

CHAPTER VII

ANTERIOR MAXILLARY AUGMENTATION USING HYDROXYLAPATITE: RESULTS AND OBSERVATIONS

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RESULTS AND OBSERVATIONS

I think your solution is just, but why think? Why not try to experiment?

John Hunter (1728-1793)

1. PATIENT QUESTIONNAIRE

The patients' responses to the questionnaire (Appendix II) have been expressed as histograms, one for each of the seven parameters (Fig. 32-38) (raw data Appendix VII). The responses have been grouped into three phases for each histogram; those associated with the old denture, those collected in initial response to the new dentures (1-3 months) and those collected subsequently (3-14 months). As explained in Chapter VI, Section 2.1, it was not possible to collect the same total number of replies for each time phase and therefore, to allow comparison, the results have been expressed as percentages of the total in the group. The actual number of responses for each category within the histogram has also been included at the top of each bar as a fraction of the total.

For the purpose of analysing the patients' opinions, the seven parameters can usefully be divided into three groups. The first group of parameters contains the two associated with denture function (the ability to eat and speak) (Fig. 32, 33), the second, the two of comfort and fit (Fig. 34, 35) and the third, the two least likely to be affected by augmentation, namely, taste and appearance (Fig. 36, 37). The seventh parameter of general satisfaction encompasses the previous 6 and all other factors impossible to precisely define and otherwise assess (Fig. 38). It is essentially a measure of whether the patient will be able to lead a life uncompromised by their dentures and without constant support from their prosthodontist.

The preoperative responses in three of the four parameters associated with function and comfort were either poor (ability to eat 73 per cent, comfort 47 per cent, and fit 53 per cent) and to a lesser extent fair (ability to eat 27 per cent, comfort 40 per cent, fit 40 per cent fit). The exception was speech where 46 per cent assessed their previous dentures as providing good (and 40 per cent fair) function during speech. This appears to indicate that the instability associated with hypermobile support tissue causes less effect on the ability to speak than to eat.

A perusal of all seven histograms indicates that every parameter showed an improvement following augmentation, particularly the first two groups where the quality of the denture supporting tissue is most critical.

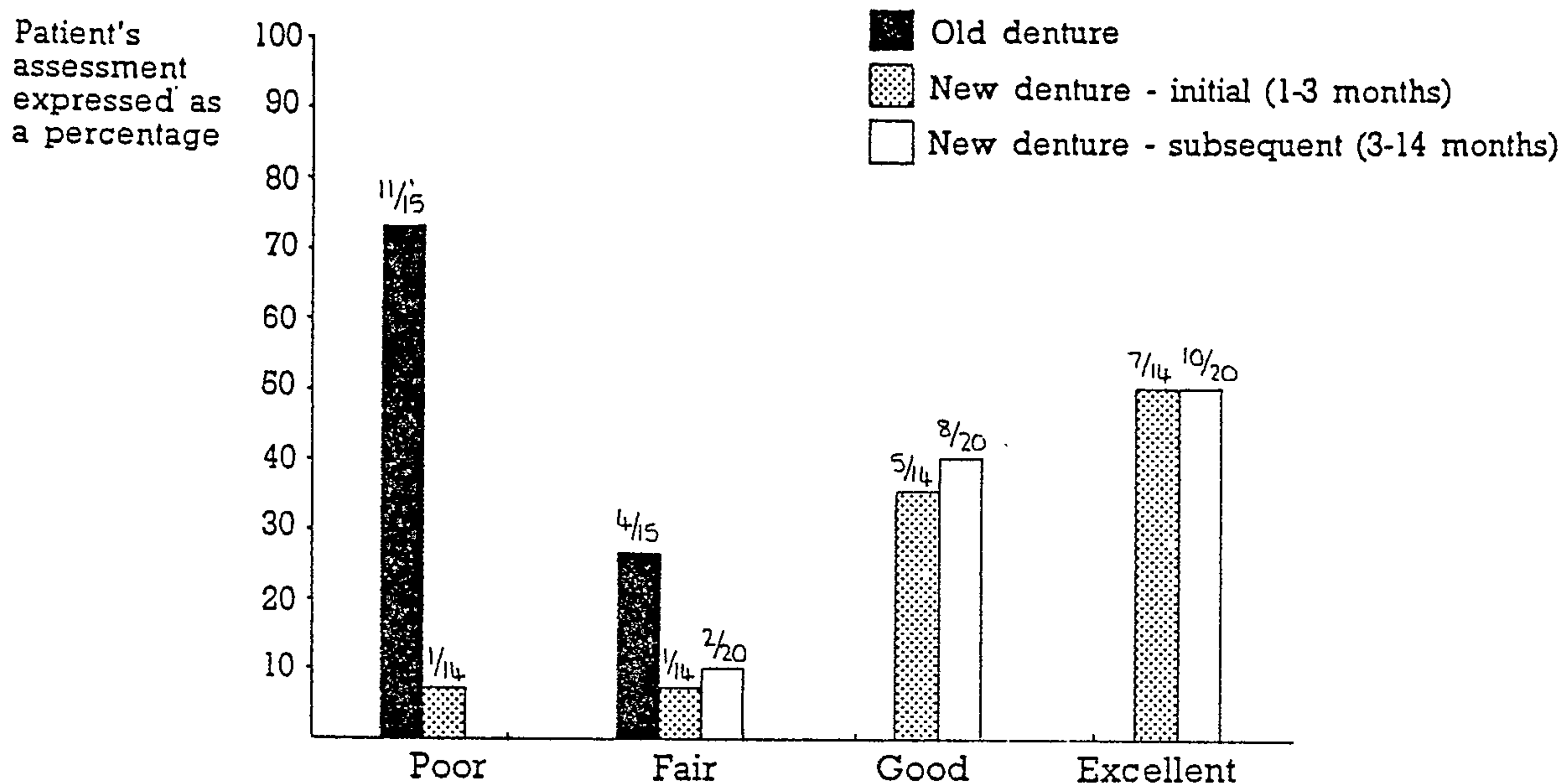
Analysis of the postaugmentation responses in the group associated with function shows a substantial improvement in the ability to eat soon after the provision of new dentures, with improvement sustained over time (Fig. 32). Eighty five per cent in the initial three months, rising to 90 per cent subsequently (three months or longer), assessed their ability to eat as excellent or good compared with zero percent in these categories prior to augmentation. The complaint of patient 1 (Table 18) resolved without treatment once he had become comfortable with an increase in freeway space.

Speech, despite having a high degree of acceptance prior to augmentation, also showed postaugmentation improvement (Fig. 33). Eighty five per cent felt that their speech was either excellent or good following provision of the new dentures compared with 54 per cent for the same categories prior to augmentation. Subsequent assessment showed a maintenance of this improvement (86 per cent). The lisp mentioned by patient 9 (Table 18) resolved quickly without any denture adjustment.

Analysis of the postaugmentation responses in the group associated with comfort and fit shows comparable improvement in both parameters. Eighty six per cent of patients in the initial three months, rising to 100 per cent

FIGURE 32

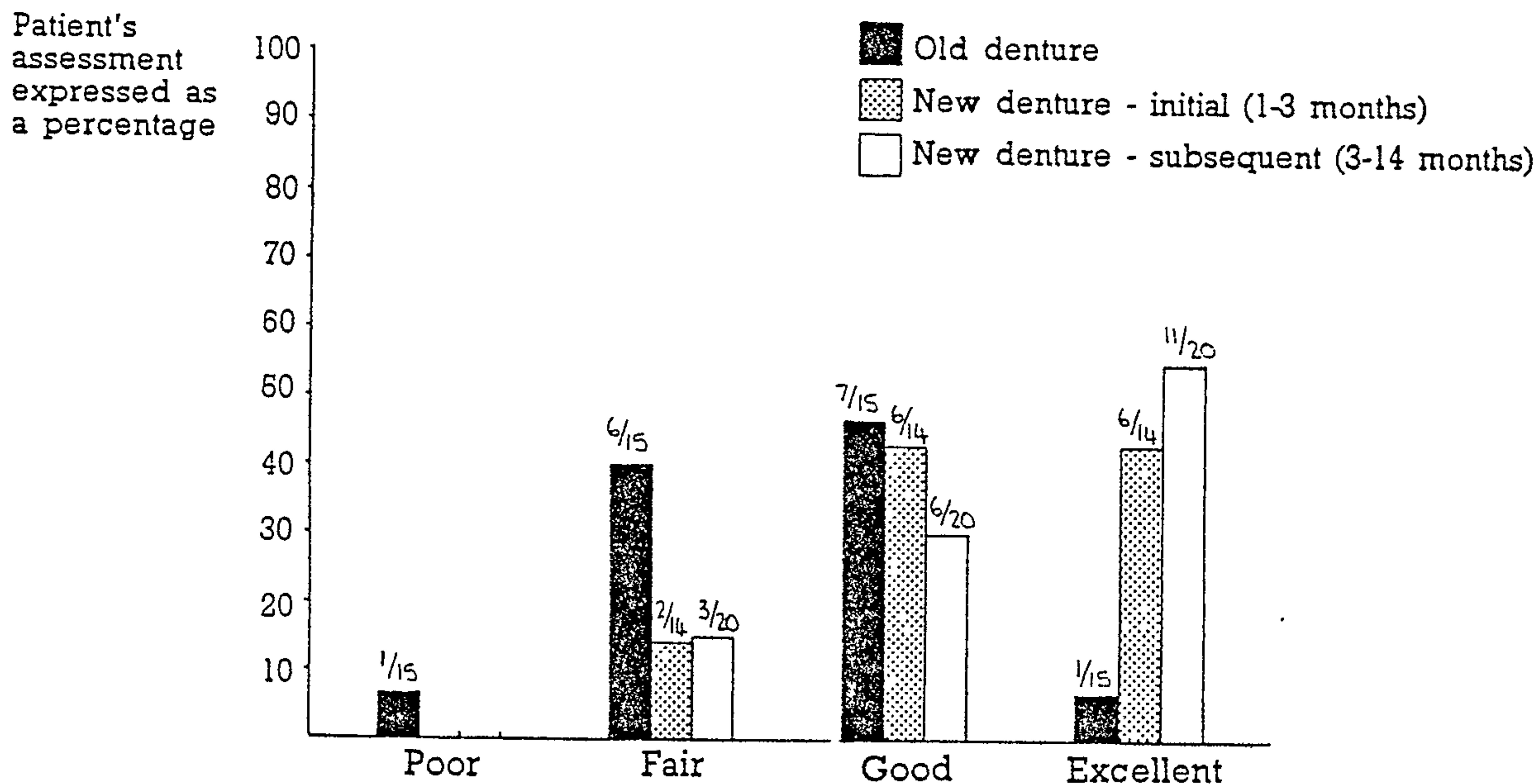
Ability to eat



Histogram of assessments of **ability to eat** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

FIGURE 33

Speech



Histogram of assessments of **speech** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

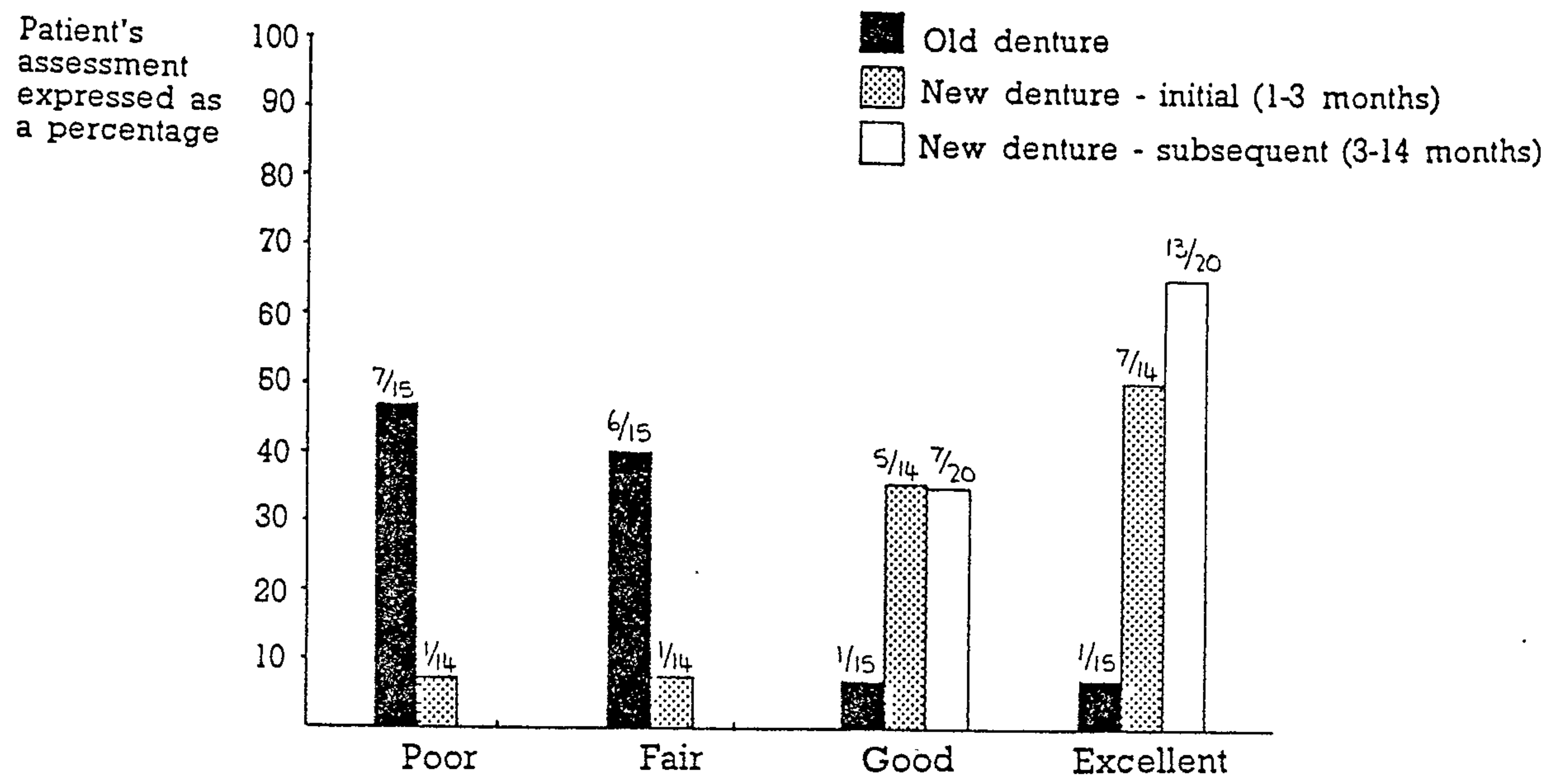
TABLE 18

**PATIENT'S COMMENTS ON THEIR OLD
AND NEW MAXILLARY DENTURES**

Patient		Old Dentures	New Dentures
1	DR	Pressure of eating caused up and down movement back and front	Noise while eating
2	BC	-	-
3	DG	Could not eat with any comfort	Excellent
4	EF	-	-
5	CS	Keeps on breaking	-
6	HT	-	-
7	JD	-	-
8	MW	Could be better	Good
9	JS	-	Not speaking normally - tending to lisp (only initially)
10	EC	-	-
11	JT	-	-
12	CM	-	-
13	LG	Too large	Sometimes pressure on palate
14	JP	-	Excellent
15	VW	-	Oh to have my other teeth

FIGURE 34

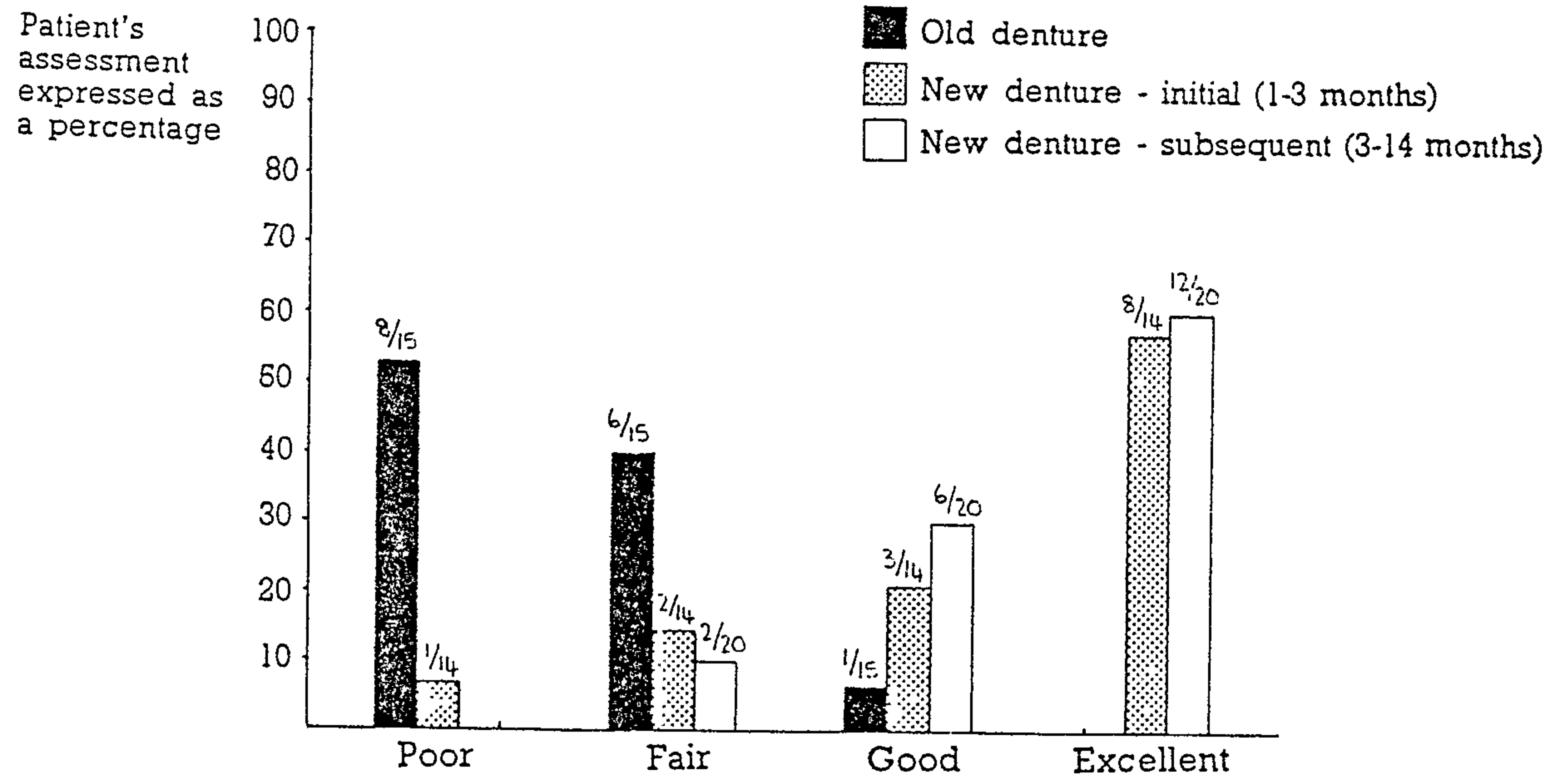
Denture comfort



Histogram of assessments of **denture comfort** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

FIGURE 35

Denture Fit



Histogram of assessments of **denture fit** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

subsequently (three months or longer) rated the comfort of their new dentures as excellent or good (Fig. 34). This was in contrast to only 14 per cent who had rated their previous dentures as either excellent or good.

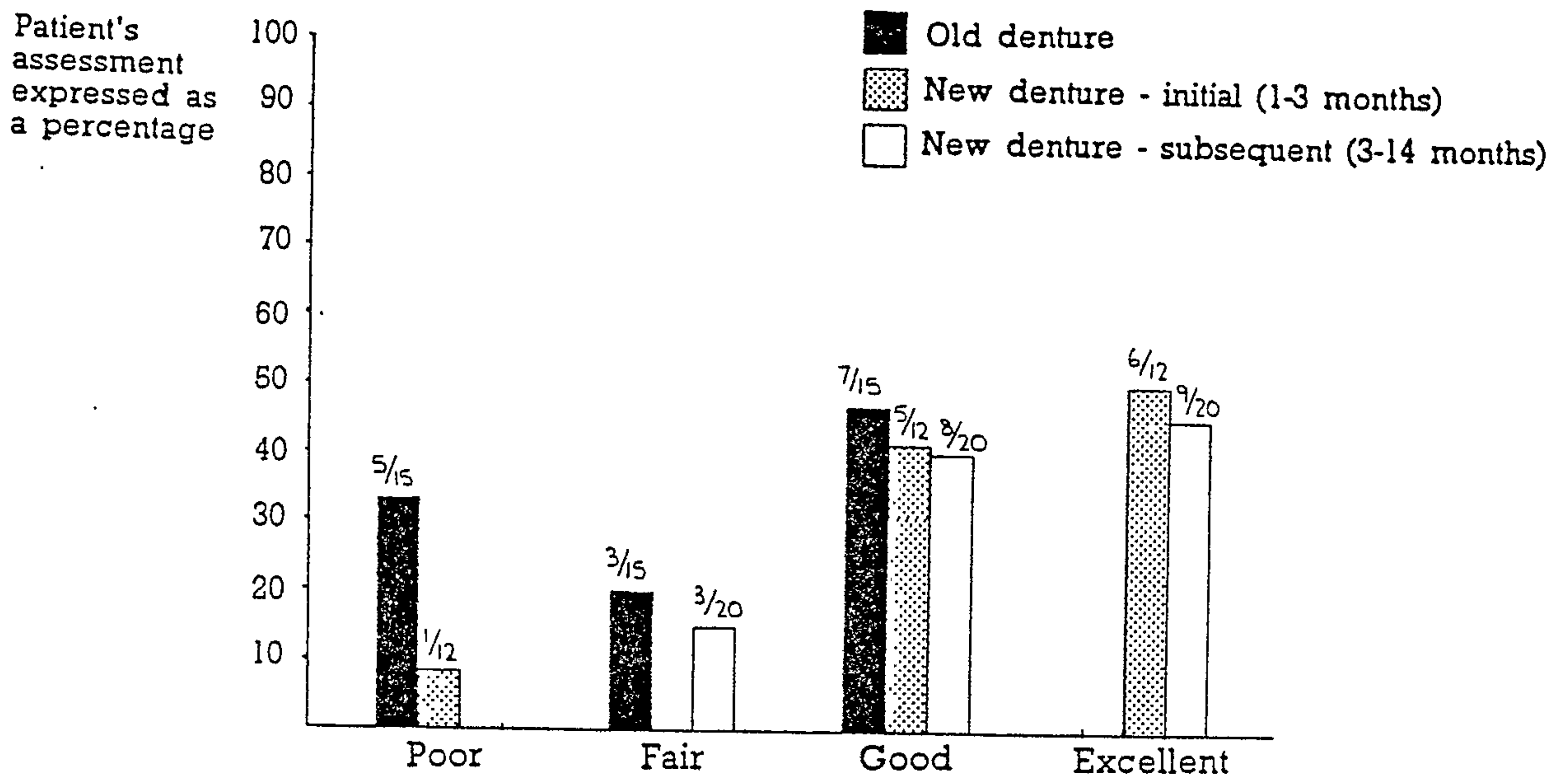
A similar degree of improvement was evident in the parameter of fit (Fig. 35). Seventy eight per cent of patients initially, rising to 90 per cent subsequently, rated the fit of their new dentures as excellent or good; in contrast to only 7 per cent who rated their previous dentures excellent or good. Ten per cent, however, still graded the fit of their new dentures in the longterm (three months or longer) as only fair, showing that the concepts of fit and comfort are distinguishable and separable to denture wearers and that in this survey a higher degree of comfort rather than fit was achieved.

