HEALING OF THE EXTRACTION WOUNDS.

| Weeks since<br>Extractions | AVERAGE CHANGES                  |                                 | RANGE   |         |
|----------------------------|----------------------------------|---------------------------------|---------|---------|
|                            | Immediate<br>denture<br>patients | Ordinary<br>denture<br>patients | Minimum | Maximum |
|                            | mm.                              | mm.                             | mm.     | mm.     |
| 2                          | 0.50                             | 0.75                            | 0.00    | 1.80    |
| 4                          | 0.75                             | 1.20                            | 0.30    | 2.20    |
| 6                          | 1.00                             | 1.65                            | 0.58    | 2.70    |
| 8                          | 1.20                             | 2.00                            | 0.68    | 3.16    |
| 12                         | 1.65                             | 2.35                            | 0.82    | 3.65    |
| 16                         | 1.85                             | 2.70                            | 0.88    | 4.00    |
| 26                         | 2.10                             | 3.00                            | 0.91    | 4.14    |
| 39                         | 2.40                             | 3.00                            | 0.94    | 4.21    |
| 52                         | 2.55                             | 3.10                            | 1.00    | 4.60    |
| 78                         | 2.75                             | 3.10                            | 1.01    | 4.82    |
| 104                        | 3.05                             | 3.30                            | 1.05    | 5.00    |
| 130                        | 3.15                             | 3.35                            | 1.10    | 5.50    |

RANGE & AVERAGE VERTICAL POST-EXTRACTION CHANGES AT LINGUAL GINGIVAL MARGIN  
IN SAGITTAL TRACES THROUGH III.

(A) PATIENTS WITH IMMEDIATE DENTURES n=12 (B) PATIENTS WITH DENTURES FITTED AFTER HEALING n=10.

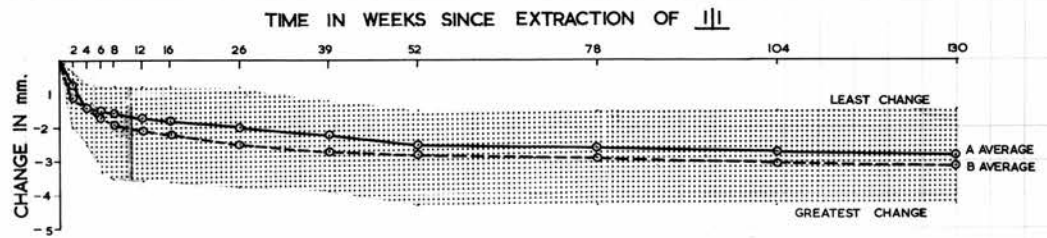


TABLE 31.

RANGE & AVERAGE VERTICAL POST-EXTRACTION CHANGES AT LINGUAL  
GINGIVAL MARGIN IN SAGITTAL TRACES THROUGH 1 / 1 OF 12  
PATIENTS WITH IMMEDIATE DENTURES AND 10 PATIENTS WITH  
DENTURES FITTED AFTER HEALING OF THE EXTRACTION WOUNDS.

| Weeks since<br>Extractions | AVERAGE CHANGES                  |                                 | RANGE   |         |
|----------------------------|----------------------------------|---------------------------------|---------|---------|
|                            | Immediate<br>denture<br>patients | Ordinary<br>denture<br>patients | Minimum | Maximum |
|                            | mm.                              | mm.                             | mm.     | mm.     |
| 2                          | 0.70                             | 1.07                            | 0.30    | 2.00    |
| 4                          | 1.40                             | 1.42                            | 0.74    | 2.50    |
| 6                          | 1.47                             | 1.70                            | 0.77    | 3.30    |
| 8                          | 1.55                             | 1.90                            | 0.80    | 3.50    |
| 12                         | 1.67                             | 2.10                            | 0.80    | 3.55    |
| 16                         | 1.80                             | 2.22                            | 0.80    | 3.60    |
| 26                         | 2.00                             | 2.50                            | 0.80    | 3.75    |
| 39                         | 2.17                             | 2.70                            | 1.20    | 3.90    |
| 52                         | 2.50                             | 2.80                            | 1.50    | 4.30    |
| 78                         | 2.60                             | 2.90                            | 1.50    | 4.30    |
| 104                        | 2.72                             | 3.05                            | 1.50    | 4.30    |
| 130                        | 2.82                             | 3.15                            | 1.50    | 4.30    |

RANGE & AVERAGE BUCCAL POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 3|3.  
 (A) PATIENTS WITH IMMEDIATE DENTURES n=7 (B) PATIENTS WITH DENTURES FITTED AFTER HEALING n=8.