Appearance and taste have only an indirect link to the quality of the denture-bearing tissues. A decrease in ridge mobility and a small increase in ridge size with augmentation should not greatly affect the appearance of a denture. Neither was appearance an important factor in the patients seeking new dentures, 47 per cent assessed their previous dentures as being of good appearance, although a further 33 per cent rated the appearance as poor. The fact that the new dentures improved the patients' perception of their appearance can be seen as a comment on the skill of the prosthodontists constructing the dentures. Initially 92 per cent of patients assessed the appearance of the new dentures as excellent or good, the percentage dropping back to 85 on longer term reflection (Fig. 36). However, at least one patient was initially unhappy enough to assess the appearance of the new dentures as poor.

Taste is a subjective sense that is difficult to quantify. Many medical conditions, medications and habits affect the perception of taste and the wearing of full dentures is known to dull taste sensation. With their previous dentures 60 per cent of the patients rated taste as good, 27 per cent fair and 13 per cent as poor (Fig. 37). It might be expected that this distribution would not be affected by the provision of new dentures. However, this was

FIGURE 36

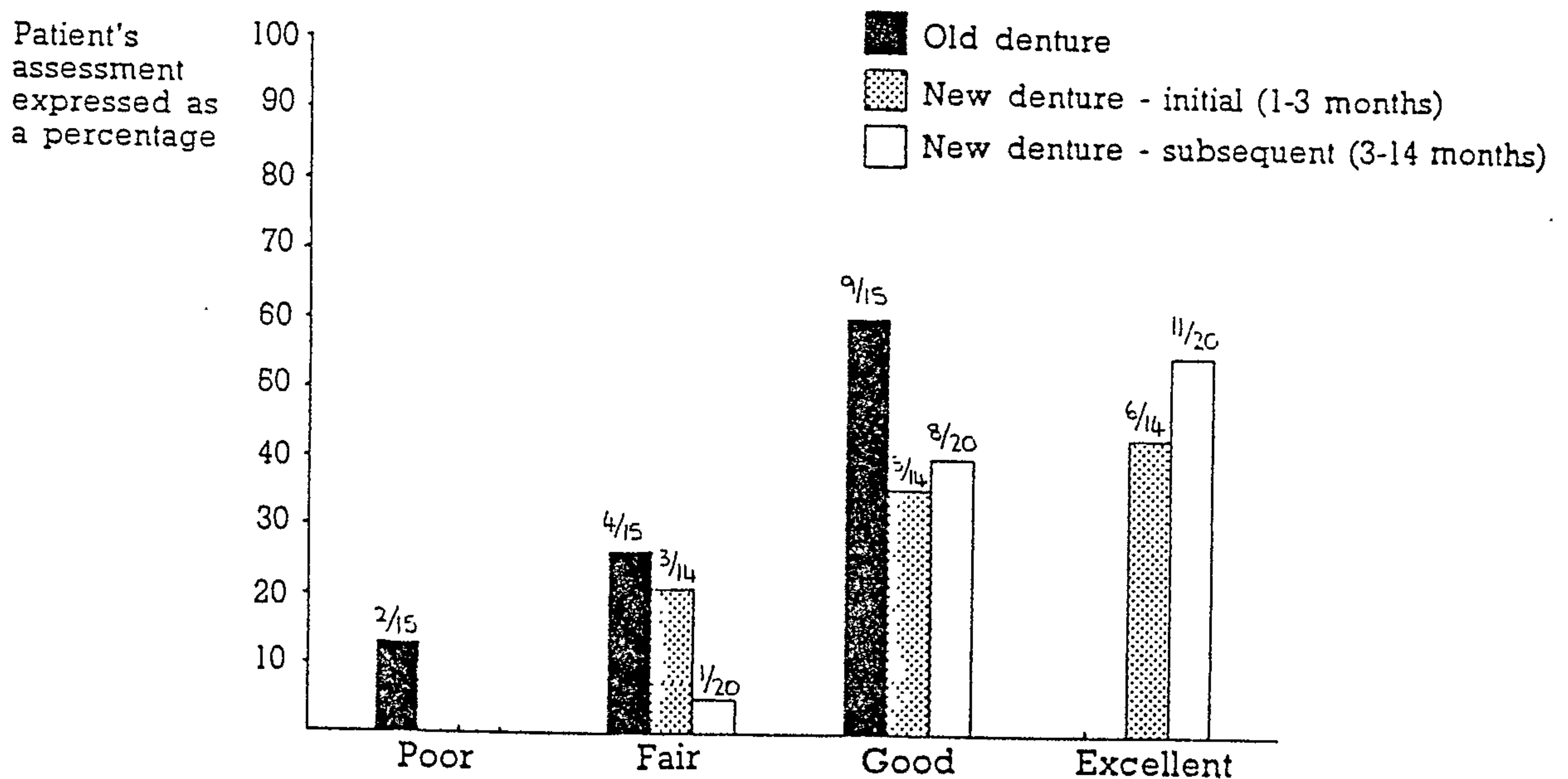
Appearance



Histogram of assessments of **appearance** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

FIGURE 37

Ability to taste



Histogram of assessments of **ability to taste** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

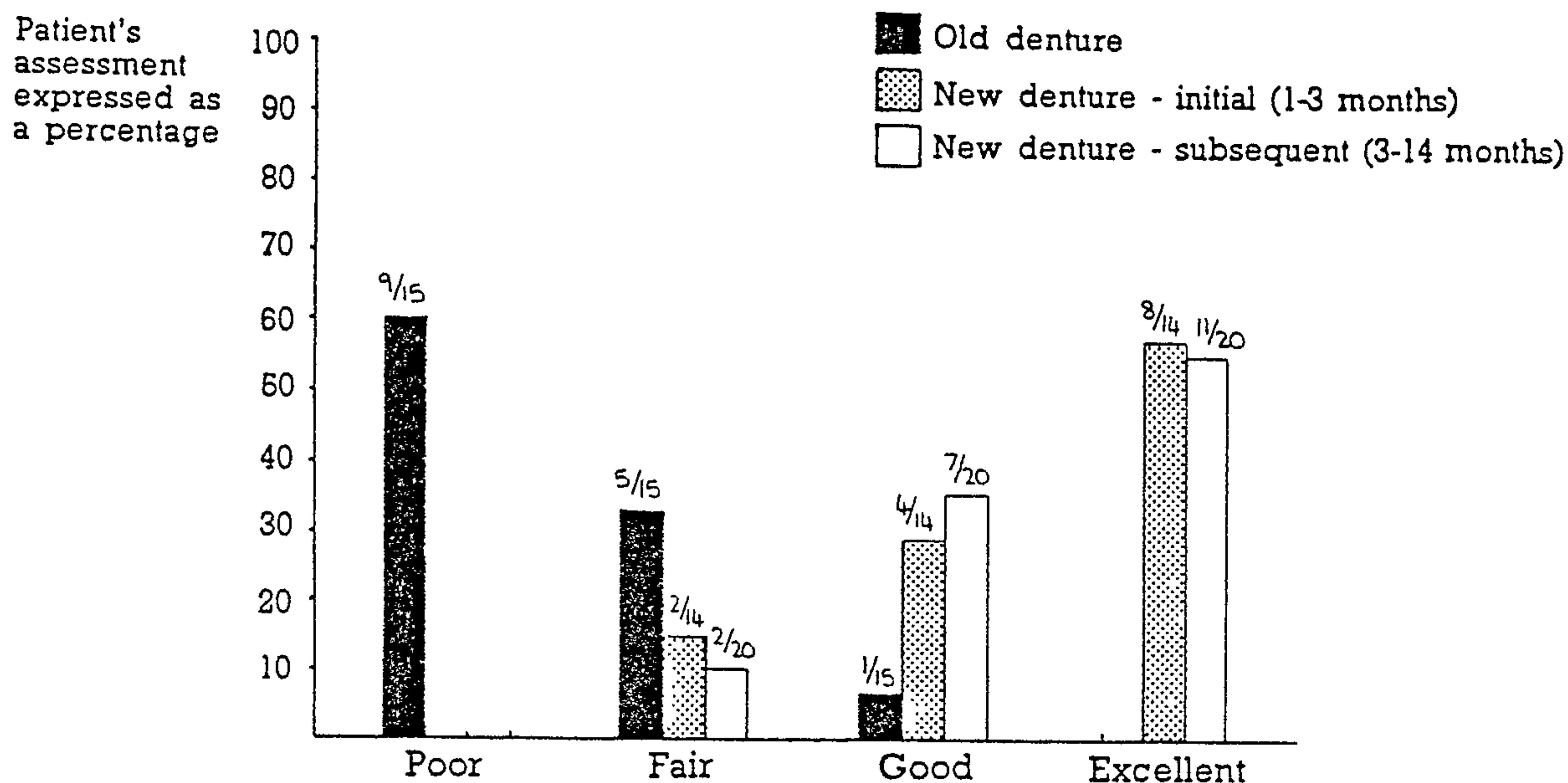
not the case, with an initial increase to 79 per cent of an excellent or good rating for taste rising to 95 per cent subsequently. This result could be interpreted either as indicating a general optimism about the dentures or possibly explained by the patients' euphoria in being provided with new, well-fitting dentures.

Dissatisfaction with one or more aspects of their previous dentures stimulated the patients to seek help initially. Sixty per cent graded general satisfaction with their previous dentures as poor and 33 per cent as fair. Following augmentation and the provision of new dentures the level of general satisfaction rose in a similar way to the six other parameters already discussed. Initial assessment showed 86 per cent of patients rated their general satisfaction as excellent or good, a figure that later rose to 90 per cent (Fig. 38).

From the results presented it is evident that patients perceived an improvement in all assessed aspects of their new dentures. It cannot be claimed that this improvement was entirely the result of H_A augmentation and some (or even all) could be attributed to the skill of the prosthodontists. Nevertheless the general response of the patients (with a single exception - Table 18) was that they had benefited from the care received and were satisfied with the results of the augmentation procedure.

FIGURE 38

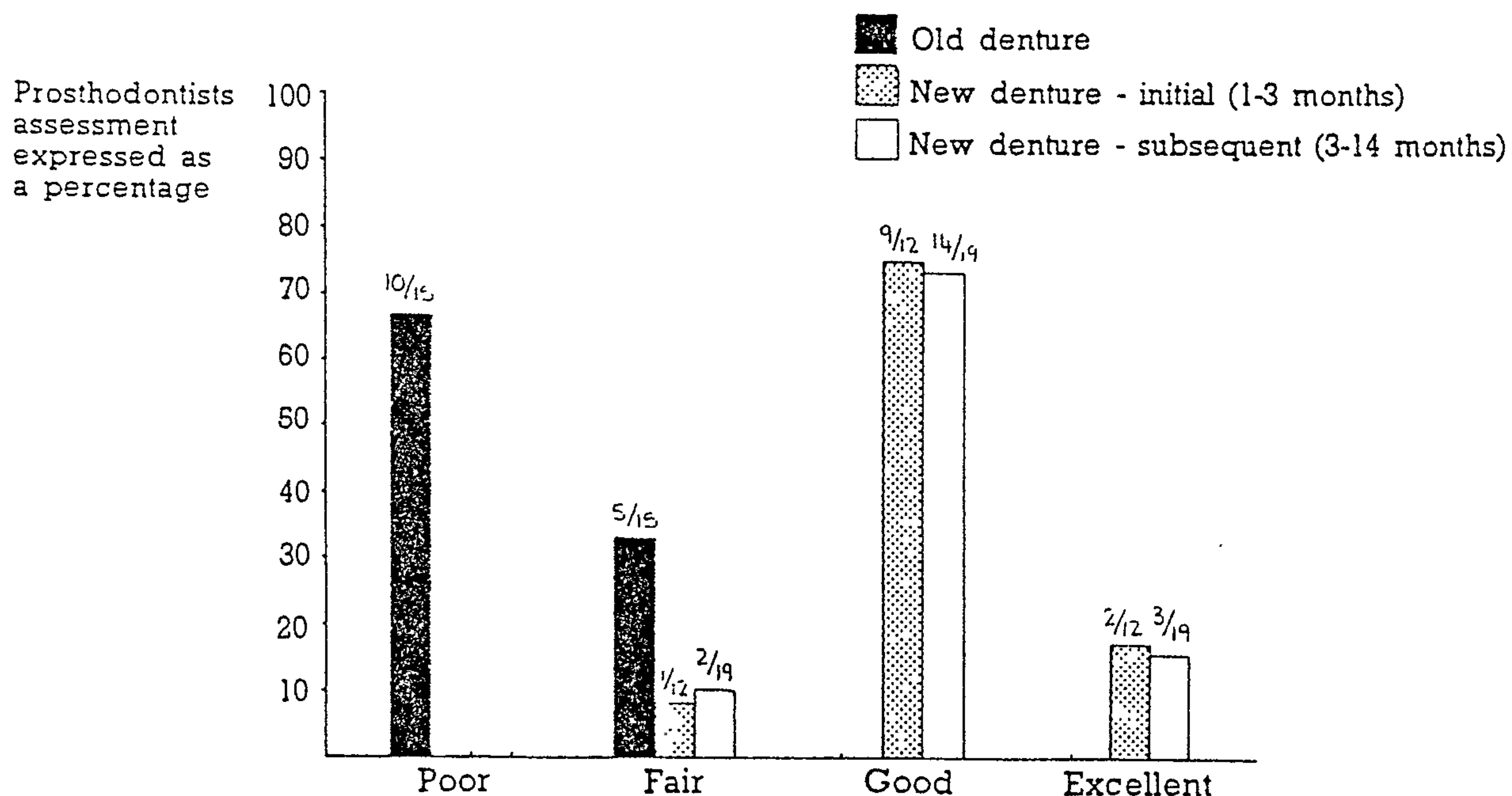
General Satisfaction



Histogram of assessments of **general satisfaction** related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

FIGURE 39

Prosthodontic assessment



Histogram of **prosthodontic clinical assessments** of dentures related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

2. PROSTHODONTIC QUESTIONNAIRE

The prosthodontic assessments were completed at the preoperative visit and most recall visits subsequent to the provision of new dentures (Questionnaire - Appendix III). The results have been presented as four histograms in a manner similar to the results from the patient responses (Fig. 39-42) (raw data Appendix VIII).

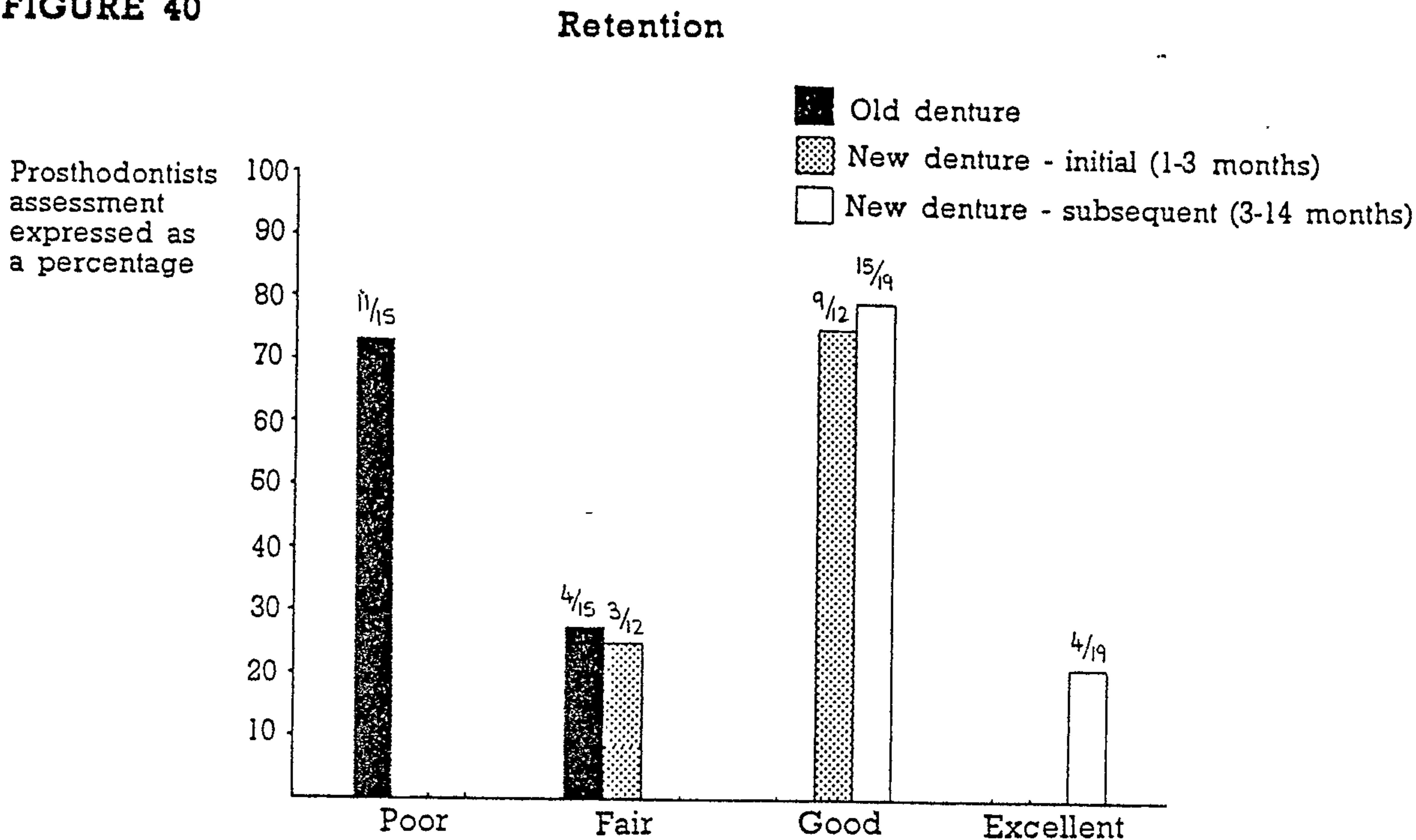
The preoperative clinical assessment (Fig. 39) demonstrates the unsatisfactory nature of the old dentures with the prosthodontists judging 67 per cent as poor and the remaining 33 per cent as fair. This overall preoperative assessment is similar to the preoperative assessments of the specific parameters denture retention and denture stability (Tables 40 and 41). Again the overwhelming number of dentures were rated poor (retention - 73 per cent, stability - 80 per cent) with the balance rating fair (retention - 27 per cent, stability - 20 per cent). Following augmentation improvement was seen in all parameters.

At the initial clinical assessment after provision of new dentures the prosthodontists rated 75 per cent as good and 17 per cent as excellent. Subsequent assessments maintained this gain with 74 per cent being rated good and 16 per cent excellent.

The improvement was as marked for the parameter of retention, but not initially, with 75 per cent of the dentures being assessed as good and the remaining 25 per cent only as fair. However in the subsequent (longer term) assessments the fair rating had dropped to zero and instead 79 per cent were assessed as good and the remaining 21 per cent as excellent, an indication that improvement in retention occurs over time.

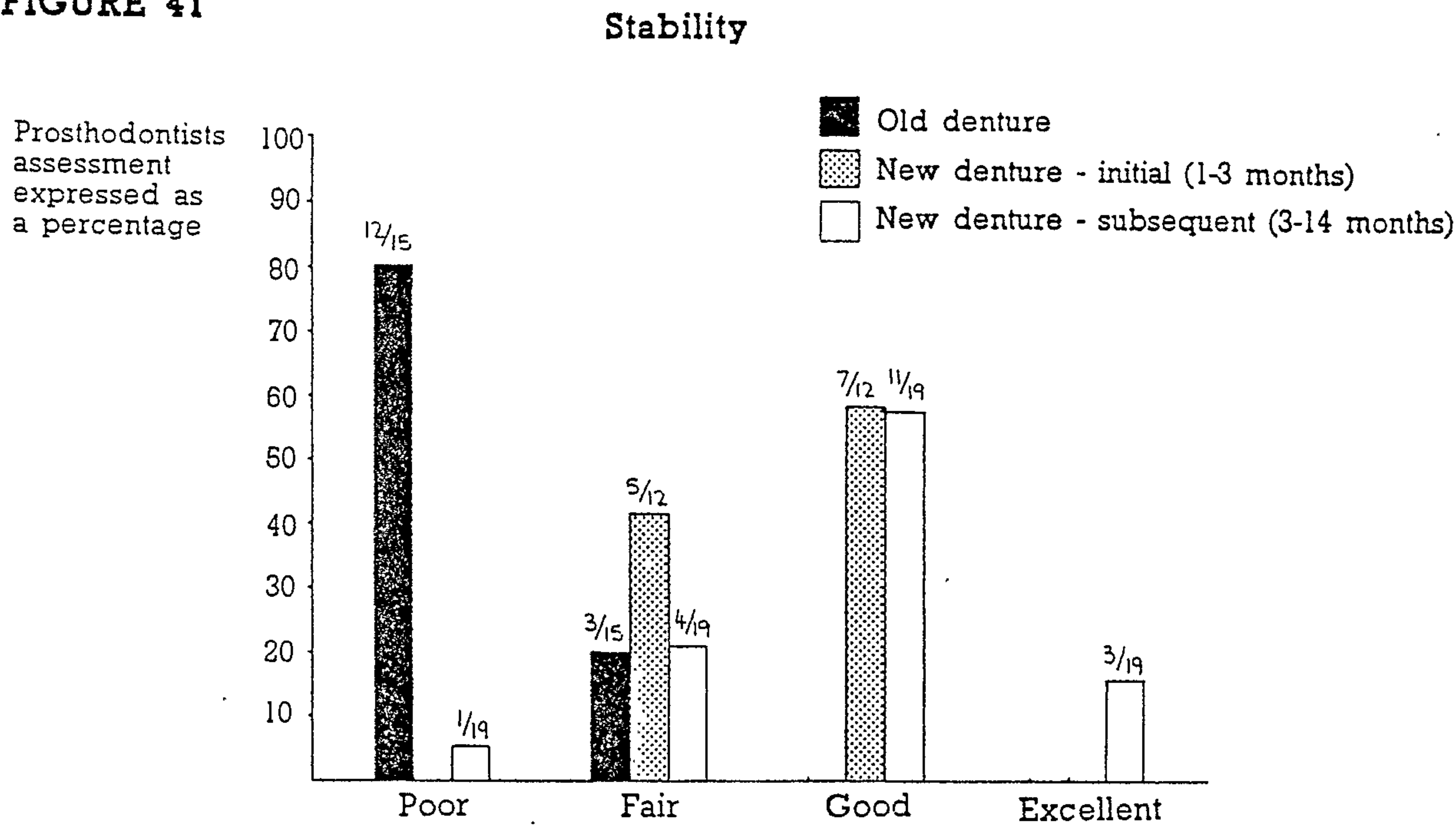
Stability also showed improvement in the postoperative phase but to a lesser degree. At the initial assessment 42 per cent of the dentures were only rated as fair with the remaining 58 per cent as good. Subsequently the stability of 16 per cent improved to excellent but for 5 per cent the stability

FIGURE 40



Histogram of **denture retention** assessments related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

FIGURE 41



Histogram of **denture stability** assessments related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

deteriorated to poor. The majority remained either fair (21 per cent) or good (58 per cent).

The preoperative mucosal health assessed by the prosthodontist ranged from poor (20 per cent) to good (27 per cent) with the majority rated as fair (53 per cent) (Fig. 42). As detailed in Table 10 four patients received medication for a candidal infection prior to surgery.

Following surgery there was an improvement in the mucosal health despite the splint being in place for three weeks. Initial assessment found the mucosal health to be predominantly good (67 per cent) with 17 per cent excellent. However 16 per cent continued to be rated either poor or fair and on subsequent assessment this rose to 26 per cent with those rated as excellent dropping back to 5 per cent. These changes must reflect the difficulty some patients experience with denture hygiene.

3. SURGICAL EVALUATION

The oral surgery assessment involved two aspects. Firstly, an assessment of the surgical technique and secondly, an assessment of the resulting ridge based on clinical examination and analysis of models, radiographs and photographs.

3.1 Surgical technique and complications

Table 19 details the complications experienced in 3 separate phases; during the operation, immediately postoperatively and subsequent to the initial healing. The complications experienced by each patient are documented and the results summarized in Table 20. Problems particularly associated with the HA granules are summarized separately in Table 21. Each phase will be discussed and mention made of technical changes where appropriate.

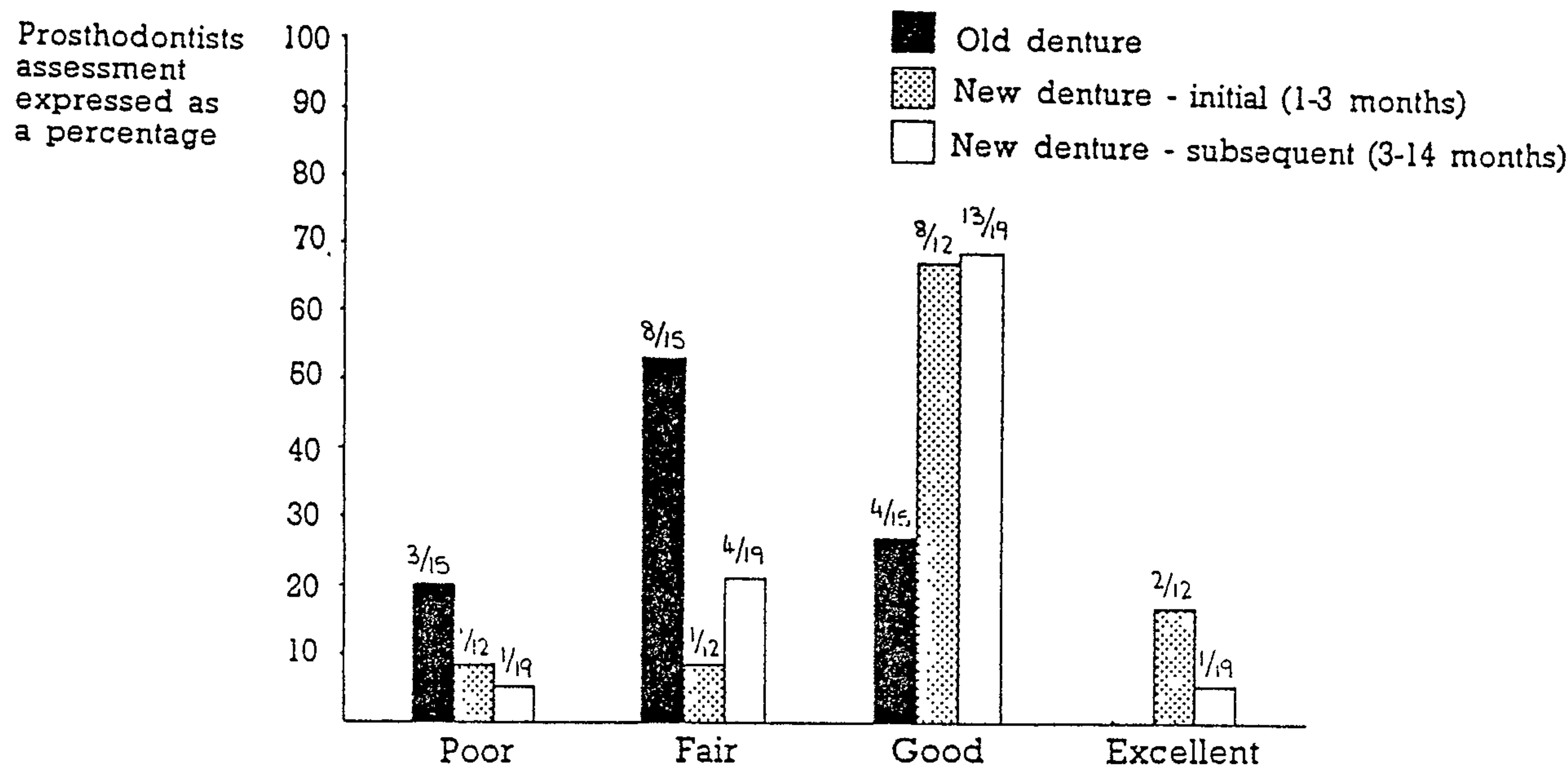
The most common intraoperative complication was inadvertent 'button holing' of the hyperplastic tissue during the reverse incisions. This is a key aspect of the procedure and avoids the hypermobile tissue remaining over the crest of the augmented ridge. The release of the mucosa also allows the augmented ridge to adopt a rounded convex shape. The fenestrations were repaired with synthetic resorbable sutures prior to placement of the HA granules and on no occasion did the wound subsequently dehisce.

Difficulty with remaining close to the irregular ridge crest during subperiosteal tunnelling caused inadvertent displacement of the elevator towards the palatal midline in two cases, however the adaptation and fixation of the splint during the healing period avoided any migration of the granules into the palatal vault.

Two minor intraoperative haemorrhages occurred. One of nasal origin followed over zealous reduction of the anterior nasal spine. The second

FIGURE 42

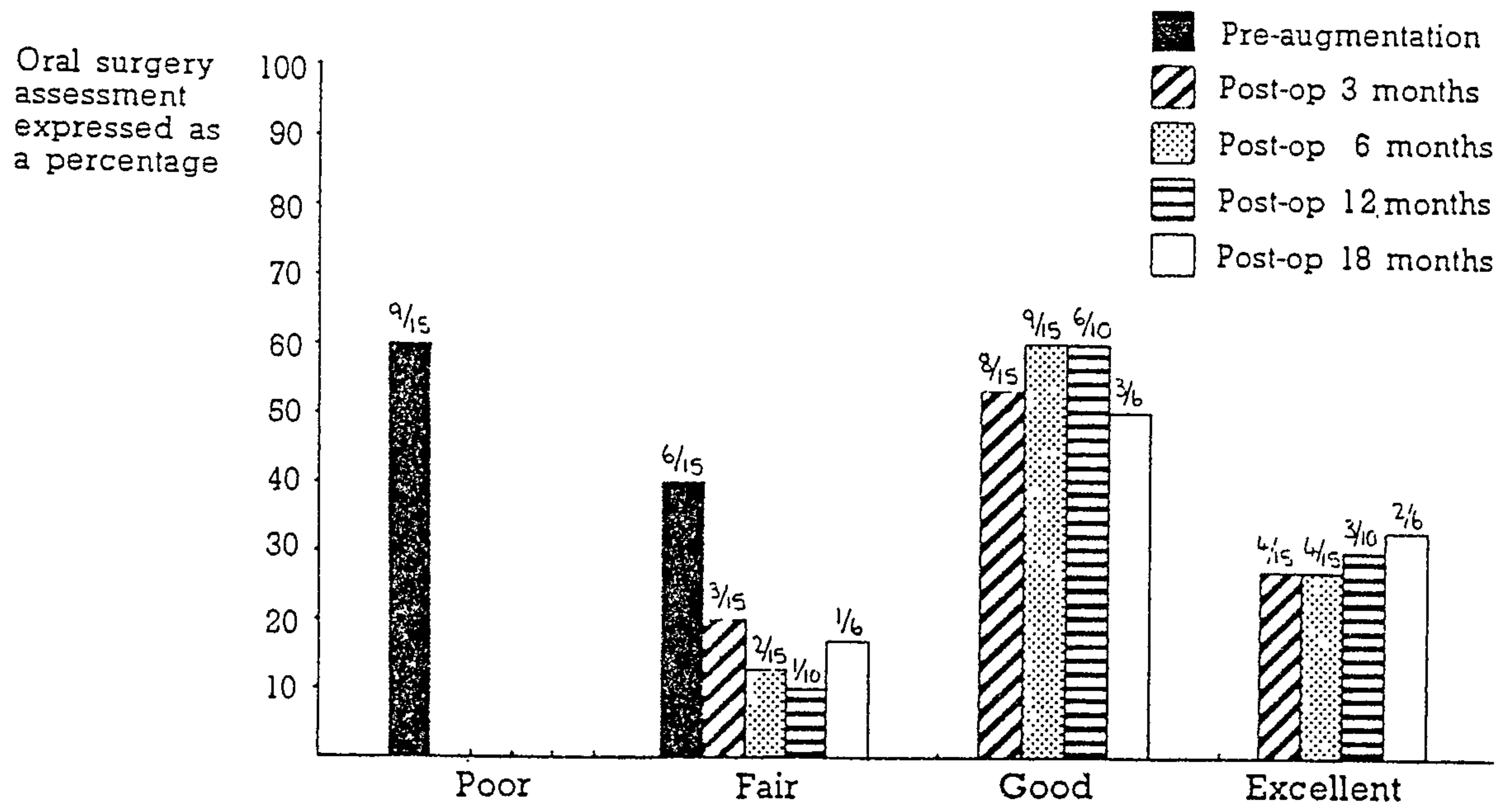
Mucosal health



Histogram of **mucosal health** assessments related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

FIGURE 43

Oral surgery assessment



Histogram of **oral surgery** assessments related to time. The fraction above each bar indicates the number of assessments for each grade over the total number of assessments.

TABLE 19

SUBMUCOUS VESTIBULOPLASTY WITH ANTERIOR MAXILLARY HA AUGMENTATION.
COMPLICATIONS (OTHER THAN SWELLING AND ECCHYMOSIS.)

No.	Initials	Intra operative	1st Month postoperative	Subsequently
1	DR	Nasal Haemorrhage	Ulcer L. tuberosity	ANS tender
2	BC	Ill fitting splint	Candida	Candida
3	DC	-	One screw lost prematurely	ANS tender
4	EF	-	ANS tender	-
5	CS	-	One screw lost prematurely	-
6	HT	-	Ulcer R. sulcus	ANS tender
7	JD	-	Severe pain ANS region	Ulcer L. palate
8	MW	Mucosal tear L. crest	Ulcer R. tuberosity	ANS tender
9	JS	-	ANS tender	ANS tender
10	EC	Greater palatine haemorrhage	Candida	Candida
11	JT	OP1 Button hole R. crest	Both screws lost	ANS tender
12	CH	OP2 Bilateral defects into antra	Splint removed after 6 days	L. crest tender
13	LG	HA fibrosis hindered reverse cutting	ANS tender	Ulcer L. sulcus
14	JP	Buttonhole L. crest	L. crest tender	-
15	VW	-	Ulcer L. sulcus	OP1 ANS tender
		OP2 Mucosal tear R. crest	OP1 Severe pain and swelling	OP2 No tenderness
		Excess R. palatal periosteal stripping	ANS tender	-
		Excess palatal periosteal stripping	Severe pain	ANS tender
			Extensive skin rash (penicillin?)	-
			Midline crest tender	-
			Ulcer R. sulcus	-
			Severe pain & R. epiphoria	ANS tender
			Ulcer R. posterior palate	-

OP1 = 1st operation, OP2 = 2nd operation.

ANS = Anterior nasal spine

TABLE 20

SUMMARY OF INTRA- AND POSTOPERATIVE COMPLICATIONS

Intraoperative			First Month Postoperative	Long Term Postoperative
Mucosal fenestration	4	Ulceration		
Excess periosteal stripping	2	(sulcus/palate)	6	2
Haemorrhage				
- Nasal mucosa	1	Tender ANS	5	8
- Gt palatine vessels	1	Lost screws	3	-
Antral floor defect	1	Severe pain	3	-
Poorly fitting splint	1	Candida infection	3	2
		Tender ridge crest	2	1
		Nasal haemorrhage	1	-
		Medication allergy	1	-

ANS - Anterior nasal spine

TABLE 21

COMPLICATIONS ASSOCIATED WITH THE HA GRANULES

No.	Initials	Granule migration	Incision dehiscence	Mucosal sloughing	Infection	Granule extrusion	Sensation change
1	DR	x	-	-	-	?	-
2	BC	-	-	-	(Candida)	-	-
3	DG	-	-	-	-	-	-
4	EF	-	-	-	-	-	-
5	CS	-	-	-	-	?	-
6	HT	-	-	-	(Candida)	-	-
7	JD	-	-	-	-	-	-
8	MW	-	-	-	-	-	-
9	JS	x	-	-	-	-	-
10	EC	-	-	-	-	-	-
11	JT	-	-	-	-	-	-
12	CH	-	-	-	-	-	-
13	LG	-	-	-	-	-	-
14	JP	-	-	-	(Candida)	-	-
15	VW	-	-	-	-	-	-

Summary of Complications

Granule migration	2	
Incision dehiscence	0	
Mucosal sloughing	0	
Infection (Candida)	3	
Granule extrusion	2	(actual granules not seen)
Sensation change	0	

originated from a greater palatine vessel following the drilling of a surgical bur hole at the base of the tuberosity prior to screw fixation. This complication in conjunction with the poor fixation achieved with bilateral screws prompted a change to the use of a single midline screw.

The bilateral antral floor defects found during the reaugmentation of patient 11 was a discovery with possible serious implications. Patient 11 presented with an extremely mobile maxillary alveolar ridge, one of the two classified as grade IV (Plate 13). An initial augmentation using four syringes of HA granules was performed but despite some improvement the hypermobility was not reduced sufficiently to improve the denture stability. The ridge was therefore re-exposed after six months and a second augmentation undertaken. During this second operation the initial granules and investing fibrous tissue were found to strip easily from the basal bone. However, on developing a tunnel it became apparent that the periosteal elevator had entered the antrum and was stripping the mucosal lining from the floor of the antrum rather than the periosteum from the alveolar bone. This experience was repeated on the contralateral side and as a result the prepared splint was not fixed following augmentation to avoid the possibility of the granules being forced into the antra. This complication did not eventuate and the ridge healed satisfactorily with minimal mobility. The defects were certainly not present at the first operation and it can only be supposed that pressure from the overlying nonresorbable granules could have caused resorption of the remaining basal bone, a possibility demonstrated experimentally by Frame et al in 1987. If proven clinically, such resorption of basal bone as a result of inserting HA granules could have serious implications for the long term prognosis of HA augmented ridges.

The most common immediate postoperative complication was ulceration due to irritation from the flange or post dam of the surgical splint during fixation. This ulceration, which affected six patients, resolved without consequence on removal of the splint and apart from two small ulcers that

developed under new dentures there was no recurrence.

Tenderness in the region of the anterior nasal spine (ANS) was also common, affecting up to eight patients and it tended to persist for many months following regression of other symptoms (Table 19). The removal of the spine was discontinued when it was realised that this unacceptable tenderness persisted and that removal of the ANS did not facilitate an increase in midline sulcus depth. It cannot, however, be confirmed that the removal was the cause of the pain, two other factors may be relevant. Firstly, the midline incision extended into the sulcus over the ANS and the tenderness could have been due to presence of the resolving fibrous repair or secondly, that the migration of granules into the labial sulcus via the submucosa would place them over the ANS and leave the granules covered by only atrophic vestibular mucosa.

In two cases screws became loose, but in only one case was the splint removed prematurely. Two of the three screws were recovered, one was swallowed and lost. The less than rigid fixation achieved using tuberosity screws contributed to screw loss and no screw has been lost from the mid-palate since the change in technique.

Postoperative pain was successfully controlled in the majority of cases using Aspirin or Paracetamol based medication. In the three cases of severe pain the loosening of the fixation screw provided substantial relief.

Surprisingly, there was little *Candida albicans* infection evident on the removal of the splints after three weeks. The patients who did exhibit signs of infection were predominantly the same as those treated prior to surgery and, despite oral hygiene instruction and repeated medication, the infections have proved resistant to long term resolution. In none of the affected patients has there been evidence of any immune deficiency disease that would have predisposed them to this infection.

Tenderness of the ridge crest was reported by two patients but the symptoms were mild and did not preclude denture wearing. In one case the

area of tenderness coincided with the site of a previous 'button hole'.

In one patient a nasal haemorrhage was generated by removal of a palatal screw. A pan-body skin rash was reported by one patient following the prescription of Penicillin. The link was not investigated but the rash resolved on cessation of the tablets.

Complications associated directly with the presence of the HA granules were minimal. The parameters developed by the initial multicentre study (Kent et al, 1982) were used and they are detailed in Table 21. No incision dehiscence, mucosal sloughing or sensation changes were observed or elicited and the evidence for granule extrusion though the mucosa was inconclusive with no granules actually observed in areas of minor ulceration. Neither was there evidence of infection associated with the granules. Granule migration was the only documented complication. It occurred clinically in at least two cases and discrete clumps of granules could be palpated in the midline associated with the location of the incision. A number of the cephalometric radiographs also show a spread of granules superficial to the ANS but this was not evident clinically.

3.2 Surgical assessment

A number of diverse factors were used to assess the surgical outcome of placing HA granules in the hypermobile anterior maxilla. The patients were recalled, if possible, at regular postoperative intervals and after each of these visits an assessment was made from the composite findings; the results are displayed in Fig. 43 (raw data Appendix IX). As the assessments were at regular intervals and started prior to the collection of data from the patients and prosthodontists, the histogram contains four separate time phases; 3 months, 6 months, 12 months and 18 months.

A rating scale of poor, fair, good and excellent, similar to the previous histograms, was used and these overall grades were developed from data

compiled from clinical assessment, radiographs, study models and photographs. Clinically, the ridge shape, size, degree of mobility plus the mucosal health and the presence of any symptoms were used to arrive at a grade.

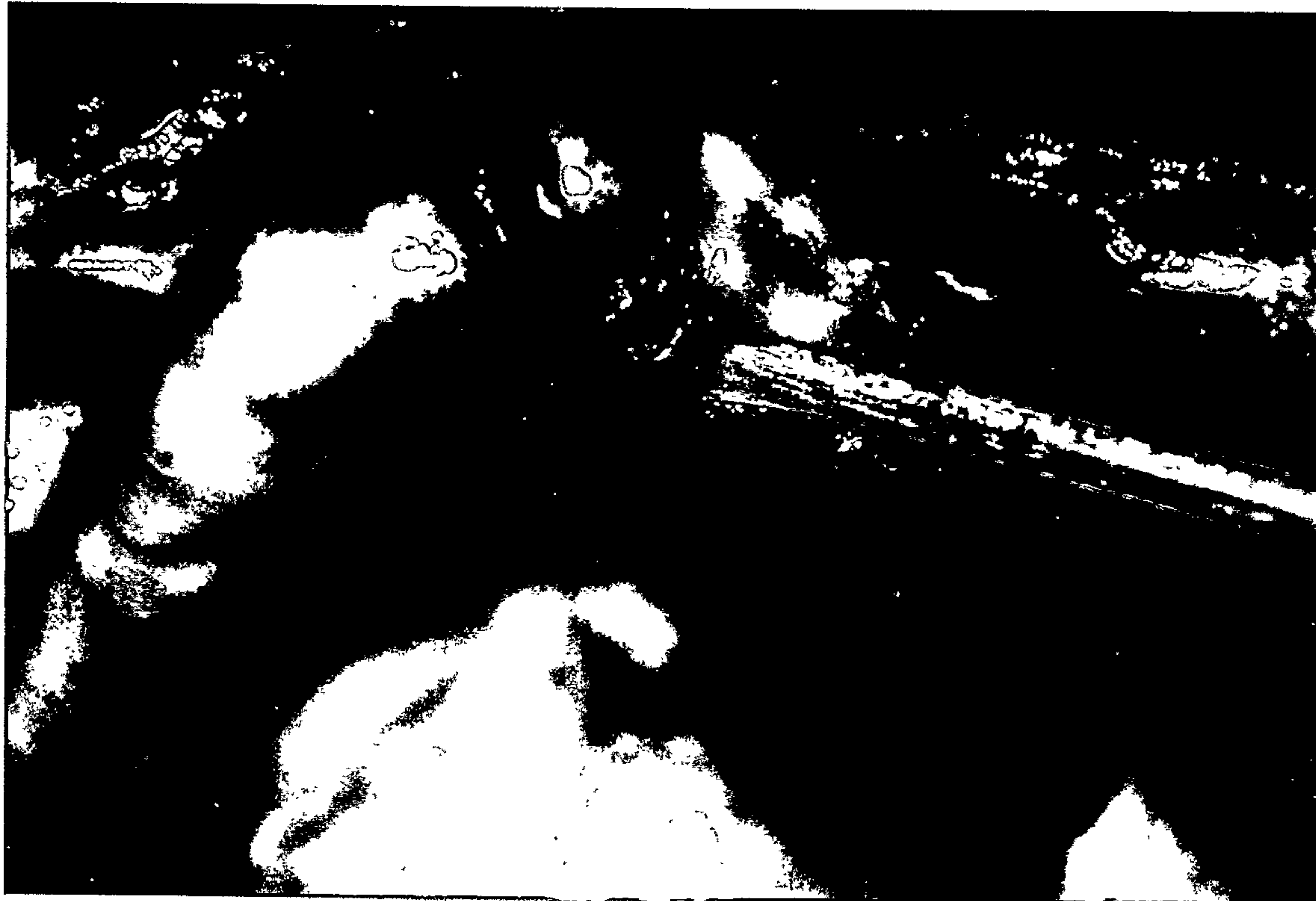
This composite technique of reaching an overall grade allowed the clinical assessment, which relies on a theoretical comparison with an ideal ridge, to be linked to, and complemented by, assessments where pre- and postoperative comparisons are made directly by studying serial radiographs, models and photographs.

As expected, the preoperative assessments were predominantly poor (60 per cent), the remaining 40 per cent being rated fair. Following augmentation a distinct improvement was apparent and this was sustained over the study period.

Postoperatively the majority of ridges were rated good with the figure fluctuating over the 18 months between 50 and 60 per cent. Over the same time interval between 27 and 33 per cent of the ridges were rated as excellent and between 10 and 20 per cent as fair. This distribution, with the postaugmentation ridges being predominantly rated as good or excellent (80 to 90 per cent), reinforces the trends identified in the responses of both patients and prosthodontists.

Plates 32 to 43 show examples of the pre- and postoperative appearances of the ridges with a swab stick providing pressure to the buccal aspect of the alveolus to demonstrate the degree of mobility. The postoperative time and the oral surgical assessment for each ridge is included in the captions.

PLATE 32



Patient 3 (DG). A preoperative view of the anterior maxilla demonstrating Class III mobility.