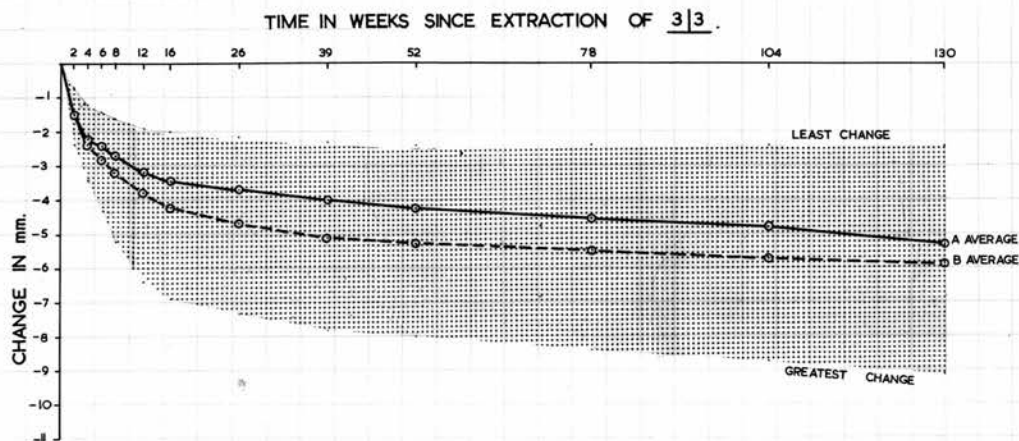


TABLE 32

RANGE & AVERAGE BUCCAL POST-EXTRACTION CHANGES IN CORONAL TRACES THROUGH 3 / 3 OF 7 PATIENTS WITH IMMEDIATE DENTURES AND 8 PATIENTS WITH DENTURES FITTED AFTER HEALING OF THE EXTRACTION WOUNDS.

| Weeks since Extractions | AVERAGE CHANGES                   |                                  | RANGE          |                |
|-------------------------|-----------------------------------|----------------------------------|----------------|----------------|
|                         | Immediate denture patients<br>mm. | Ordinary denture patients<br>mm. | Minimum<br>mm. | Maximum<br>mm. |
| 2                       | 1.50                              | 1.52                             | 0.70           | 2.35           |
| 4                       | 2.21                              | 2.36                             | 1.20           | 3.40           |
| 6                       | 2.40                              | 2.80                             | 1.40           | 4.30           |
| 8                       | 2.72                              | 3.19                             | 1.60           | 5.20           |
| 12                      | 3.21                              | 3.79                             | 1.90           | 6.40           |
| 16                      | 3.43                              | 4.19                             | 2.00           | 6.88           |
| 26                      | 3.70                              | 4.68                             | 2.15           | 7.35           |
| 39                      | 4.02                              | 5.10                             | 2.30           | 7.82           |
| 52                      | 4.23                              | 5.25                             | 2.40           | 8.02           |
| 78                      | 4.56                              | 5.48                             | 2.40           | 8.40           |
| 104                     | 4.80                              | 5.69                             | 2.40           | 8.75           |
| 130                     | 5.28                              | 5.90                             | 2.40           | 10.75          |

RANGE & AVERAGE VERTICAL POST-EXTRACTION CHANGES AT LINGUAL GINGIVAL MARGIN  
IN CORONAL TRACES THROUGH 3/3.

(A) PATIENTS WITH IMMEDIATE DENTURES n=7 (B) PATIENTS WITH DENTURES FITTED AFTER HEALING n=8.

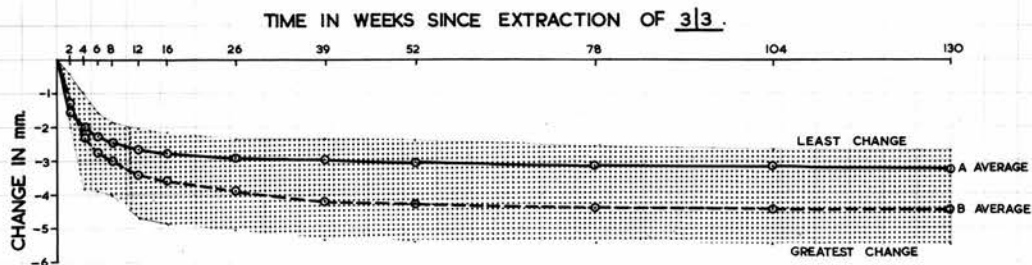


TABLE 33

RANGE & AVERAGE VERTICAL POST-EXTRACTION CHANGES AT LINGUAL  
GINGIVAL MARGIN IN CORONAL TRACES THROUGH 3/3 OF 7  
PATIENTS WITH IMMEDIATE DENTURES AND 8 PATIENTS WITH DENTURES  
FITTED AFTER HEALING OF THE EXTRACTION WOUNDS.