PLATE 33



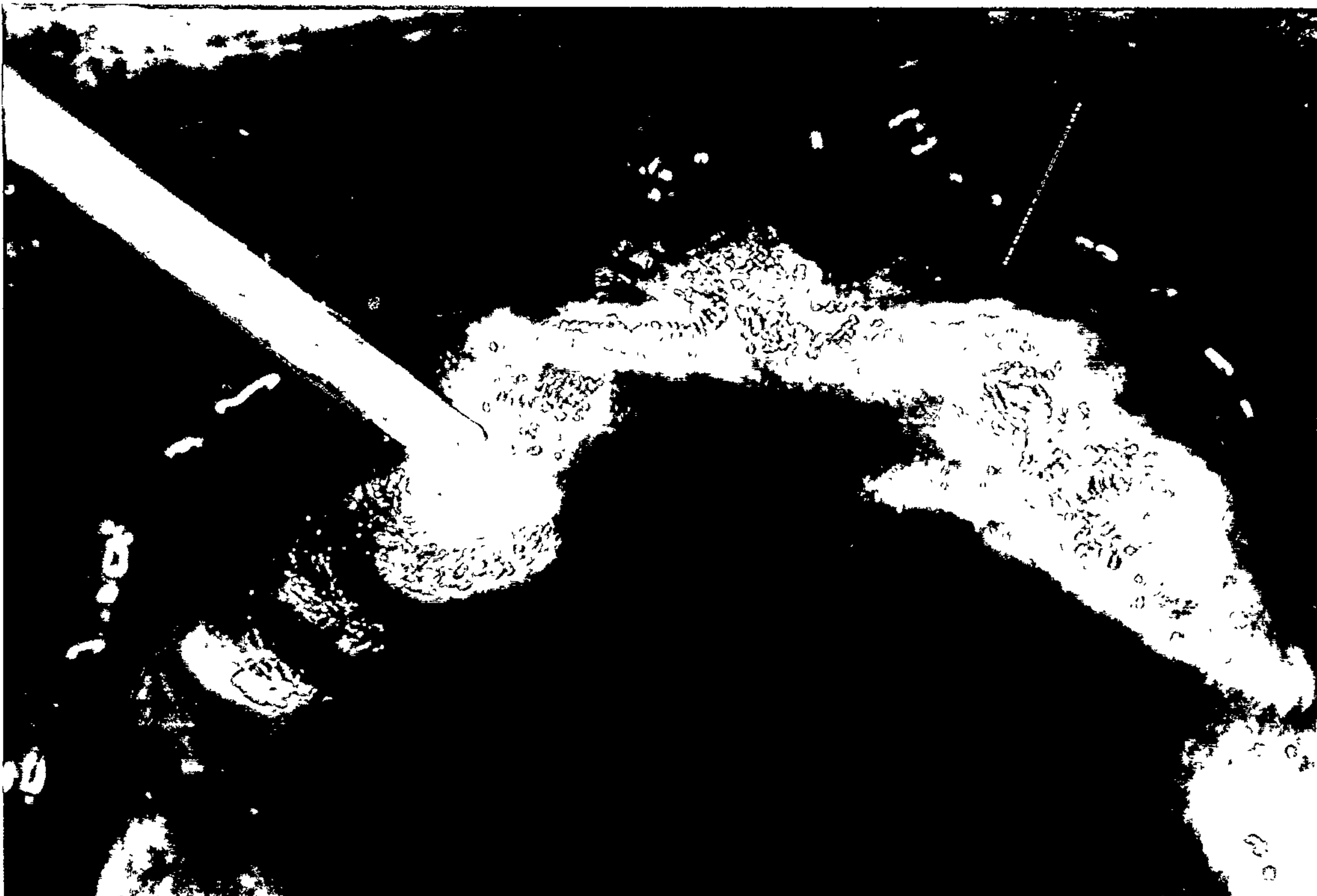
The same ridge six months postaugmentation rated good in the overall oral surgery assessment.

PLATE 34



Patient 5 (CS). A preoperative view of the anterior maxilla demonstrating Class II mobility.

PLATE 35



The same ridge 12 months postaugmentation rated excellent in the overall oral surgery assessment. Note the improvement in the mucosa health and the broadening of the ridge.

PLATE 36



Patient 7 (JD). A preoperative view of the anterior maxilla demonstrating Class III mobility.

PLATE 37



The same ridge six months postaugmentation rated good in the overall oral surgery assessment.

PLATE 38



Patient 9 (JS). A preoperative view of the anterior maxilla demonstrating Class II mobility.

PLATE 39



The same ridge six months postaugmentation rated good in the overall oral surgery assessment.

PLATE 40



Patient 10 (EC). A preoperative view of the anterior maxilla demonstrating Class III mobility.

PLATE 41



The same ridge 12 months postaugmentation rated excellent in the overall oral surgery assessment.

PLATE 42



Patient 12 (CH). A preoperative view of the anterior maxilla demonstrating Class III mobility.

PLATE 43



The same ridge three months postaugmentation rated excellent in the overall oral surgery assessment. Note the increase in ridge width.

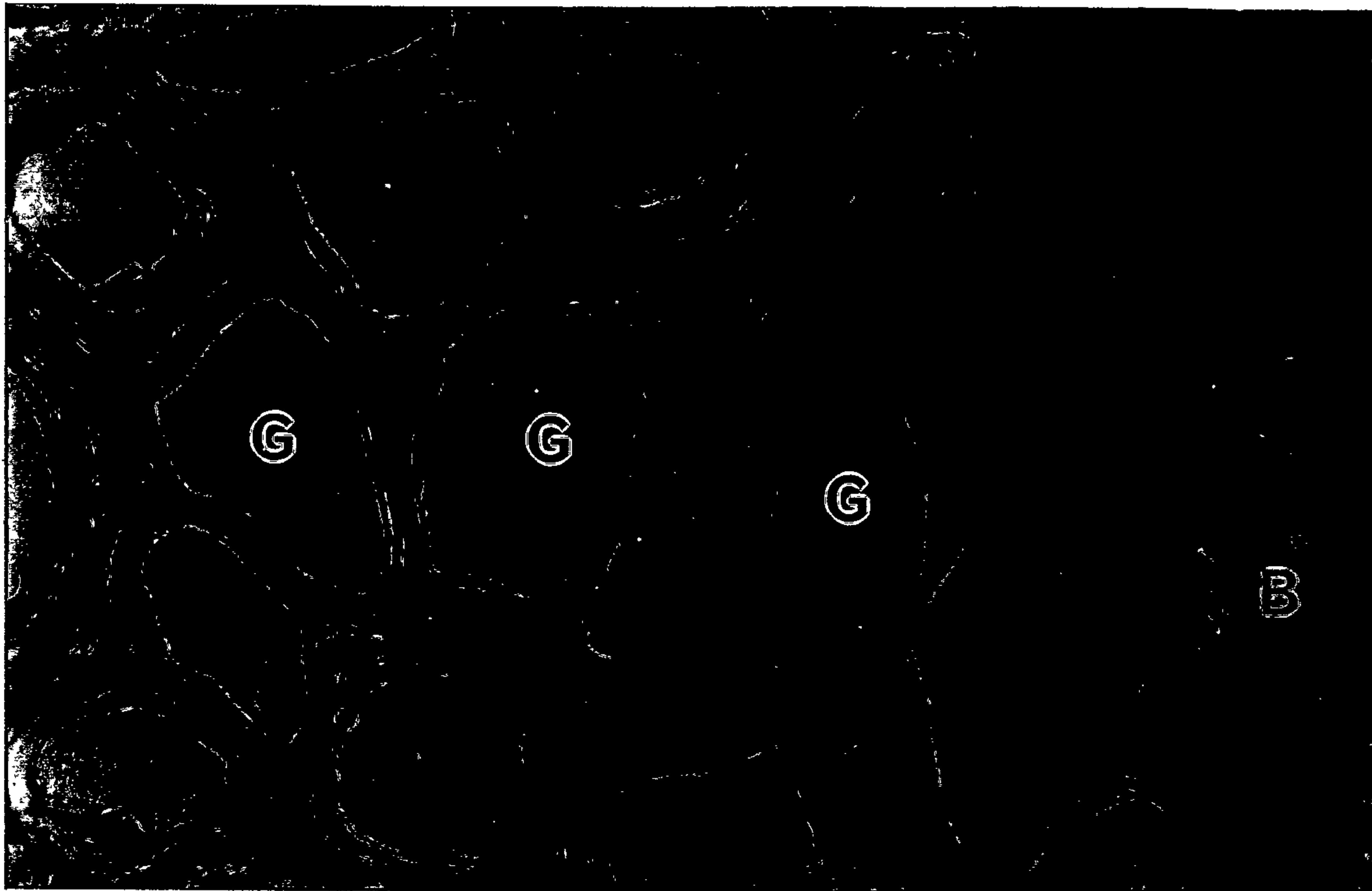
4. HISTOLOGY

Clinical histological tissue was only available from patient 11 following re-exploration of the augmented ridge.

The specimens were fixed in formal saline and submitted to the Department of Anatomical Pathology at the Royal Prince Alfred Hospital (Missenden Road, Camperdown) for preparation. The specimens were slowly decalcified and stained with haematoxylin and eosin. The resulting histological preparations were then examined microscopically and showed 'numerous spaces' (previously occupied by the HA granules prior to decalcification) 'lined by giant cells and histiocytes'. The matrix between the spaces contained 'poorly cellular fibrous tissue with no evidence of inflammation or osteogenesis'. Small spicules of bone were present at the end of one specimen but were separated from the HA granules by intervening fibrous tissue.

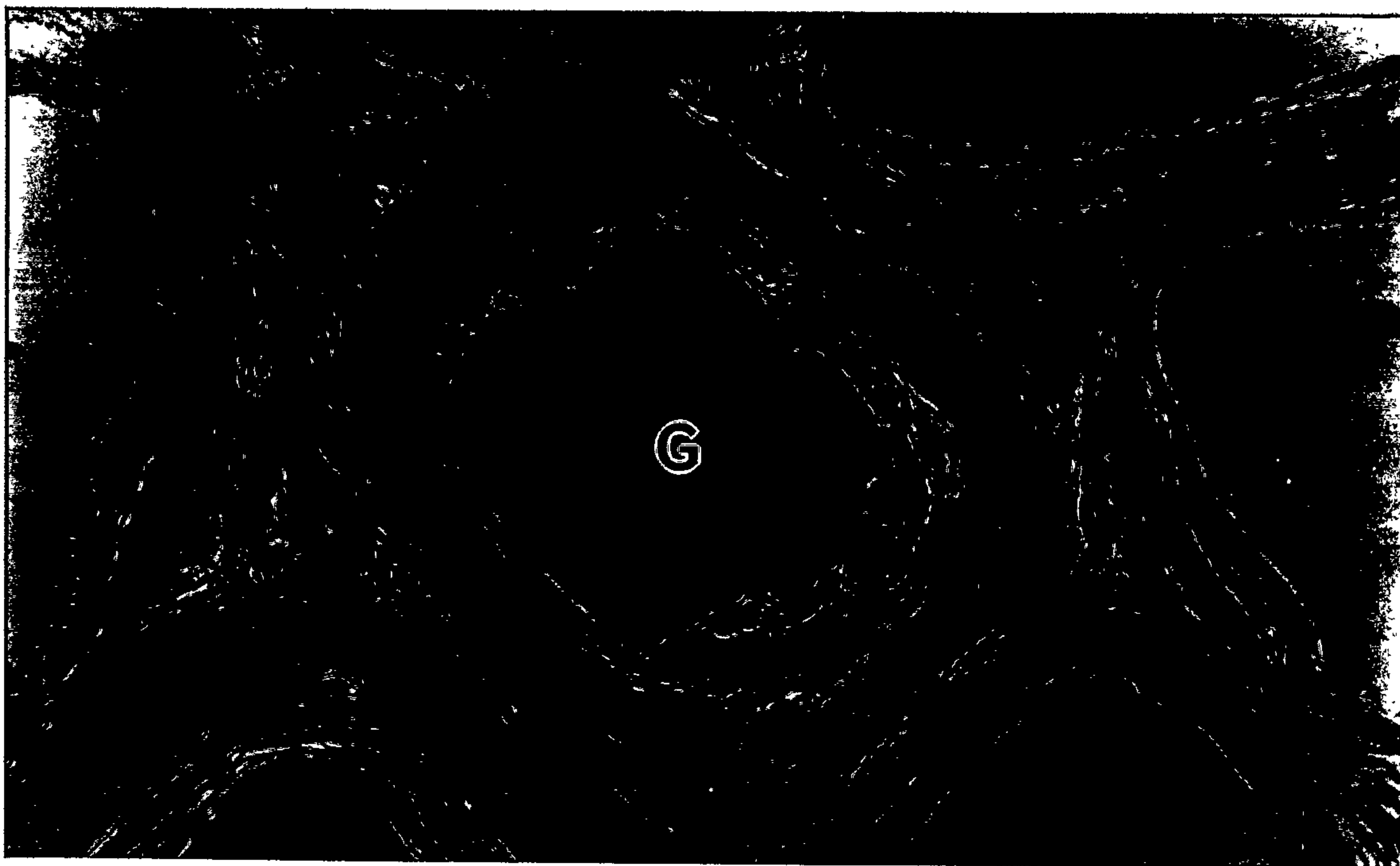
Plates 44 and 45 show representative samples of the specimens including the features mentioned in the report.

PLATE 44



A photomicrograph of the biopsy material from patient 11 showing the HA granules (G) surrounded by 'poorly cellular fibrous tissue' and in close proximity to, but not in contact with, a bone spicule (B). (H + E section x40 orig. mag.).

PLATE 45



A higher power photomicrograph of the same specimen showing an HA granule surrounded by 'giant cells and histiocytes' which in turn are surrounded by fibrous tissue. There is no evidence of an inflammatory response or stimulation of osteogenesis. (H + E section x400 orig. mag.).

5. RADIOGRAPHS

The lateral cephalometric and OPT radiographs were each studied in turn to assess:

Granule retention (migration)

Granule apposition (the space between ridge crest and granules)

Granule radiodensity (bone infiltration)

Height increase.

The parameters of granule apposition and height increase proved impossible to measure with any degree of accuracy. In the mandible the granules are placed on a flat plane parallel to the X-rays. This provides an obvious boundary between the granules superiorly and the underlying bone. The height of the remaining bone can also be measured accurately and therefore any height increase can be measured and calculated directly.

In the maxilla the remaining alveolar bone is often a knife edge in cross-section and the palate is rarely flat. Granules placed in this situation show superimposition of the bone in all of the standard radiographic projections and therefore the HA/bone interface could not be defined and measurement was not attempted.

Superimposition is also one of the factors making the measurement of height increase very inaccurate. The others are the distortion and artifactual shadows created in the anterior region of the OPT and the inability to define the residual ridge height. However, it is evident from study of the clinical appearance (Plates 32-43) and the study model data (section 6) that the benefit of HA augmentation in the anterior maxilla is in stabilising and broadening the ridge rather than achieving an absolute height increase. The measurements taken to assess height have therefore been discarded as being unreliable and inaccurate.

Table 22 records the assessments of Retention and Radiodensity taken from both the lateral cephalometric and OPT radiographs, and graded poor,

TABLE 22

RADIOGRAPHIC MEASUREMENTS

Patient No.	Initials	Granule Retention		Radiodensity					
		LC	OPT	LC	OPT				
1	DR	E	E	P	F				
2	BC	F	G	P	P				
3	DG	F	G	P	P				
4	EF	G	G	P	P				
5	CS	E	E	G	F				
6	HT	E	G	P	P				
7	JD	P	G	P	P				
8	MW	E	E	P	P				
9	JS	P	G	P	P				
10	EC	P	G	P	P				
11	JT	G	G	P	P				
12	CH	P	-	P	P				
13	LG	E	E	P	P				
14	JP	G	G	F	P				
15	VW	F	G	P	P				
Poor		4	(27)	0	(0)	13	(86)	13	(86)
Fair		3	(20)	0	(0)	1	(7)	2	(14)
Good		3	(20)	10	(71)	1	(7)	0	(0)
Excellent		5	(33)	5	(29)	0	(0)	0	(0)

LC - Lateral Cephalometric
OPT - Orthopantomogram

P - Poor
F - Fair
G - Good
E - Excellent

(percentages in brackets)

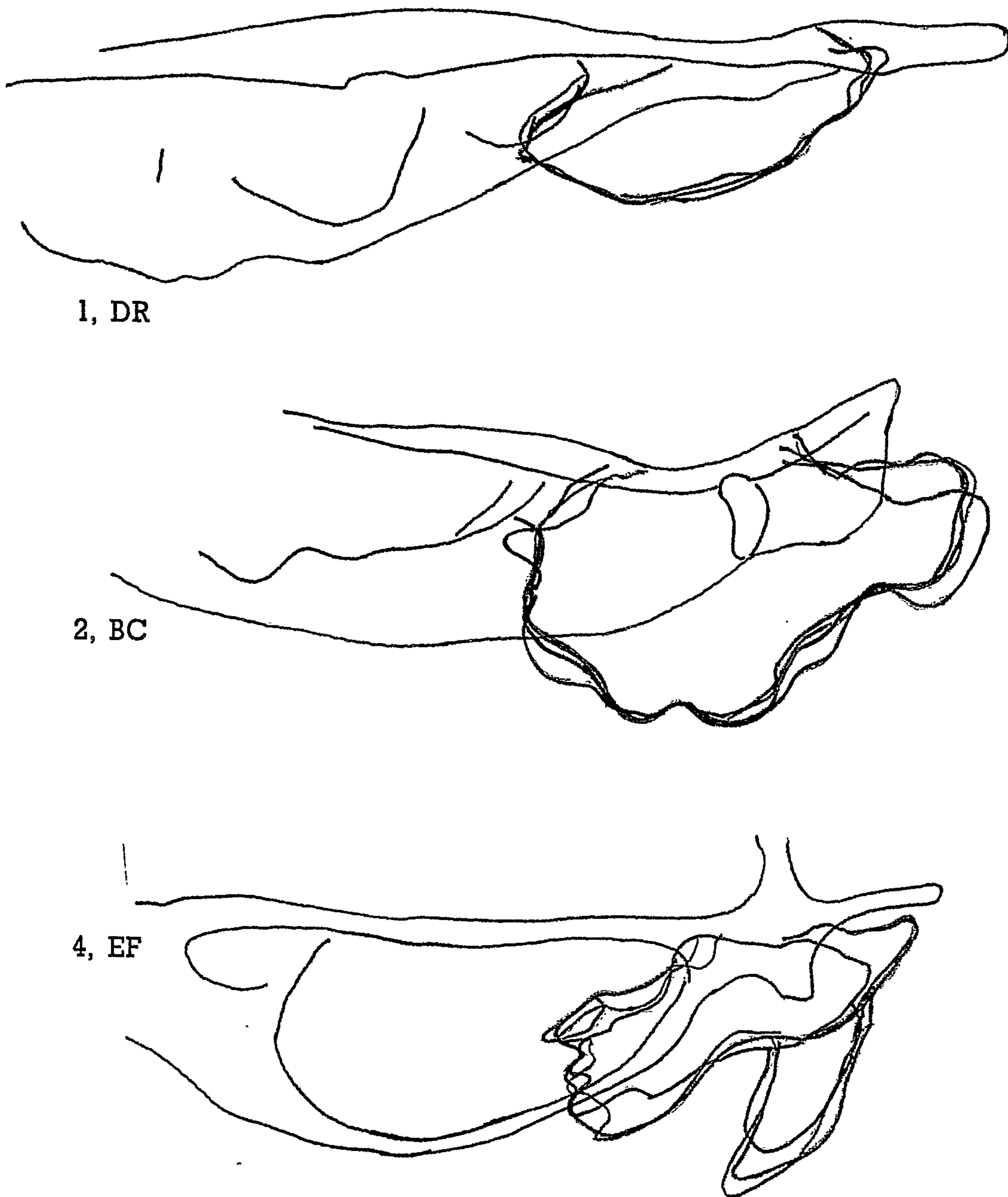
fair, good or excellent.

Retention was seen to be better in the plane of the OPT than in the true lateral projection. This was because the migration of granules under the incision line and along the anterior nasal spine could only be detected in the lateral plane. Four of the cephalometric radiographs exhibited this migration and were graded poor as a result. The remaining cephalometric assessments covered the range from fair to excellent depending on the degree of flattening and spreading of the granules with the elapse of time. These changes can be seen best in the composite tracings taken from the enlarged cephalometric radiographs (Fig. 44-48). In contrast, the OPT radiographs showed little migration of granules either distally or inferiorly. It is also interesting that no granules appeared to enter the antra of patient 11, despite there being defects in the bone of the antral floor. Without pressure from a splint, the antral mucosa appears to have been sufficient to limit migration.

In contrast to the varied but predominantly favourable results of granule retention, the development of increased radiodensity, signifying bone infiltration, was rarely evident in either radiographic projection. The technique employed required comparisons with previous radiographs with allowances being made for the range of exposures, as these had not been standardised. A more accurate, quantifying technique such as computer analysis of density was not employed as there was little visual evidence to show any change and therefore the time and expense was not justified. The visual assessment showed no discernible difference in radiodensity in any patient other than patient 5. It can therefore be inferred that little or no bone growth had taken place, a conclusion in agreement with the histological findings in patient 11.

The second technique utilising the lateral cephalometric radiographs to produce magnified composite tracings was more successful. This technique allowed the changes in position of the granules over time to be recorded

FIGURE 44

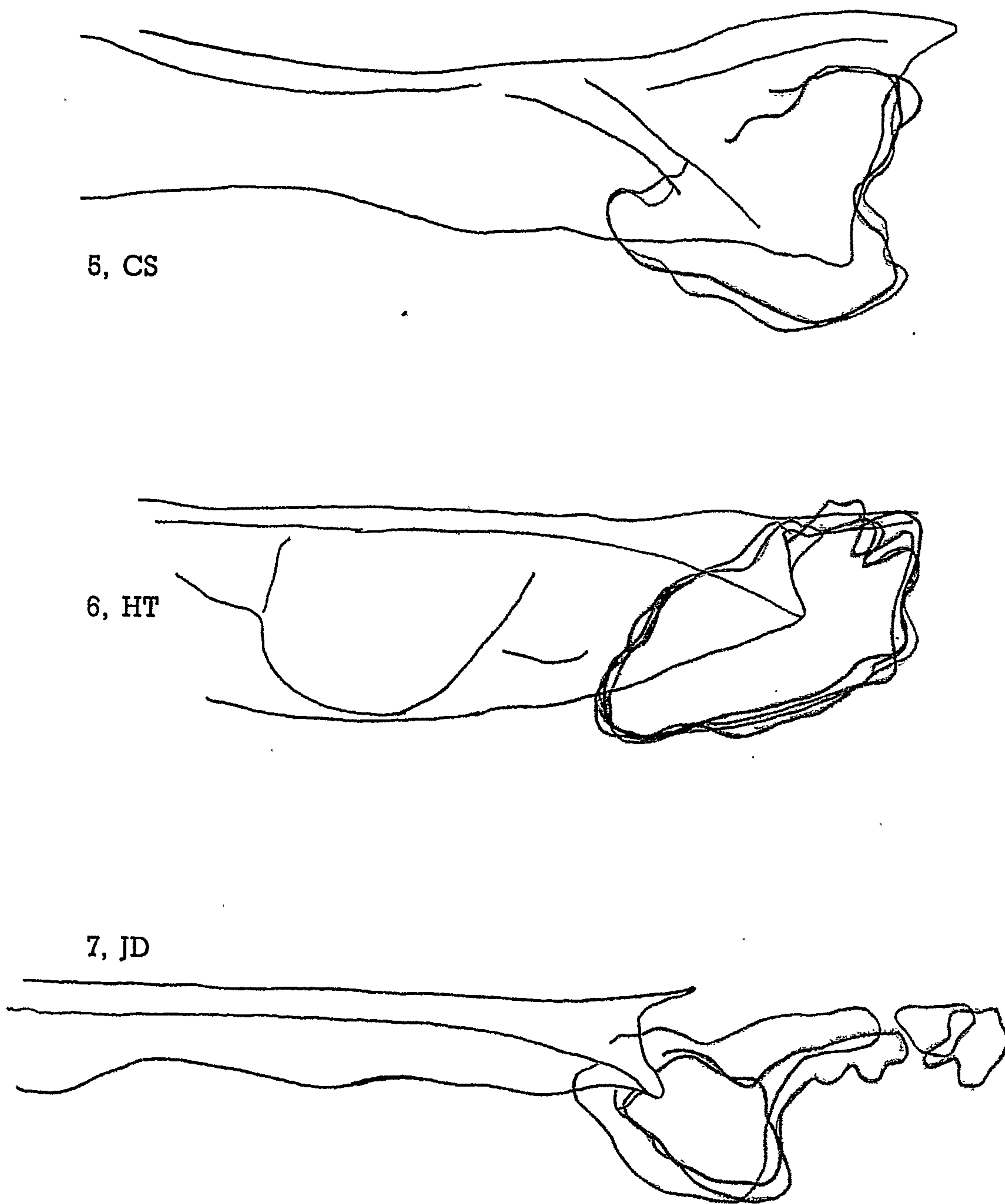


Composite tracings of the magnified images created from the lateral oblique radiographs of patients 1, 2 and 4. The patients number and initials identify each tracing and the time phases are represented by:

preaugmentation	-	black
postaugmentation		
1-4 months	-	brown
6 months	-	red
12 months	-	green
18 months	-	blue

(The confusing image traced for patient 4 (EF) shows the HA granules both to the left and right of the midline as it is not a true lateral of the anterior maxilla.)

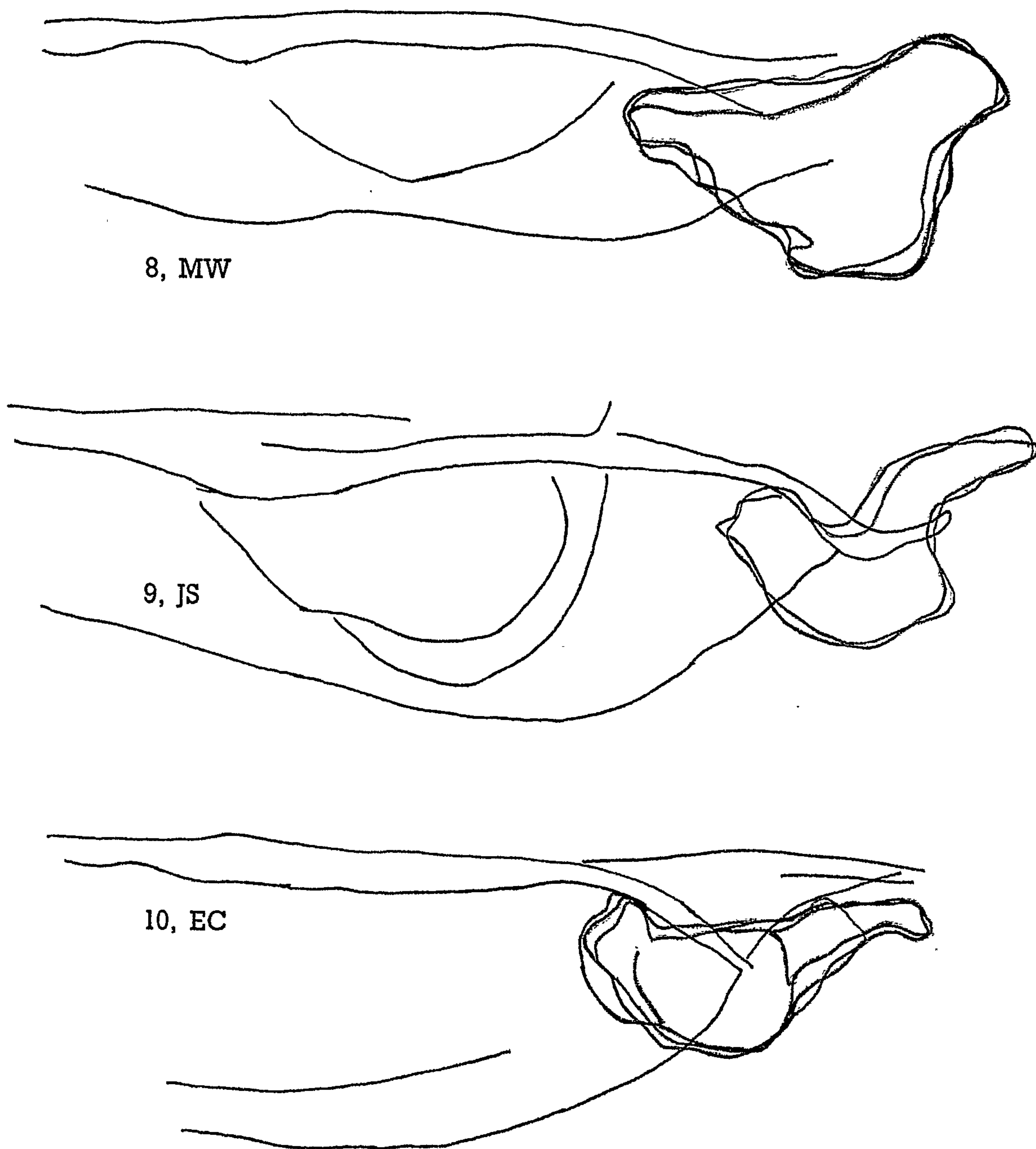
FIGURE 45



Composite tracings for patients 5-7. The patients number and initials identify each tracing and the time phases are represented by:

preaugmentation	-	black
postaugmentation		
1-4 months	-	brown
6 months	-	red
12 months	-	green
18 months	-	blue

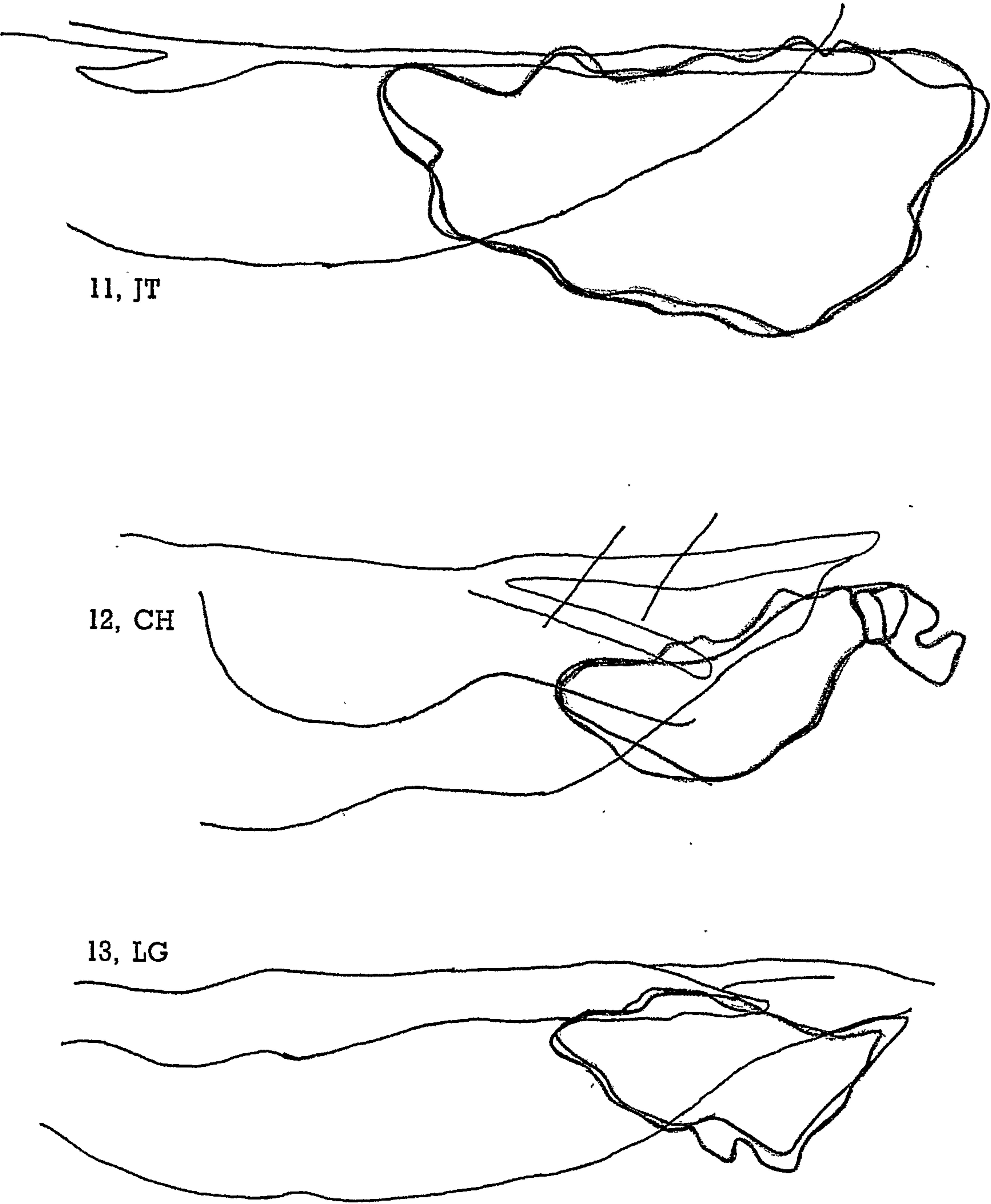
FIGURE 46



Composite tracings for patients 8-10. The patients number and initials identify each tracing and the time phases are represented by:

preaugmentation	-	black
postaugmentation		
1-4 months	-	brown
6 months	-	red
12 months	-	green
18 months	-	blue

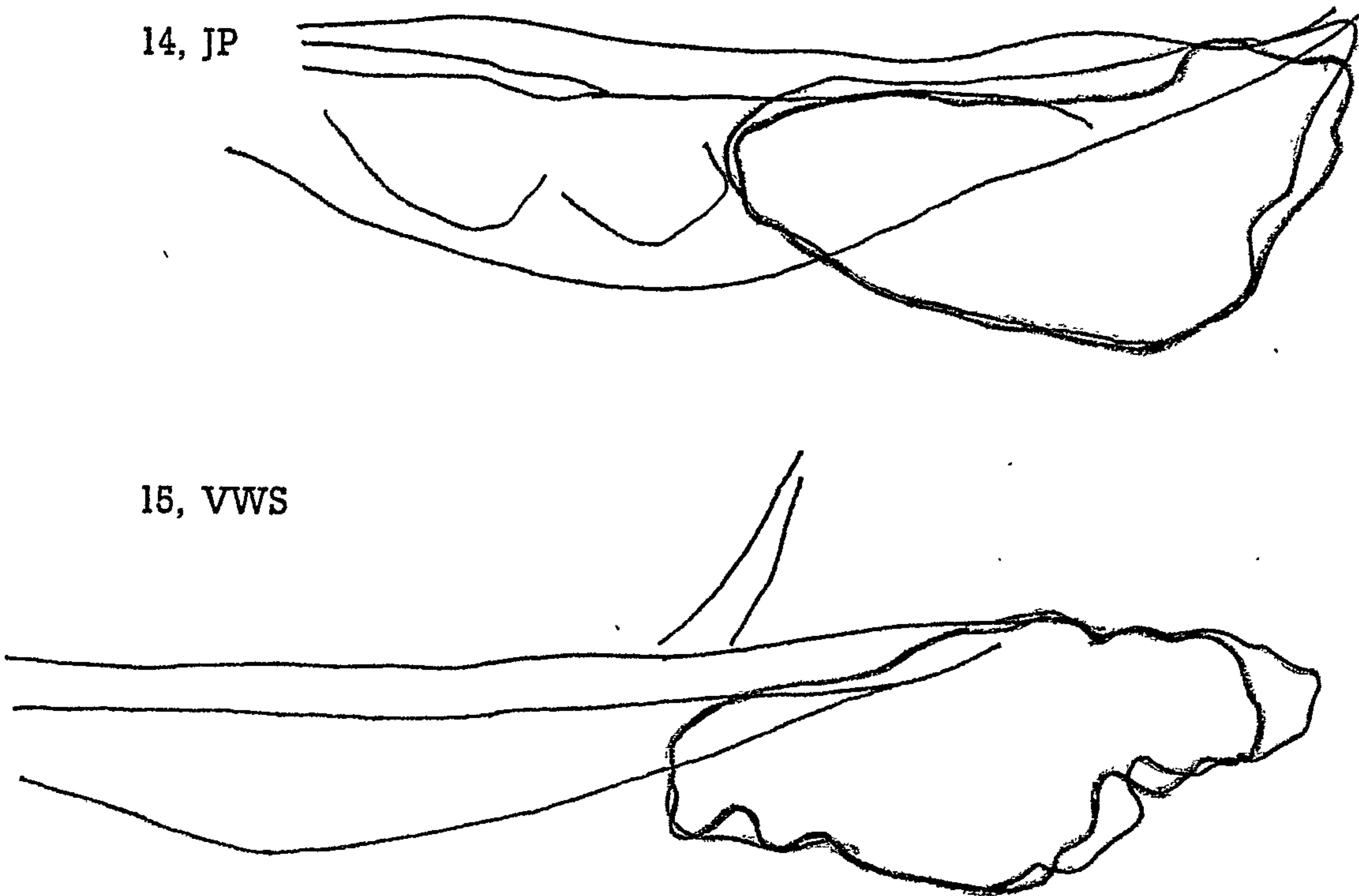
FIGURE 47



Composite tracings for patients 11-13. The patients number and initials identify each tracing and the time phases are represented by:

preaugmentation	-	black
postaugmentation		
1-4 months	-	brown
6 months	-	red
12 months	-	green
18 months	-	blue

FIGURE 48



Composite tracings for patients 14 and 15. The patients number and initials identify each tracing and the time phases are represented by:

preaugmentation	-	black
postaugmentation		
1-4 months	-	brown
6 months	-	red
12 months	-	green
18 months	-	blue

and compared with the soft tissue changes noted in the composite tracings drafted from the study models images (Section 6) (Fig. 49-51).

The 14 composite tracings are presented in Figures 44-48 and show minimal change over the time of the study (the preoperative cephalometric radiograph for patient 3 was not available and therefore that tracing has been excluded). The augmentation height varies little and in no case has there been a substantial relapse even after 18 months. The granule masses appear to be stable and there is no apparent movement even of the granules initially displaced into the midline vestibule.

Plates 46-55 are examples of the radiographs obtained from patients 2, 10 and 11 during this study. They show both the preoperative appearance and postoperative views taken at various intervals. The difficulty associated with superimposition in the anterior maxilla can be appreciated in the OPTs illustrated whereas the lateral cephalometric radiographs can be seen to give a reproducible image which highlights the position and cross-sectional shape of the HA augmented ridge.

PLATE 46



PLATE 47



Plate 46 is a preoperative lateral cephalometric radiograph of patient 2 (BC) showing Class III maxillary atrophy.

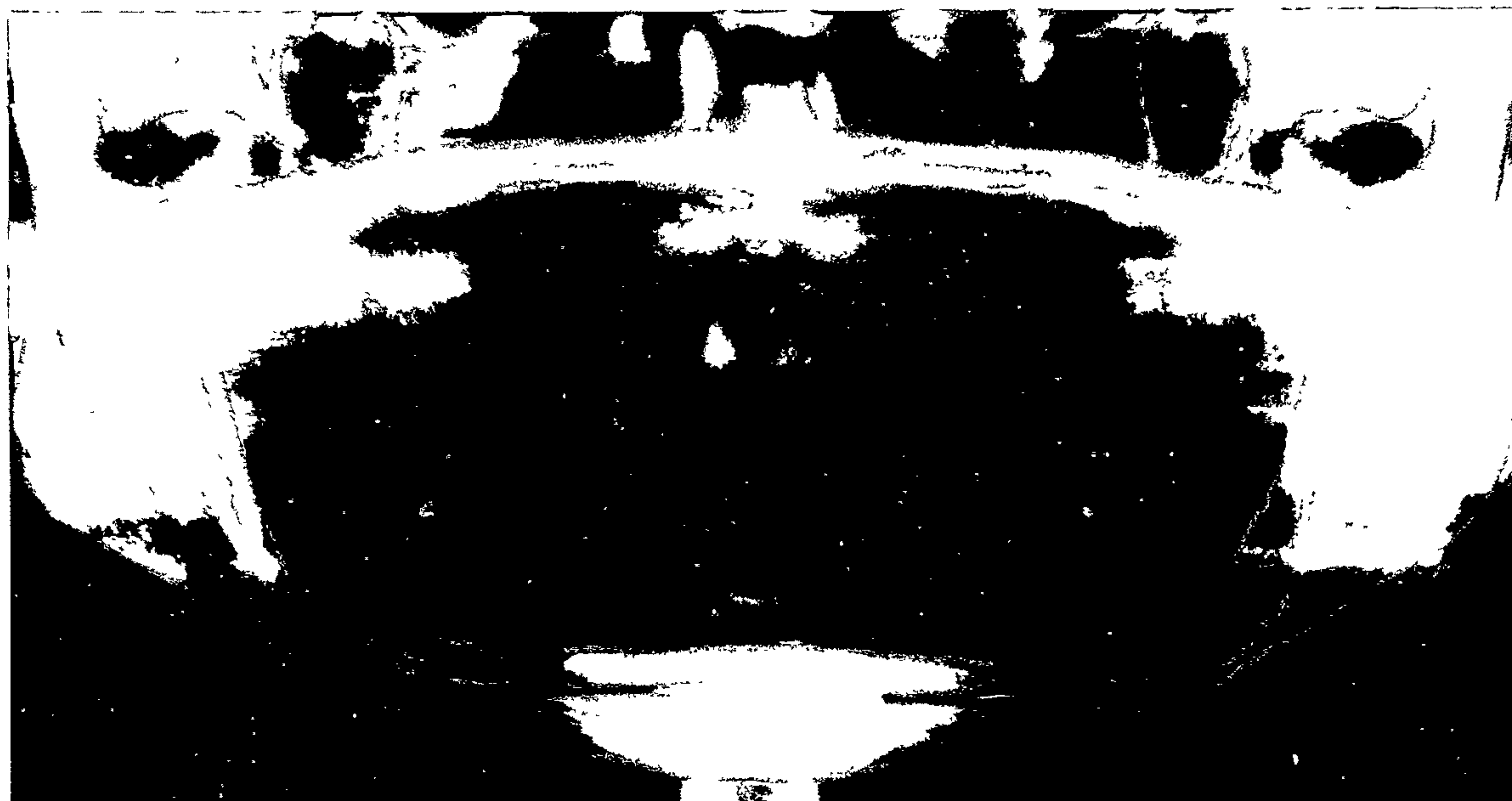
Plate 47 shows the position of the maxillary HA granules 12 months postaugmentation.

PLATE 48



Patient 10 (EC). A preoperative OPT showing Class III maxillary and Class IV mandibular atrophy.

PLATE 49



The same patient six months after anterior maxillary augmentation and three weeks after mandibular augmentation. Note the ease with which apposition and height increase can be measured in the mandible but not in the maxilla due to superimposition.

PLATE 50

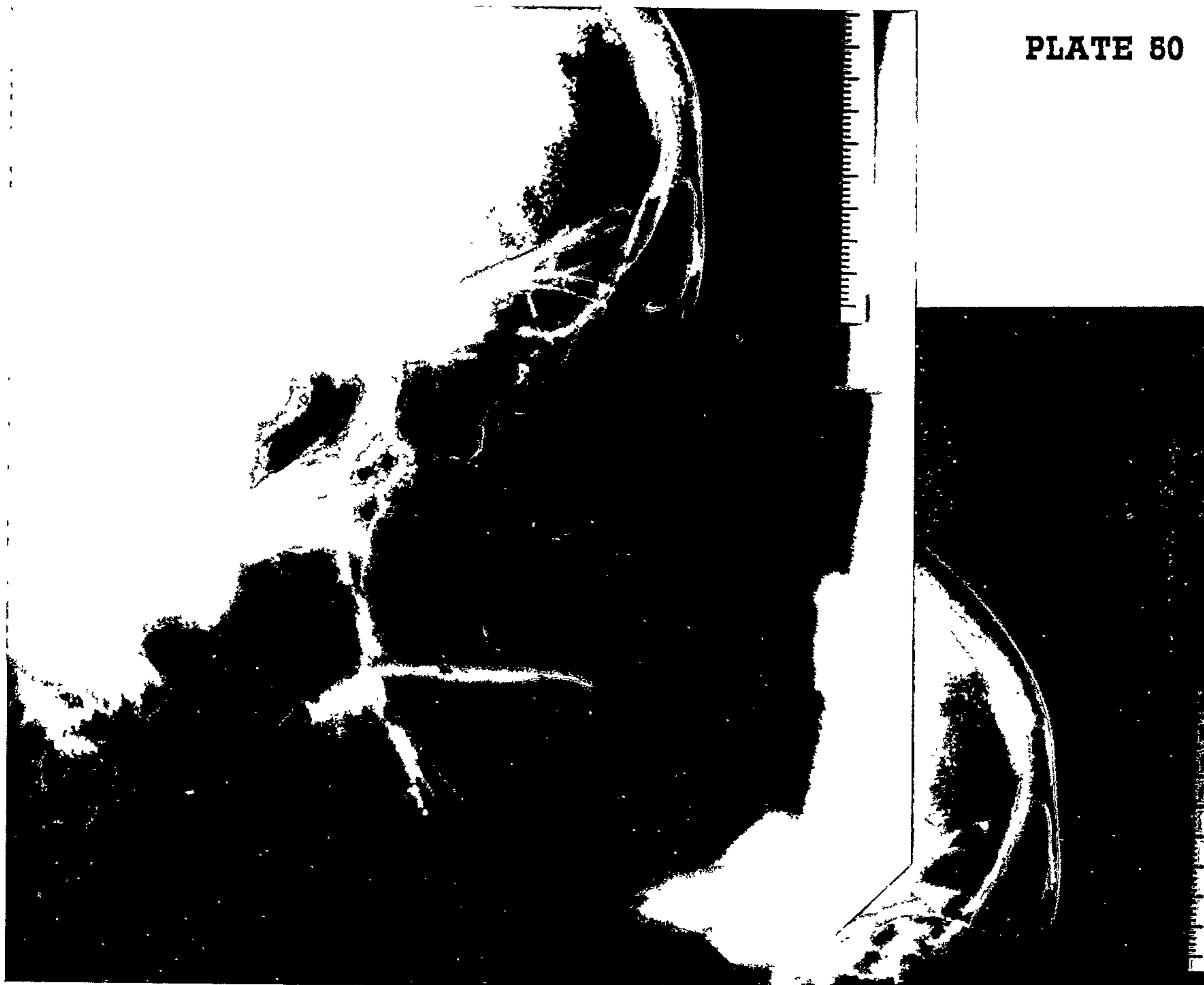


PLATE 51

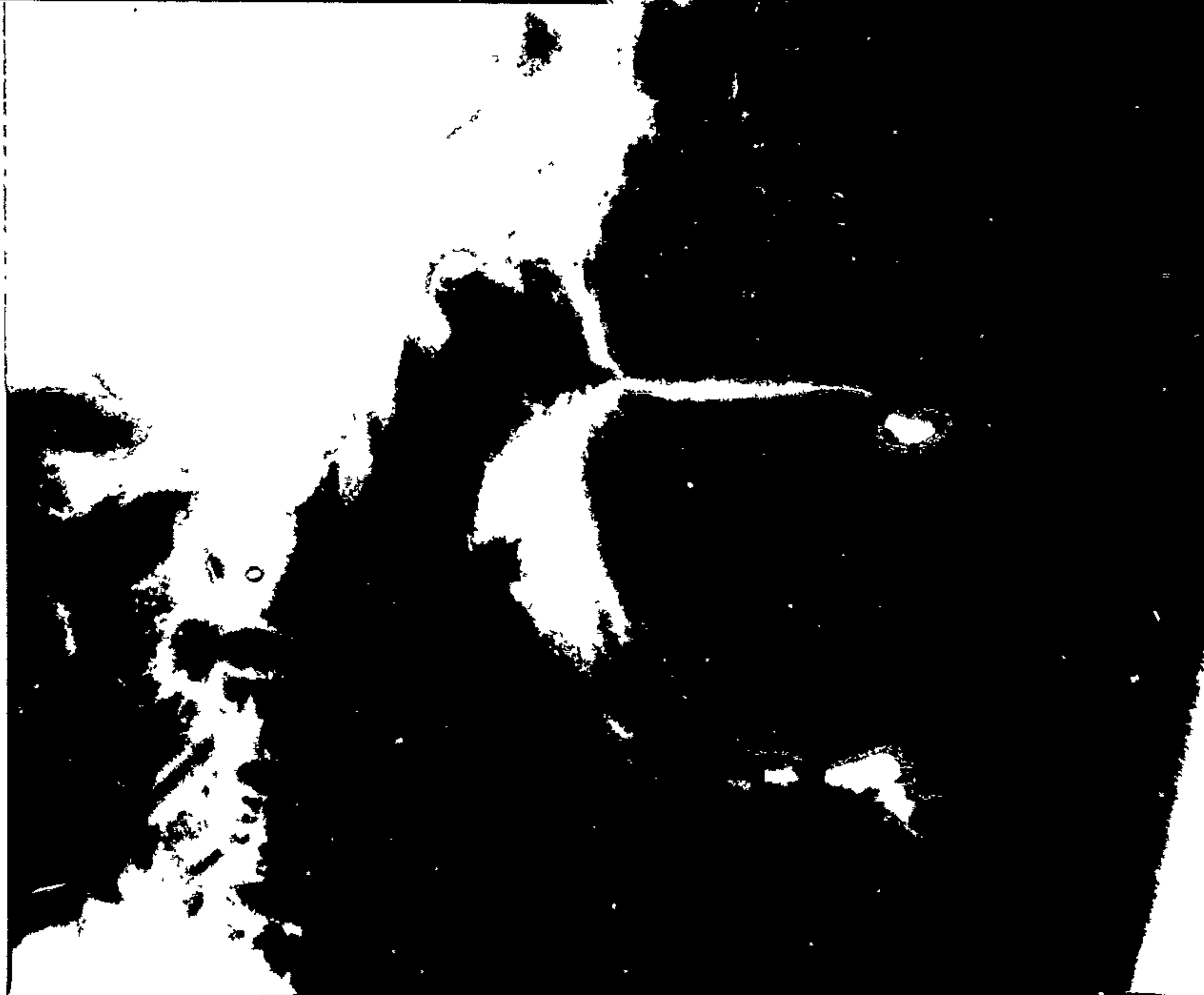


Plate 50 is a preoperative lateral cephalometric radiograph of patient 10 (EC) showing Class III maxillary and Class IV mandibular atrophy.