| Weeks since<br>Extractions | AVERAGE CHANGES                  |                                 | RANGE   |         |
|----------------------------|----------------------------------|---------------------------------|---------|---------|
|                            | Immediate<br>denture<br>patients | Ordinary<br>denture<br>patients | Minimum | Maximum |
|                            | mm.                              | mm.                             | mm.     | mm.     |
| 2                          | 1.53                             | 1.32                            | 0.40    | 2.00    |
| 4                          | 2.02                             | 2.36                            | 1.00    | 3.83    |
| 6                          | 2.29                             | 2.73                            | 1.60    | 3.92    |
| 8                          | 2.43                             | 3.02                            | 1.87    | 4.00    |
| 12                         | 2.67                             | 3.41                            | 2.05    | 4.70    |
| 16                         | 2.80                             | 3.61                            | 2.14    | 4.90    |
| 26                         | 2.97                             | 3.92                            | 2.34    | 5.05    |
| 39                         | 3.02                             | 4.20                            | 2.35    | 5.35    |
| 52                         | 3.07                             | 4.30                            | 2.42    | 5.40    |
| 78                         | 3.14                             | 4.39                            | 2.58    | 5.47    |
| 104                        | 3.19                             | 4.46                            | 2.70    | 5.50    |
| 130                        | 3.24                             | 4.52                            | 2.70    | 5.52    |

SUMMARY & CONCLUSIONS.

1. The relevant literature is reviewed.
2. A method of recording and measuring the changes in the surface form of the denture bearing area following extraction of the maxillary teeth is presented.
3. Errors of the measurement were investigated and it is concluded that the method was sufficiently accurate and reliable for the purpose of this investigation.
4. The technique was exacting and time-consuming thus only a relatively small sample of patients were studied. Impressions of the denture bearing area in a selected sample of 25 patients were taken before, and at intervals after the forceps extraction of the teeth over periods of  $2\frac{1}{2}$  years or more.
5. The material comprised 1285 vertical and 50 horizontal section traces of the 206 casts from the sample. It was unsuitable for the investigation of the biological mechanisms which were responsible for the morphological changes and no attempt was made to study them.
6. Spots were tattooed on the buccal and lingual gingivae prior to tooth extraction in 8 of the patients. A decrease in the bucco-lingual distance between the spots was observed in every case  $2\frac{1}{2}$  years after extraction and seemed to indicate that the greatest reduction in mucosal area took place in the areas of the extraction wounds.

7. A change in the position of the incisive papilla relative to the stable area of the palate was observed, following the extraction of maxillary central incisors, in every patient in the sample. It is therefore concluded that this change commonly accompanies the extraction of maxillary central incisors.
8. It is possible that changes in the shape of the incisive papilla also commonly accompany the extraction of maxillary incisors but the changes were assessed only by general observation and no measurements were made.
9. Changes in the position and shape of the rugae were observed but not specifically measured, and together with the change in position of the incisive papilla were chiefly attributed to a general contour change of the palatal mucosa concomitant with the resorptive changes in the alveolar ridge, rather than to movement on the mucosal surface.
10. Reduction in the height and buccal contour of the residual alveolar ridges was observed in every case at the positions of measurement and was greatest in amount at the end of the study. Wide variations were observed in the amounts of change between patients and between measurements in the same mouth and differences of 4 mm. were not uncommon between patients showing the greatest and least buccal and lingual vertical changes. The average buccal change in the sample  $2\frac{1}{2}$  years after the extraction of the teeth, was approximately 3.5 mms. in the median plane, central incisor and premolar

traces and between 4 and 5 mms. in the molar traces. The average lingual vertical changes  $2\frac{1}{2}$  years after extraction in seven of the eight regions traced were roughly between 3 and 4 mms. but in the median plane the average change at the lingual vertical point of measurement was 2.3 mm.

11. No significant difference was found in the average lingual vertical or buccal changes between males and females in the sample.
12. No evidence of progressive enlargement of the residual ridges was found in the sample at any position of measurement during the course of the study.
13. The atrophy of the residual ridges affected the shape of the palate, and its contour in a given plane widened as the atrophy of the ridges progressed. The area of palatal change progressed towards the centre of the palate until only a relatively small median area remained unchanged by the end of the study. On average, this area was roughly bounded by a line drawn on the surface of the palate at a horizontal distance of about 1 centimetre from the lingual gingival margins of the teeth.
14. The rate of change varied considerably between individuals and between points of measurement and was assessed by expressing the average changes in each region at 4, 12, 26 and 52 weeks after extraction as percentages of the average changes observed  $2\frac{1}{2}$  years after extraction.

In very general terms the approximate modal rate of change in the sample was as follows:-

40% by the end of the first post-extraction month.

65% " " " " " third " " "

80% " " " " " sixth " " "

90% " " " " " first " " year.

15. The majority of individual graphs of post-extraction changes showed no appreciable deflection after dentures were fitted but no conclusions could be reached on the effects of dentures on the surface form of the denture bearing area.
16. The average buccal and lingual vertical post-extraction changes, in the central incisor and canine regions, were slightly less in a group of 12 patients with immediate dentures than in a group of 10 patients who had dentures fitted after healing of the extraction wounds, but the difference was not significant.

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