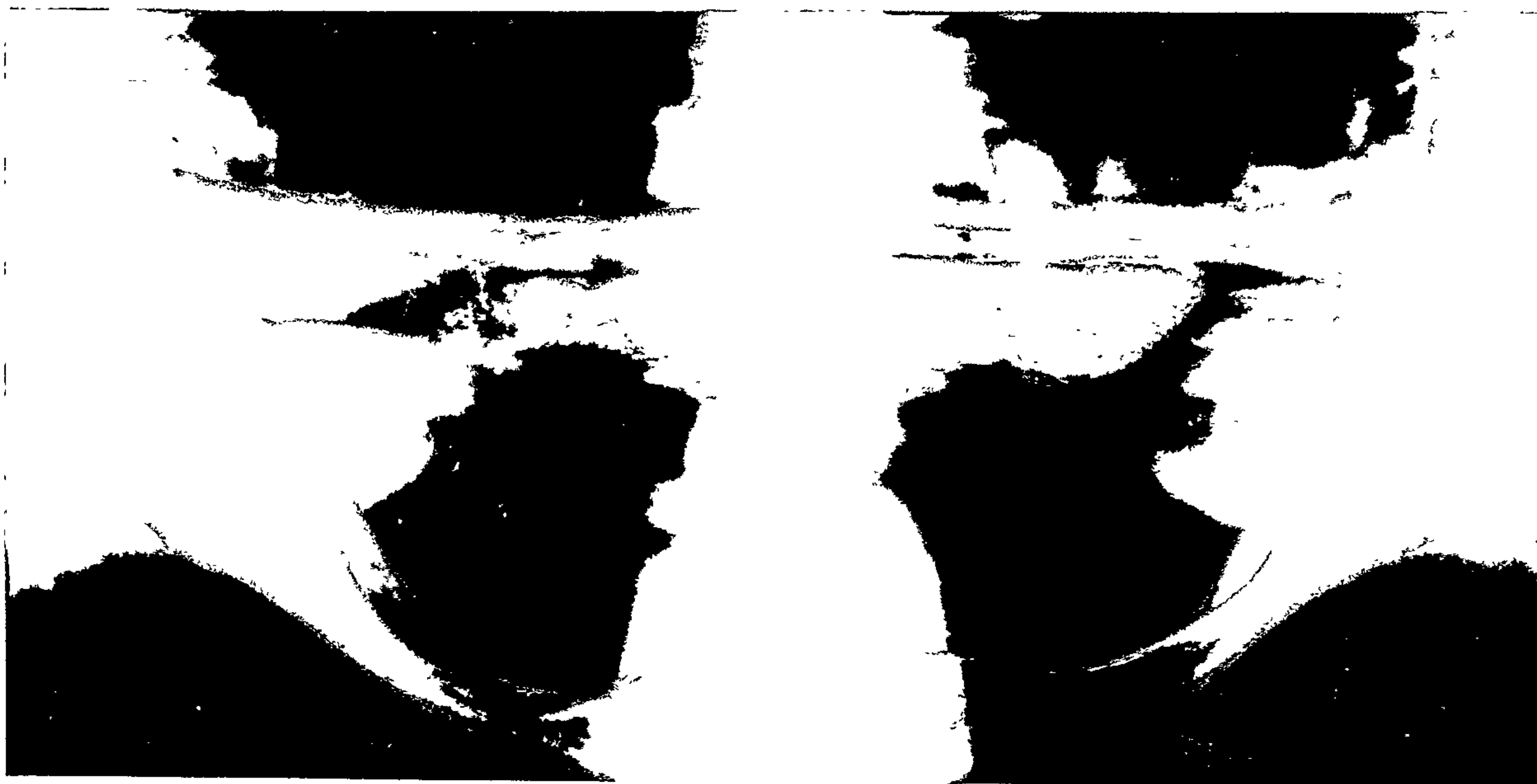
Plate 51 shows the postaugmentation position of the HA granules after six months in the maxilla and three weeks in the mandible.

PLATE 52



Patient 11 (JT). A preoperative OPT showing Class IV anterior maxillary atrophy.

PLATE 53



The same patient one day after the second of a two stage augmentation in which a total of 7.5 g (10 syringes) of HA granules were used.

PLATE 54

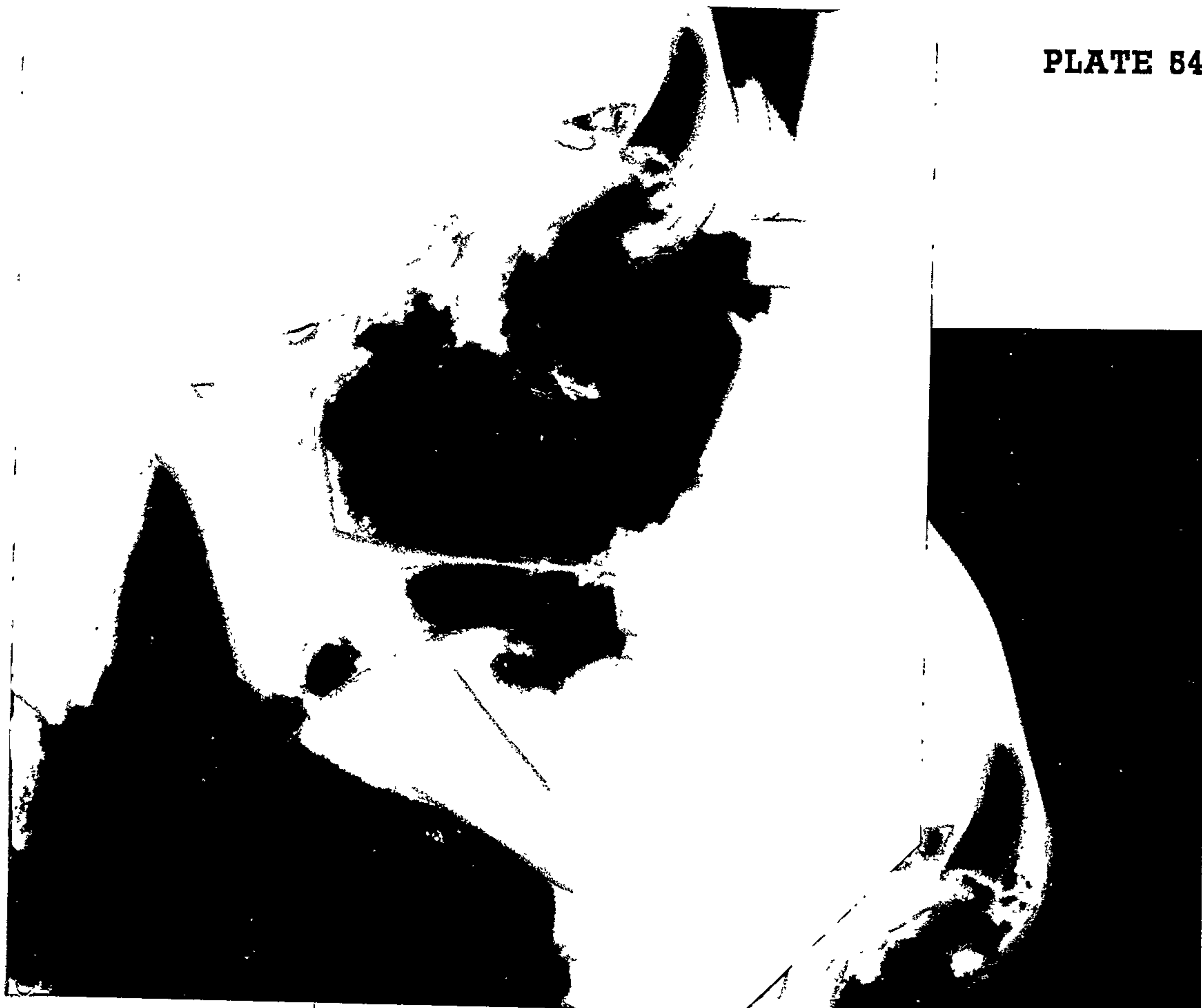


PLATE 55



Plate 54 is a preoperative lateral cephalometric radiograph of patient 11 (JT) showing Class IV maxillary atrophy.

Plate 55 shows the position of the maxillary HA granules one day postaugmentation.

6. STUDY MODELS

Images produced from study models by photocopying (described in Chapter VI, Section 2.6) were analysed in two ways. Firstly, composite tracings were drafted to allow direct comparison of changes in the size and contour of the augmented ridges. Secondly, increases in the cross-sectional areas of the augmented ridges were quantified using computerised image analysis.

6.1 Composite tracings

Figures 49, 50 and 51 show the composite tracings taken from the cross-sectional images (enlarged x2). Five sets of tracings are included in each figure, grouped according to the length of time the cases have been reviewed postaugmentation. Figure 49 contains the tracings of patients who have been under review for 18 months postaugmentation, figure 50 those under review for 12 months (apart from patient 6 who had been reviewed over 18 months) and figure 51 those under review for six months.

In all cases, examination of the composite tracings confirms that little, if any, relapse has occurred over the 18 months maximum period of this study. A further general observation is that the degree of cross-sectional area increase is not easily correlated with the amount of HA granules placed. For example, the substantial increase for patient 13 was achieved with one syringe of HA granules whereas patients 14 and 15, who both received four syringes of granules, showed a less marked area gain. A similar disparity can be observed in figure 49 where patient 5, who only received two syringes of granules, showed an increase in cross-sectional area greater than patient 2 who received four syringes. The remaining cases in figure 49 all received three syringes of HA but again a disparity in area gain can be seen, with patient 4 showing the greatest cross-sectional area increase of the three cases.

FIG. 49

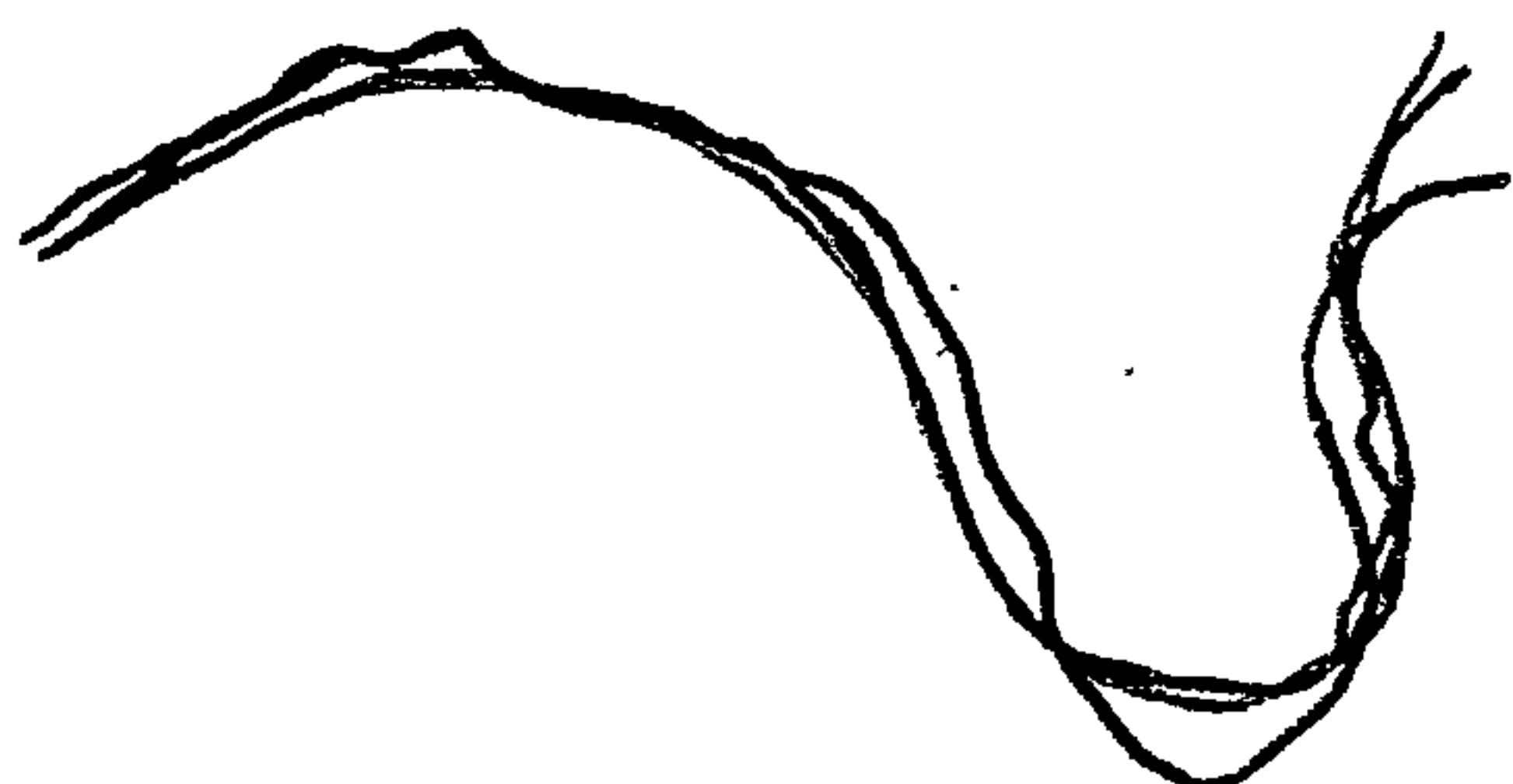
1. DR



2. BC



3. DG



4. EF



5. CS



pre-op - black
post-op 6 months - red
post-op 12 months - green
post op 18 months - blue

Tracings of dental model cross-sections (enlarged x 2) to show degree of augmentation achieved at 6, 12 and 18 months for five patients.
(Patient identified by number and initials.)

FIG. 50

6. HT



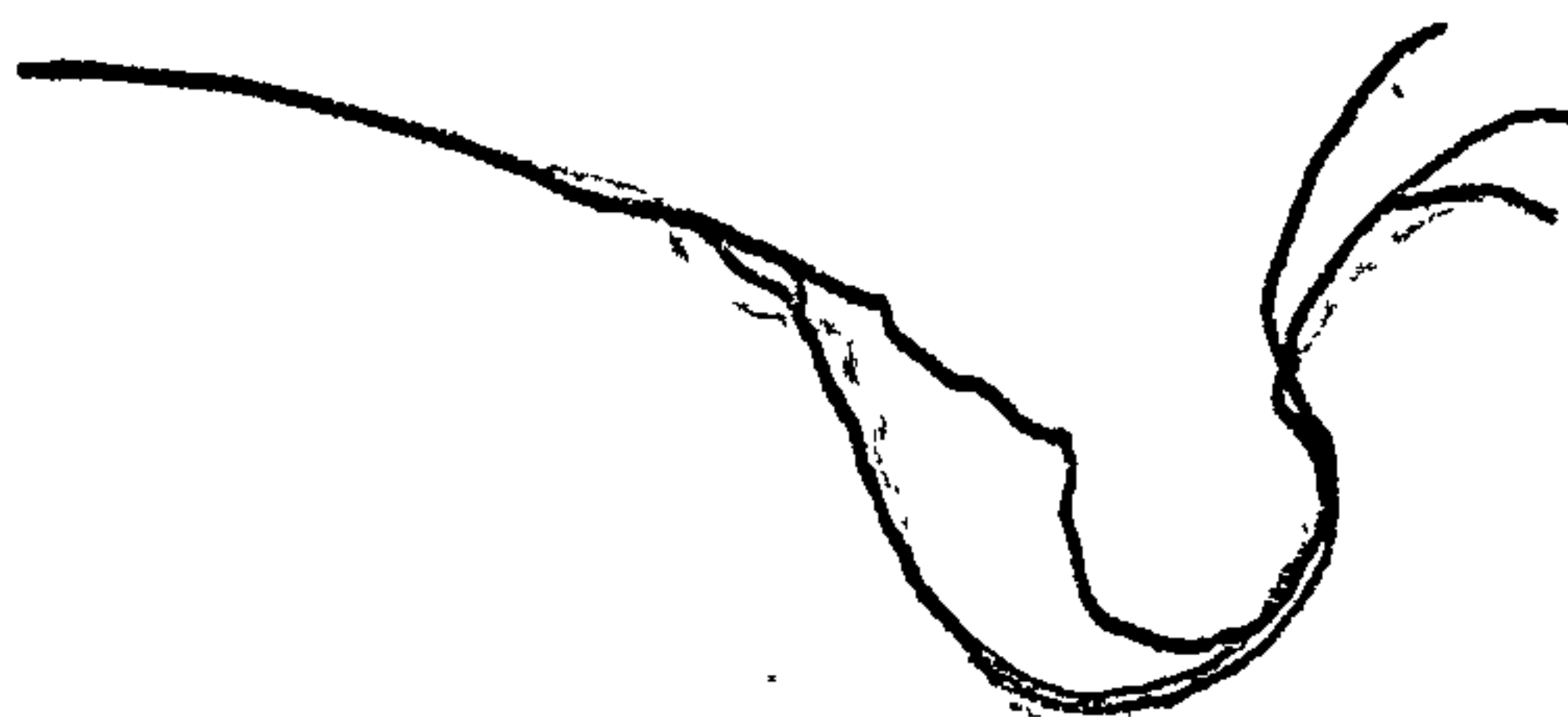
7. JD



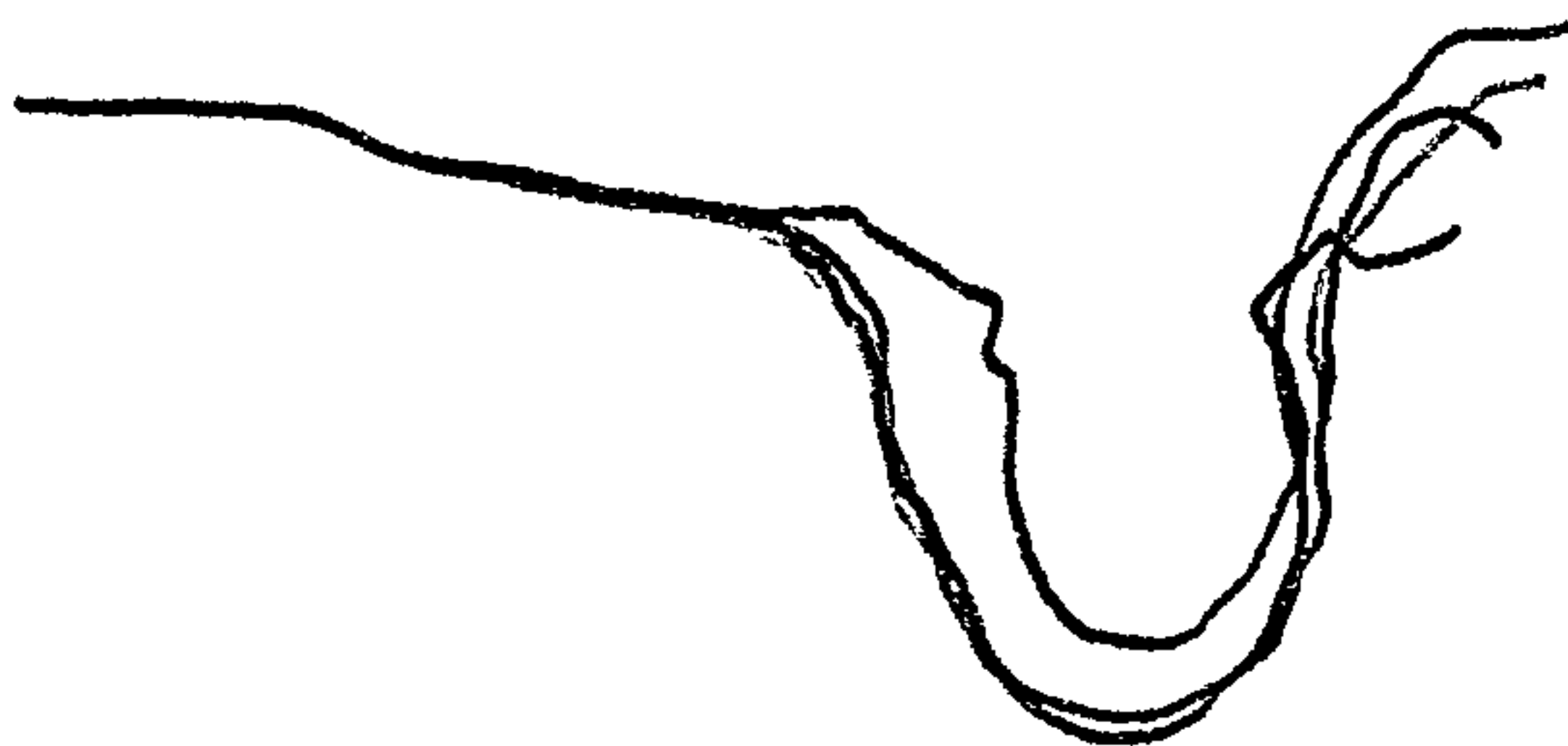
8. MW



9. JS



10. EC

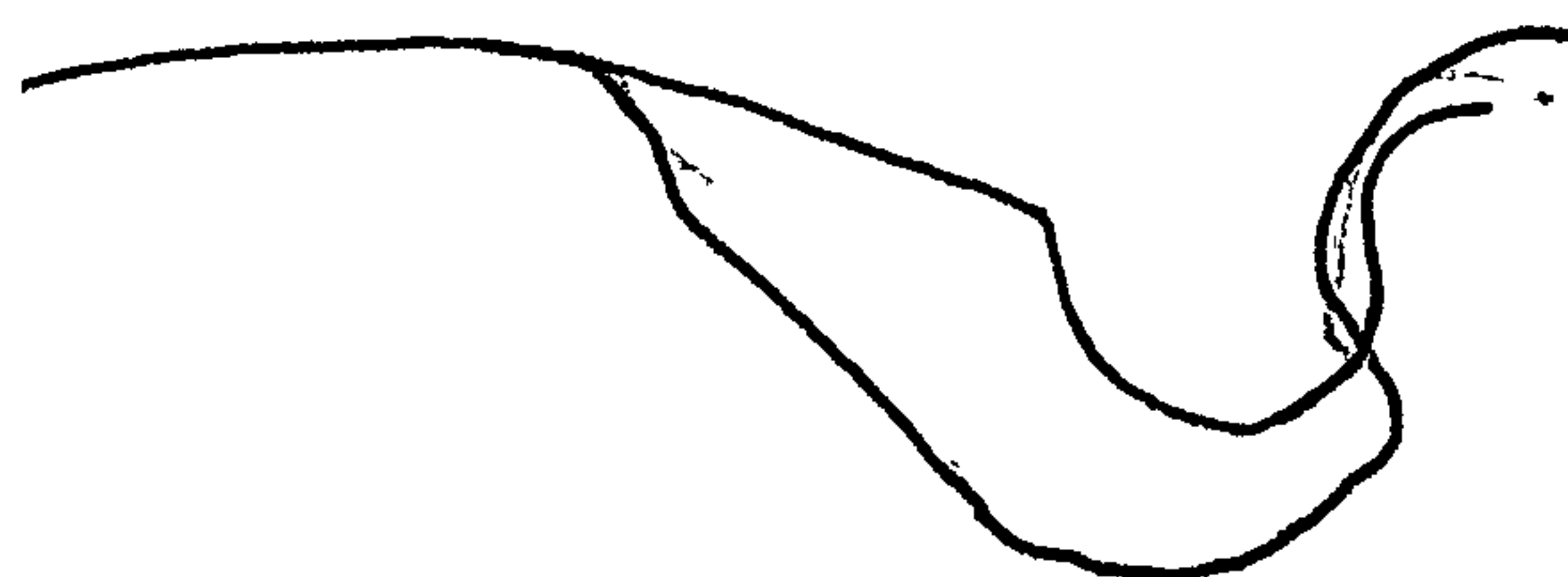


pre-op	- black
post-op 3 months	- yellow
post-op 6 months	- red
post-op 12 months	- green
post-op 18 months	- blue

Tracings of dental model cross sections (enlarged x 2) to show degree of augmentation achieved at 3, 6, 12 and 18 months for five patients. (Patient identified by number and initials.)

FIG. 51

11. JT



12. CH



13. LG



14. JP



15. VW



pre-op - black
post-op 3 months - yellow
post-op 6 months - red

Tracings of dental model cross-sections (enlarged x 2) to show degree of augmentation achieved at three and six months for five patients.
(Patient identified by number and initials.)

It must be remembered, however, that measurements were only made in one plane and an even distribution of granules cannot be assumed.

A further observation is the varied changes in sulcus depth. To some degree this could be attributed to the selection of the impression tray and the impression technique employed. Only patients 1, 3, 10 and 14 showed any degree of increased sulcus depth whereas patients 8, 9, 11 and 15 exhibited a loss of sulcus depth. It would appear that the submucous vestibuloplasty, which was performed in every case, does not show a uniformly beneficial increase in sulcus depth.

The contours of the traced profiles do not show any obvious uniformity either. In some cases, notably patients 4, 5, 7, 9, 11, 12 and 13, the augmentation has moved the ridge crest in a palatal direction in addition to showing an increase in ridge height. Patients 1, 6, 8, 10 and 15 also showed an increase in ridge height but in a similar labio-palatal plane as the original ridge. All patients demonstrated a broadening of the ridge to some degree creating a more rounded convex shape, however for patient 2 this broadening produced no height gain and in the cases of patients 3 and 14, an actual loss in height is apparent. Patient 14 also shows the greatest change in profile on the labial aspect of the ridge which may indicate that the HA granules were positioned too far labially, so losing the support provided by the palatal vault. In contrast, there is no evidence of the granules placed over the palate migrating into the palatal vault.

These findings confirm that HA augmentation produces a broader and more convex ridge. This improvement in ridge size and contour can be expected to provide better denture stability and increased retention. The findings do not prove any change in ridge stability.

6.2 Measurements of cross-sectional areas

All the preoperative ridge profiles and alterations in area following

augmentation were measured using the equipment and technique detailed in Chapter VI, Section 2.6. Table 23 records the details of the data. The preoperative cross-sectional area for each ridge was measured in mm² (enlarged x2). Following augmentation, the increases in cross-sectional area were measured and then expressed as percentage increases according to the formula

$$\frac{Aa}{Ao} \times 100$$

where Aa = area gain after augmentation and Ao = the preoperative area. These percentage increases are recorded in Table 23 and are tabulated according to the number of months after augmentation.

In order to examine the changes, the patients were divided into three groups; those whose measurements extended over 18 months (patients 1-6), those that extended over 12 months (patients 7-10) and those that extended over six months (patients 11-15). Graphs for each of these groups (Figs.52, 53, 54) were then prepared to illustrate the initial augmentation and changes in area of the augmented ridge relative to time. In the two instances where a one month model was measured (patients 5 and 11), the result was not incorporated into the graph because of possible inaccuracy due to the presence of persisting surgical oedema.

Figure 52 records the area changes of patients 1-6 over the 18 month period. Apart from patient 4, the initial increases are modest, being between 7 and 26 per cent. As might be expected, patients 1, 2, and 4 show some degree of relapse over time; however it is less obvious why there should be an increase in ridge size over time for patients 3, 5, and 6. The increases are in fact small (7, 4 and 2 per cent respectively) and in the light of the order of accuracy calculated as ± 6 per cent for this measurement technique (Chapter VI, Section 2.6) it is possible that the apparent continuing increase in ridge area is due to experimental error. More difficult to interpret is the increase of 13 per cent between six and 12 months for patient 4; the reason

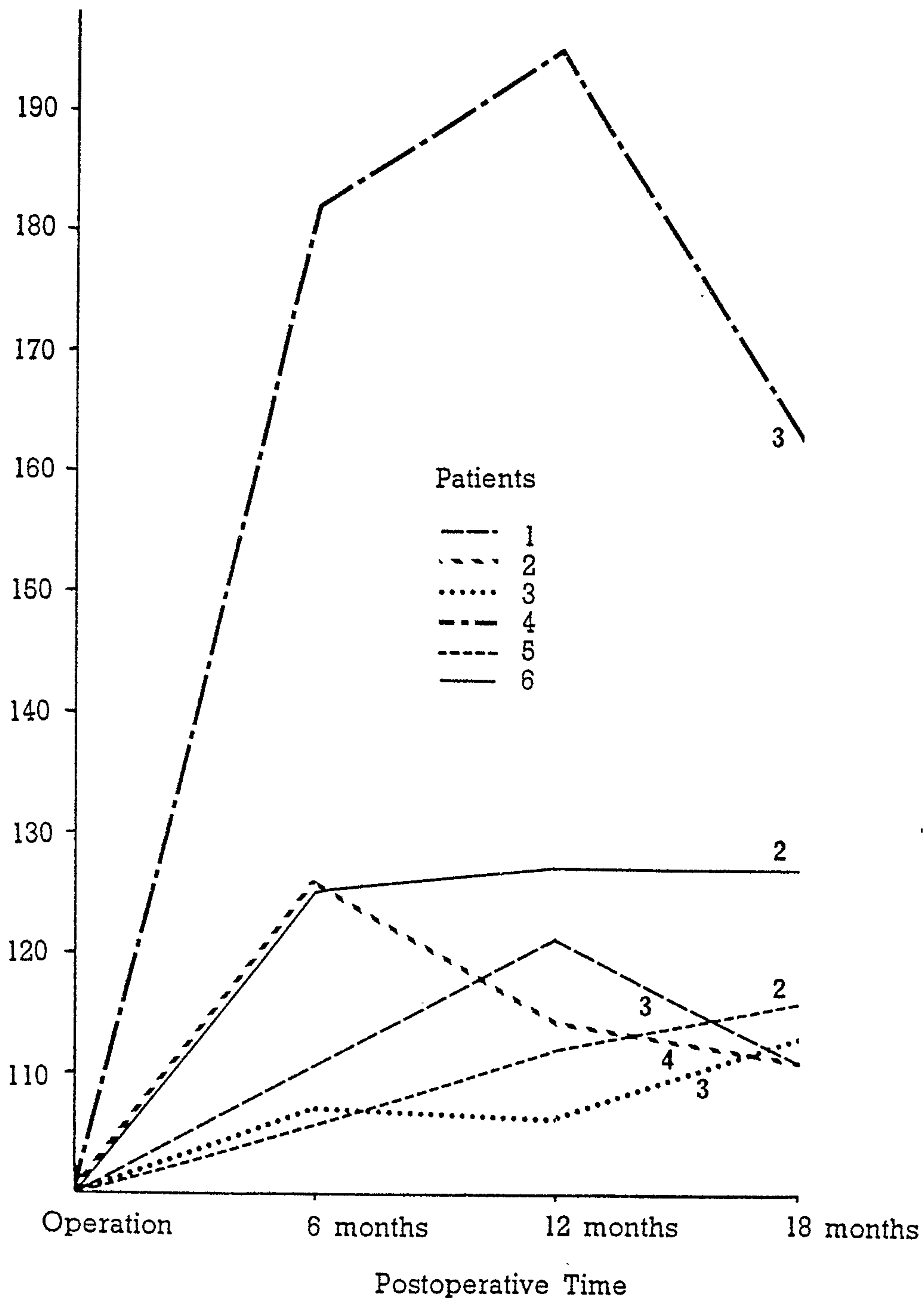
TABLE 23

ALVEOLAR RIDGE CROSS-SECTIONAL AREAS
 (expressed as a percentage increase
 of preoperative area (100 per cent))

Patient No.	Initial	Pre-op area (mm ²) (x2 magnification)	Months postaugmentation (percentage increase)				
			1	3	6	12	18
1	DR	367				121	111
2	BC	523			126	114	111
3	DG	425			107	106	113
4	EF	235			182	195	163
5	CS	648	109			112	116
6	HT	285			125	127	127
7	JD	442			129	114	
8	MW	564		109	108	108	
9	JS	462		124	122	117	
10	EC	255		160	159	148	
11	JT	280	304	193	195		
12	CH	270		138	141		
13	LG	181		168	168		
14	JP	306		132	122		
15	VW	305		133	130		

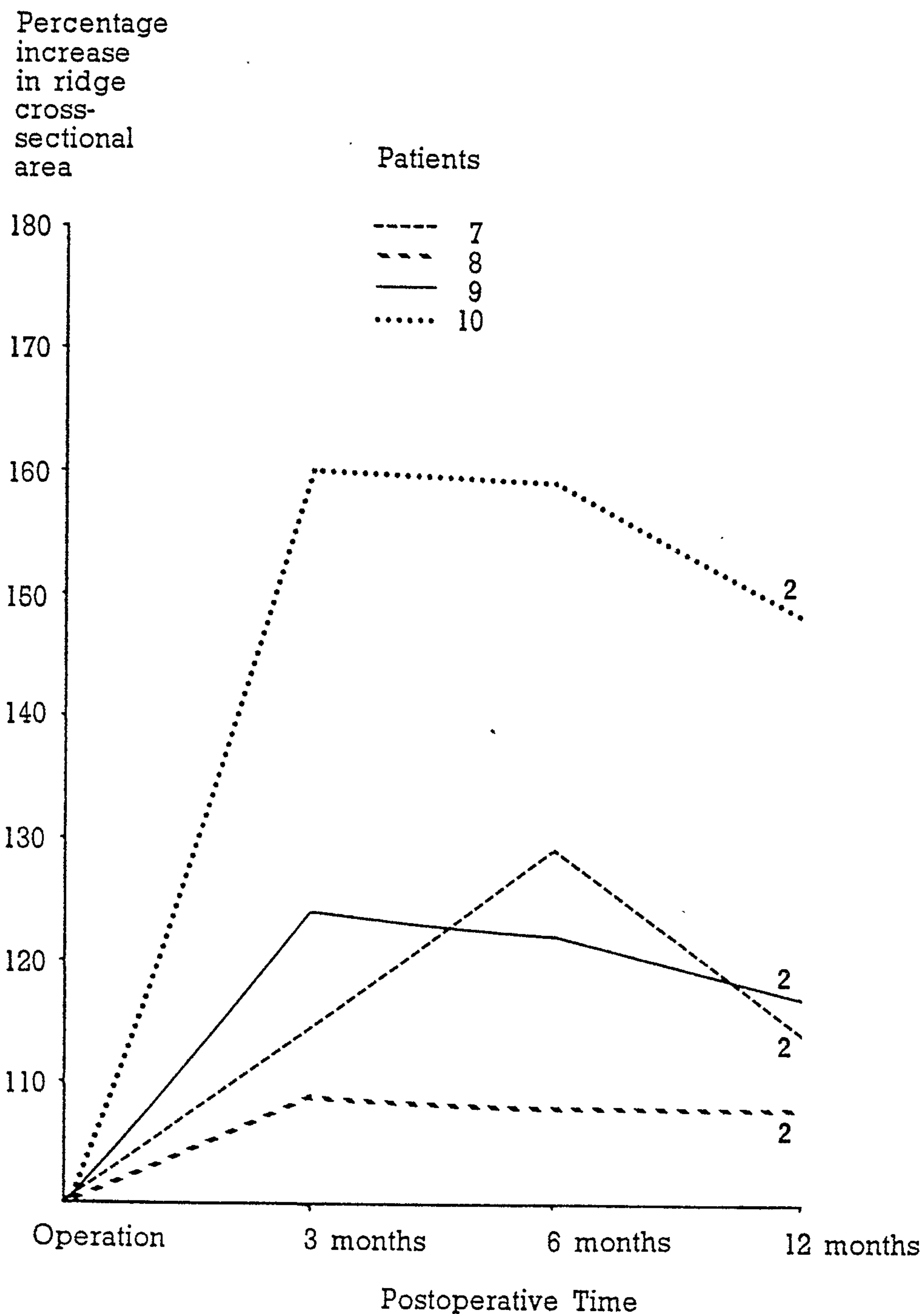
FIGURE 52

Percentage
increase
in ridge
cross-
sectional
area



Graph showing the percentage increase in ridge cross-sectional area for patients 1-6 over an 18 month period. Each line records the changes in area for one patient, the preoperative cross-sectional area being taken as 100 percent. (Number of syringes used is marked at the end of each line.)

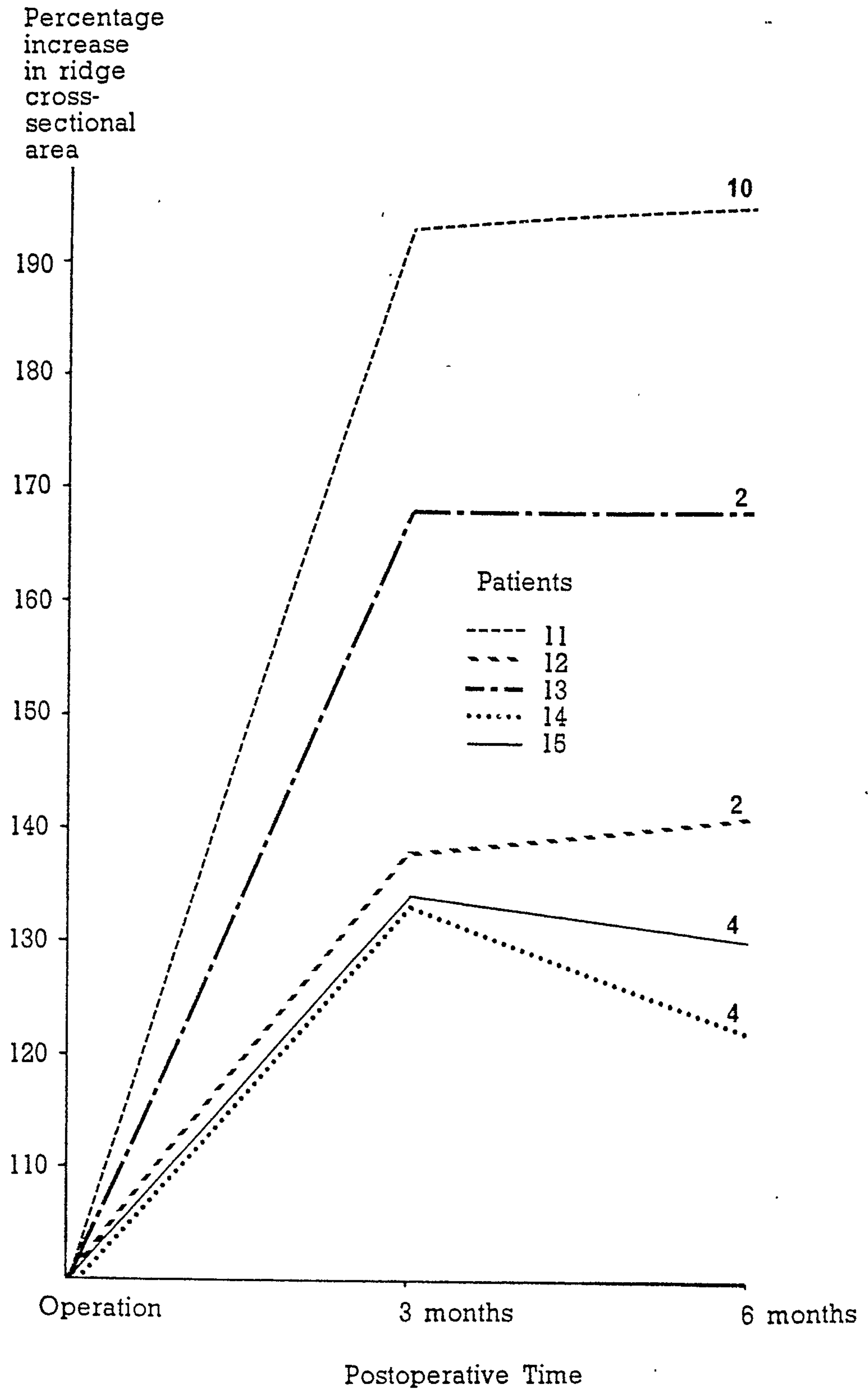
FIGURE 53



Graph showing the percentage increase in the ridge cross-sectional area for patients 7-10 over a 12 month period. Each line records the changes in area for one patient, the preoperative cross-sectional area being taken as 100 percent.

(Number of syringes used is marked at the end of each line.)

FIGURE 54



Graph showing the percentage increase in the ridge cross-sectional area for patients 11-15 over a six month period. Each line records the changes in area for one patient, the preoperative cross-sectional area being taken as 100 percent. (Number of syringes used is marked at the end of each line.)

for this finding is unclear.

Figure 53 records changes in the ridges of patients 7-10 over a 12 month postaugmentation period. Again the initial percentage increases are varied, ranging between 9 and 60 per cent. Subsequent measurements show a degree of relapse varying from 15 per cent to 1 per cent.

Figure 54 records the changes in patients 11-15 over a six month postaugmentation period. In all of these cases the initial increases were substantial, ranging from 32 per cent to 93 per cent in the case of patient 11 who received two separate augmentations and a total of 10 syringes of HA granules. For patients 14 and 15 the initial increase was followed by a slight relapse from 7 per cent to 10 per cent respectively. Patient 13 showed no relapse while patients 11 and 12 showed small increases of 2 per cent and 3 per cent respectively.

It can be seen from these three graphs that the gain in ridge cross-sectional area can vary considerably between patients. This cannot be easily explained by the quantities of granules used, an observation previously commented on in the discussion on the composite tracings. The number of syringes used has been included on the graphs next to each line to make this point graphically.

A further important factor related to the varied percentage increases must be the preoperative cross-sectional area which ranged from 181 mm² to 648 mm² (enlarged x2). In order to examine the percentage ridge gain relative to the size of the preoperative ridge, Table 24 lists the preoperative cross-sectional areas arranged in ascending order tabulated with the percentage increases in area relative to time. If the final percentage increases (taken as the finally measured profile either at 6, 12 or 18 months) are then examined, it can be seen that the smaller the preoperative cross-sectional area the greater the degree of percentage gain.

This finding is presented more clearly in Table 25 in which the preoperative cross-sectional areas have been grouped according to mm² sizes

TABLE 24

**PERCENTAGE CHANGES IN CROSS-SECTIONAL
AREA OVER 18 MONTHS**

(arranged by preoperative area size
(mm² x 2 magnification))

Patient		Percentage change in area over time months postaugmentation					
No.	Initials	PA	3	6	12	18	PI
13	LG	181	+ 68	+ 68			+ 68
4	EF	235		+ 82	+ 13	- 32	+ 63
10	EC	255	+ 60	- 1	- 11		+ 48
12	CH	270	+ 38	+ 3			+ 41
11	JT	280	+ 93	+ 2			+ 95
6	HT	285		+ 25	+ 2	0	+ 27
15	VW	305	+ 33	- 3			+ 30
14	JP	306	+ 32	- 10			+ 22
1	DR	367			+ 21	- 10	+ 11
3	DG	425		+ 7	- 1	+ 7	+ 13
7	JD	442		+ 29	- 15		+ 14
9	JS	462	+ 24	- 2	- 5		+ 17
2	BC	523		+ 26	- 12	- 3	+ 11
8	MW	564	+ 9	- 1	0		+ 8
5	CS	648			+ 12	+ 4	+ 16

PA - Preoperative area (arranged by size) (mm² x 2 mag).
PI - Percentage increase (irrespective of time).

TABLE 25

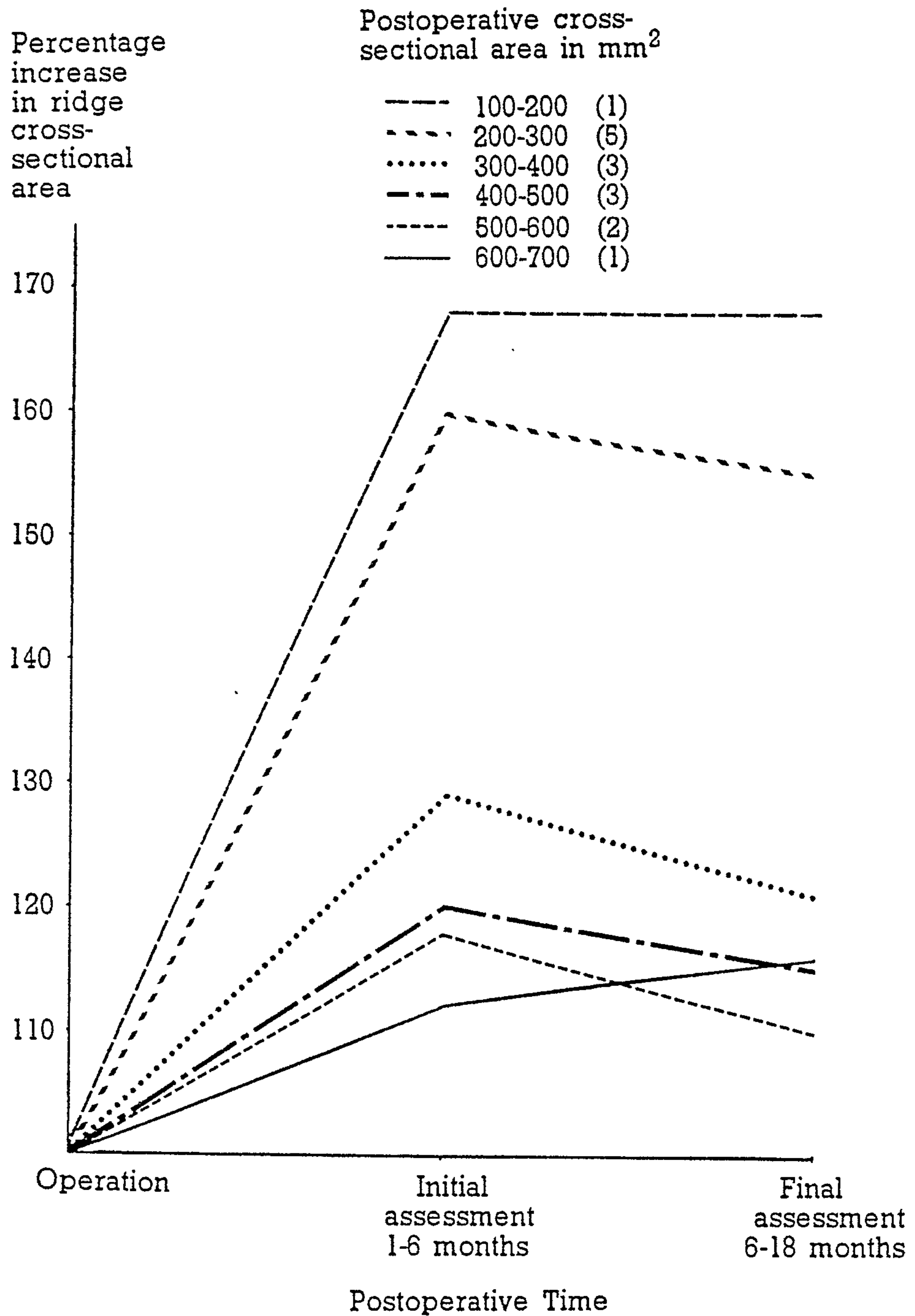
**PERCENTAGE CHANGES AVERAGED
FOR EACH AREA SIZE GROUP**

Pre-op Area Range (mm ² x 2 mag)	No. in group	Initial average percentage increase (range)	Final average percentage increase (range)
100-200	1	+68	+68
200-300	5	+60 (+25 to +93)	+55 (+27 to +95)
300-400	3	+29 (+21 to +33)	+21 (+11 to +30)
400-500	3	+20 (+7 to +29)	+15 (+13 to +17)
500-600	2	+18 (+9 to +26)	+10 (+8 to +11)
600-700	1	+12	+16

at 100 mm² intervals. The average initial and final percentage increases for each group were then calculated by averaging the total of all results for patients within the group. The results are demonstrated graphically in Figure 55 and show that the smaller the original ridge cross-section the larger the percentage gain in cross-sectional area following augmentation. It also shows that for all groups, except the largest (600-700 mm²), only a small degree of relapse (ranging from 0 to 8 per cent) occurred over the period studied. In the case of the 600-700 mm² group, an increase in area of 4 per cent was recorded but as this falls with the order of accuracy range for the experimental technique ($\pm$ 6 per cent) it probably represents experimental error.

It is concluded that the smaller the original ridge cross-section the greater will be the increase in cross-sectional area postaugmentation and that this increase will be maintained with minimal relapse for at least 18 months.

FIGURE 85



Graph showing the average percentage increase in ridge cross-sectional area relative to time based on a preoperative reading of 100 percent. The number of ridges within each category is included in brackets in the key.

CHAPTER VIII

DISCUSSION AND CONCLUSION

CHAPTER VIII

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DISCUSSION AND CONCLUSION

'The time has come' the Walrus said, 'to talk of many things'.

Lewis Carroll (1832-1898)

Through the Looking-Glass

This study was conducted to assess the suitability of HA granules placed subperiosteally to augment the atrophic anterior maxilla and reduce the mobility of any overlying hypermobile tissue. The experience gained in treating 15 patients who underwent this preprosthetic surgical procedure has allowed certain observations and conclusions to be made. These are pertinent to the surgical technique, the methods of assessing results and the role of the technique as a valid alternative to other procedures used to overcome the problem of hypermobile tissue in the atrophic anterior maxilla.

1. DISCUSSION

1.1. Surgical technique

The surgical technique used in this study was originally developed by Kent et al (1982) and subsequently modified by Kent et al (1986A). The technique has proved to be a simple, outpatient procedure with minimal complications, minimal morbidity and a predictable outcome. From the experience gained in the 15 cases reported it is apparent that certain aspects of the technique require reappraisal and possible further modification.

For example, the initial submucous vestibuloplasty may not be indicated in every case. To provide any benefit there must be both sufficient vestibular tissue available and an area into which the tissue can be displaced. If there is not sufficient vestibular tissue, the mucosa overlying the adjacent

ridge becomes displaced under tension causing granule migration and a loss of augmentation height. Neither is there space beneath the piriform aperture into which the sulcus can be deepened. In the atrophic anterior maxilla the anterior nasal spine lies directly beneath the sulcus and the original surgical protocol recommended its resection to create vestibular depth. However, the nasal spine, in turn, lies immediately beneath the nasal mucosa, so obstructing any intended increase in sulcus depth. Furthermore, the marked increase in postoperative pain and prolonged tenderness render excision of the spine unacceptable. In cases of anterior maxillary atrophy a submucous vestibuloplasty can only be used successfully distal to the piriform aperture. This would allow the procedure to be performed through vertical bilateral incisions buccal to the ridge in the canine region independent of the augmentation procedure.

If a submucous vestibuloplasty is indicated for the area beneath the piriform aperture, it would appear from this study that it should still be kept independent of the augmentation procedure. This would leave intact the buccal periosteum between the two tunnels. The division of the periosteum is an important feature of the original protocol and was employed to create a more substantial pocket for the granules. However, in certain cases in the present study it allowed the granules to be freely displaced away from the ridge resulting in ectopic collections of granules in the sulcus and a corresponding loss of augmentation height.

It is important to restrict periosteal elevation to within the palatal rim and limit the subperiosteal tunnel to a narrow band just palatal of the alveolar crest. If the buccal periosteum is not breached, the narrow restricted tunnel can still be extended sufficiently to accommodate an HA syringe by extensive filleting of the overlying fibrous tissue. This tunnel of reduced width requires less granules and because of the intact buccal periosteum there is less opportunity for the granules to migrate buccally, so maintaining the augmentation height gain.

The disadvantage of this modification is the creation of a ridge more palatally placed than preoperatively. This can exacerbate the Class III skeletal discrepancy which is prevalent in long term edentulous patients. HA augmentation has no role in correcting this discrepancy as it would be inappropriate to place granules on the labial face of the maxilla because they would quickly migrate superiorly. If an atrophic maxilla with a hypermobile ridge also has a Class III skeletal relationship it would be more appropriate to combine two surgical techniques, using the HA granules for the hypermobile tissue and a Le Fort I osteotomy for the skeletal discrepancy.

A further aspect of the surgical protocol that requires analysis is the relevance of the preformed surgical template. It is difficult to create an augmented preoperative study model that will bear any resemblance to the postaugmented ridge. The quantity and position of the granules is dictated by the overlying mucosal tension rather than by a predetermined ideal. An optimistic prediction is reflected in the resultant template which, in turn, gives an impression of underaugmentation when placed. In this study, the modified denture used as a splint was found to limit granule migration and protect the surgical site satisfactorily despite its less than precise adaptation. Therefore, the surgical template would appear to be superfluous and not fabricating it would also have the advantage of reducing costs and laboratory time.

One of the difficult problems presented by the surgical technique which has received no attention, is how to satisfactorily close the midline incision. It is not possible to mobilise tissue towards the midline and following augmentation the wound tends to gape and can only be closed under tension. A midline dehiscence with loss of granules commonly results and a midline cleft forms over time. In an effort to overcome this dehiscence, slowly resorbed sutures were employed with some success. An alternative is to underaugment the area adjacent to the incision; this reduces the chance of dehiscence but still results in a midline deficiency. It is not

possible to effectively close the buccal periosteum either and therefore the incision provides a submucosal plane along which the granules can migrate to lie between the anterior nasal spine and the sulcus. Even the placement of deep periosteally tethered sutures failed to contain the granules completely.

As a result of this retrospective analysis of the surgical technique described in Chapter VI section 1.3, certain modifications to the procedure could be beneficial. In summary they are:

- To discontinue the use of the surgical template
- To use a submucous vestibuloplasty only if indicated and not necessarily as an integral part of the augmentation procedure
- If a submucous vestibuloplasty is performed, then, to limit granule migration, the buccal periosteum between the subperiosteal tunnel and the submucous vestibuloplasty should be maintained intact
- Not to resect the anterior nasal spine
- To limit the periosteal elevation to a narrow band on the palatal aspect of the ridge crest

1.2. Assessment

The range of assessments used in this study allowed for both subjective and objective results to be collected and integrated. The clinical assessments allowed the three individuals involved in each case (patient, prosthodontist and surgeon) to make their own independent judgements in as comprehensive a manner as possible. The objective analysis of the relevant radiographs, study models and in one case the histology served to complement and supplement this clinical data.

1.2.1. Subjective assessments - Patient, Prosthodontist and Surgeon

Analyses of the independent opinions of the patient, prosthodontist and surgeon all show that the postaugmentation dentures were perceived as superior to the preaugmentation dentures. It is not, however, possible to say that this improvement was solely the result of the surgery as the success of dentures is dependent on the many physical and psychological factors discussed in Chapter II.

In analysing the results of this study it must be appreciated that as each method of assessment appraised a different aspect of the treatment each must be considered separately, with appropriate reference to conflicting or supporting evidence from other studies.

In every parameter used to assess their new dentures a majority of patients noted an improvement. This improvement could, in part, be due to the skill of the prosthodontists or possibly an unconscious desire on the patient's part to provide a more positive response than was warranted. The patients understandably had the keenest interest in a successful result but equally their previous histories of unsatisfactory dentures could have engendered a pessimistic outlook. These factors cannot be excluded but, in a bid to avoid bias, patients were always left to complete their questionnaire alone, before any comment from the prosthodontist or oral surgeon.

The improvements noted in the functions of eating and speaking were particularly gratifying as these two aspects are of great importance to a patient's perception of a successful denture. Of equal importance is denture comfort and appearance. The continuing postoperative improvement in denture comfort supports the clinical experience that comfort improves after a 'settling in' period.

It is also interesting that satisfaction with denture comfort was greater than with the denture fit. As can be seen from Table 20, many patients complained both in the long and short term of tenderness to pressure either

over the ridge or in the sulcus over the anterior nasal spine. This tenderness would be expected to heighten discomfort but this does not seem to have been the case.

Neither was the health of the mucosa, as assessed by the prosthodontists, a factor in the denture comfort and fit. The improvement in mucosal health in the immediate postoperative phase was probably due to the use of surgical dressing packs or tissue conditioners as temporary relining materials. This benefit was then lost when the new dentures were fitted and the patients returned to their previous denture hygiene regimens. The patients who required anti-fungal medication following the issue of their new dentures were predominantly those who required preoperative medication but they registered no less favourable response to denture comfort or fit.

Aesthetics is another important aspect of the acceptance or rejection of dentures by patients. In this study a majority expressed increased aesthetic satisfaction from their new dentures. Ideally, successful aesthetics should result from a consensus derived from the prosthodontists judgement and the patients' self image, however that consensus is not always achieved. There are certain anatomical situations such as a Class II or III skeletal relationship, or bone expansion as a result of diseases such as Paget's, which can compromise denture aesthetics. The hypermobile anterior maxillary ridge is not such a condition but the instability of a denture worn on such a ridge can cause aesthetic embarrassment when retention is lost. It follows, therefore, that a reduction in the mobility of the denture bearing area can indirectly benefit denture aesthetics and the confidence of the patient.

A further aesthetic advantage to the patients, and one which should not be underestimated, was that they were never without a denture, either as the fixed splint or as a modified, temporary denture for the duration of the postoperative phase. This was complemented by the provision of new dentures after only a short postsurgical convalescence. This is in marked contrast to other procedures utilising inlay or onlay bone grafts where the

patient is denied a denture for as long as six months following surgery. There is no doubt that this was a major factor in the patients' deliberations on whether or not to proceed with surgery.

The patients' perceptions of their new dentures are encapsulated in the parameter of general satisfaction, which probably represents the most significant result of the whole study. However objective and analytical the assessment of clinical and experimental data, the ultimate test of success is the patients' satisfaction with the treatment provided. Even the most technically perfect denture can fail if it does not find favour with the patient. In this context the surgical and prosthodontic care provided for the patients involved in this study must be seen to have won the approval of the patients. Every patient perceived that they had benefited from the treatment to a lesser or greater degree. There was no patient who felt the treatment had failed and the caustic comment by patient 15 (Table 18) was not reflected by her assessments, which showed an improvement.

It is dangerous to draw definite conclusions from such a small number of patients (15), however it is interesting to compare the results of this study with those published in association with the American multicentre study (Kent et al 1982 Kent et al 1983, Rothstein et al 1984B, Rothstein et al 1984C). Each of these studies published data concerning the various parameters measured in this present study. However the majority of the American data did not always differentiate between results in the maxilla and the mandible and included cases treated either with HA alone or in combination with bone. The number of maxillary cases treated was also small in comparison to mandibular cases (eg nine maxillae to 47 mandibles in Kent et al 1983) and neither was every maxilla treated for hypermobility as was the case in this present study. However, in the absence of any series dealing specifically with the hypermobile anterior maxillary ridge, a comparison has been made between the American results as detailed in their four published papers and the results from this present study. These comparisons are presented in

Tables 26 to 33.

Some difficulty has been experienced in tabulating these results because the range of assessment categories in this present study was slightly different from the American data. In this study all the assessments by the patient, prosthodontist and surgeon were encompassed in the categories poor, fair, good and excellent. In the American data the number of categories varied. The patients used the four categories already mentioned (poor, fair, good and excellent); however, the prosthodontists used only the three categories poor, fair and good when assessing denture stability and denture retention.

In contrast, the clinical assessments by the prosthodontist and oral surgeon and the radiographic assessments of granule retention (migration) and radiodensity (bone infiltration) used five categories; poor, fair, good, very good and excellent. These differences are reflected in the tables but to allow comparisons to be drawn, the categories of good and excellent in this present study have been amalgamated in the cases of denture stability and retention and in the situation where the American data has five categories the good and very good categories have been amalgamated.

Neither did the American studies differentiate between 'initial' and 'subsequent' in postoperative time and instead presented all their data from a range of postoperative times under the one heading of post-implant. To allow comparison, the data used from this present study will be that of the 'subsequent' (long term) assessment.

In an attempt to simplify the data relevant to the patients' evaluations Table 26 records the patients' general satisfaction with their new dentures in the five studies (four American and this present study). Whereas Table 27 compares the patient data for all the postaugmentation parameters between Rothstein et al 1984C and this study but only in the good and excellent categories.

Table 26 shows a similar distribution of results for all the studies with

TABLE 26

**PATIENTS' GENERAL SATISFACTION
WITH THEIR POSTAUGMENTATION DENTURES**

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988
No. of ridges treated	31	56	142	79	15
Categories of assessment					
Poor	0	0	1.4	1	0
Fair	0	0	14.1	9	10
Good	72	68.4	55.6	57	35
Excellent	28	31.6	28.9	33	55

All figures in percentages.

the predominant assessments being good or excellent. However, there is a slightly higher percentage in the excellent category from this present study. This trend is continued in Table 27 with all categories other than appearance showing an increased percentage in the excellent category for this study when compared with Rothstein et al (1984C).

The fact that the American patients were predominantly assessing mandibular dentures could account for the differences as the mandibular denture is traditionally the more unsatisfactory. The numbers are too small to justify any statistical conclusions, but they do emphasise that a similar improvement was apparent in this present study to those recorded in the American studies.

Table 28 compares the data from the five studies on denture stability as assessed by the prosthodontist and Table 29 assesses denture retention. Denture stability shows a distribution of results similar to the patients' data, with the majority of dentures being classified as good, the American studies ranging from 68 to 85.7 per cent and this study 74 per cent (58 + 16 per cent) (Table 28).

Less correlation is seen in the case of denture retention (Table 29). In the good category the American studies range between 60 and 66.6 per cent which is in marked contrast to the 100 per cent (79 + 21 per cent) in this present study. It would be tempting to explain this by the greater retention capacity of a maxillary denture when compared with a mandibular denture. However, in the assessments of denture stability and denture retention the results from mandible and maxilla were presented separately in the American studies and therefore these data are a direct comparison of maxillary dentures. There is, therefore, no clear explanation for the perceived improvement in denture retention in this present study. It is interesting to note in passing that in the American study of Rothstein et al (1984C) the mandibular denture was rated higher for good retention than the maxillary denture (68 to 60 per cent).

TABLE 27

COMPARISON OF THE GOOD AND EXCELLENT CATEGORIES
FOR ALL PATIENT ASSESSMENT PARAMETERS
POSTAUGMENTATION

Studies	Good		Excellent	
	Rothstein et al (1984C)	This study	Rothstein et al (1984C)	This study
No. of patients	79	15	79	15
Parameters				
Ability to eat	57	40 (-17)	20	50 (+30)
Speech	44	30 (-14)	49	55 (+6)
Denture comfort	53	35 (-18)	25	65 (+40)
Denture fit	54	30 (-24)	29	60 (+31)
Appearance	44	40 (-4)	52	45 (-7)
Taste	57	40 (-17)	37	55 (+18)
General satisfaction	57	35 (-22)	33	55 (+22)

All figures in percentages.

Figures in brackets represent the differences in per cent between the two studies.

TABLE 28

PROSTHODONTISTS' ASSESSMENT OF
DENTURE STABILITY

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988
No. of maxillae treated	6*	9*	21	15	15
Categories of assessment					
Poor	12	7.9	0	0	5
Fair	16	23.7	14.3	27	21
Good	72	68.4	85.7	73	58
Excellent					16

All figures in percentages.

* Kent et al data from total number of treated ridges.
1982 - 31 ridges
1983 - 56 ridges

TABLE 29

PROSTHODONTISTS' ASSESSMENT OF
DENTURE RETENTION

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988
No. of maxillae treated	6*	9*	21	15	15
Categories of assessment					
Poor	4	2.6	0	0	0
Fair	36	34.2	33.3	40	0
Good	60	63.7	66.6	60	79
Excellent	-	-	-	-	21

All figures in percentages.

* Kent et al data from total number of treated ridges,
1982 - 31 ridges
1983 - 56 ridges

Table 30 compares the data concerning the clinical assessment by the prosthodontists. A similar distribution is evident in all the studies with the majority of results within the excellent and good/very good categories. However, there are fewer dentures assessed as excellent in this present study (16 per cent) than in the American studies (25-36 per cent).

Table 31 correlates the oral surgery assessments and shows the greatest variance of all the results. The present study gives the least optimistic appraisal, with 17 per cent of the ridges rated fair compared with a range from 0-6 per cent in the American studies. This is reflected throughout the other categories with 33 per cent rated excellent in this present study compared with a range of 30 to 65 in the American studies. These wide differences in the American data is in itself interesting and it is in the two studies with the greatest number of cases (Rothstein et al 1984B, 1984C) that the results most closely approximate those of this present study. There was, however, a marked difference in the method of assessment between the American studies, which relied heavily on radiographic interpretation, and this present study which utilised a composite of clinical, photographic and radiographic sources.

1.2.2. Objective assessments - Histology, Radiographs and Study models

It is difficult to draw any conclusions from the histological examination of only one specimen but the results were not unexpected. The encapsulation of the granules by fibrous tissue rather than bone supports the work of Beirne and Greenspan (1985)(Chapter IV, section 1.4.2.) and would explain the finding in this study that the radiodensity of the augmented areas did not increase with time (Chapter VII, section 5).

The presence of a bone spicule could indicate that the specimen was taken closer to the HA/bone interface than those in the Beirne and

TABLE 30

**CLINICAL ASSESSMENT
BY THE PROSTHODONTISTS**

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988
No. of ridges treated	32	56	136	89	15
Categories of assessment					
Poor	0	0	1	0	0
Fair	0	3	6	10	10
Good	(14) 64	(10) 63	(25) 65	(25) 65	74
V. good	(50)	(53)	(40)	(40)	
Excellent	36	34	28	25	16

All figures in percentages.

TABLE 31

ASSESSMENT BY THE ORAL SURGEONS

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988
No. of ridges treated	32	56	141	95	15
Categories of assessment					
Poor	0	0	1	0	0
Fair	0	0	1	4	17
Good	(0) 35	(3) 45	(23) 63	(20) 57	50
V. good	(35)	(42)	(40)	(37)	
Excellent	65	55	35	30	33

All figures in percentages.

Greenspan study but nowhere in the specimen was there evidence of bone in contact with the granules as was observed by Chao and Poon (1987) in biopsies removed from close to the HA/bone interface. It is now clear that only the granules in closest apposition to the underlying bone will show evidence of envelopment by bone. The majority of granules, if placed without the addition of fresh autogenous bone, become surrounded only by acellular fibrous tissue.

This lack of bone ingrowth could favour consideration of using fresh autogenous bone in conjunction with the HA granules in a bid to stimulate osteogenesis at sites distant from the HA/bone interface so denying, to some degree, the infiltration of the fibrous connective tissue. However, as mentioned previously, this would create all the problems associated with a donor site that HA alone avoids.

While this study did not attempt to quantify the degree of mobility following surgery, due to the impossibility of developing an objective method of measurement, nevertheless a subjective clinical impression was gained and could possibly be linked with the histological observations.

In the small number of cases where comparisons of tissue mobility could be observed over an extended period, it appeared that the initially firm augmented ridge became increasingly mobile; but never to the degree originally present. A similar observation was made when sclerosing solutions were used to stimulate the formation of fibrous tissue within hypermobile ridges (Desjardins and Tolman 1974, Chapter III, section 2.1.4.2.). In that study, the mobility did not increase past the initial relapse and never approached the pretreatment state. It is, however, a possible long term disadvantage of allowing the granules to become surrounded by fibrous tissue.

Beirne and Greenspan (1985) demonstrated a minimal inflammatory response to the presence of granules and identified multi-nucleated giant cells in contact with the implant. In the biopsy specimen available to this

study the quantity of giant cells and histiocytes present appeared to be greater than previously reported.

The presence of these cells could possibly be linked, in the case biopsied, to the concurrent bilateral antral floor defects. These defects, which were not present at the first operation, could indicate that bone resorption is promoted by the presence of HA granules. The mechanism might be either direct pressure by the granules on the underlying bone or an immune response to the HA material, both of which could stimulate the formation of osteoclasts. The potential for this complication was raised by Desjardins (1985) and Frame et al (1987) found experimental evidence of resorption in the initial phase following implantation of granules into dogs, even though the augmented ridges were never placed in function.

The resorption of underlying bone is a recognised feature of certain alloplastic materials but if it is proved to be a feature of HA granules it would negate any benefit gained from the augmentation. It is an important question that is presently unanswered and one that would require a comprehensive long term clinical study to resolve.

Analysis of the radiographs provided some insights but they were not as informative as had been indicated by previously reported studies. This was partly due to the inherent difficulties of adequately demonstrating the anterior maxilla without distortion or superimposition and partly due to lack of standardisation which did not allow direct measurements.

Tables 32 and 33 compare the radiographic data available from the four American studies detailed previously with the results obtained in this present study.

Table 32 records the data on granule retention (poor, signifying gross granule migration, excellent, no granule migration). As mentioned earlier, the American data was primarily collected from OPTs and predominantly assessed mandibles. When the OPT was used in this present study results comparable with the American data were achieved, with the overwhelming

TABLE 32

RETENTION OF GRANULES ASSESSED RADIOGRAPHICALLY

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988	
No. of ridges treated	32	56	141	93	15	
Categories of assessment					OPT	LC
Poor	0	0	1	0	0	27
Fair	0	3	3	2	0	20
Good	(13) 39	(5) 51	(18) 62	(14) 65	71	20
V. Good	(26)	(46)	(44)	(51)		
Excellent	61	46	34	33	29	33

All figures in percentages.

OPT = Orthopantomogram

LC = Lateral Cephalometric

majority of radiographs showing no or minimal migration. However, a different, less optimistic set of data was collected from the lateral cephalometric radiographs. The difference was due to midline migration of the granules along the surface of the anterior nasal spine (Fig. 44 to 48) which could only be identified in the lateral view. It is possible that the American studies would not have reported so favourably if a lateral radiograph had been included in their assessment.

Table 33 compares the data on radiodensity which was used to assess the degree of bony ingrowth around the granules. Comparing radiodensities can be an extremely unreliable method of assessment unless a rigorous set of standardisation procedures has been followed. This applies not only to exposure and developing but also to other aspects such as calibrating the densitometer. This strict protocol was followed by neither the American studies nor this present one and therefore the results must be suspect and any interpretation guarded.

In comparing the results, a marked difference can be observed. The American data is again favourable with the majority of results falling within the good and excellent categories. The reverse is true of the results from this study. In only two cases was there any evidence of the radiodensity increasing in both the OPT and lateral cephalometric radiographs and only to a limited degree. This resulted in 86 per cent being rated poor and the remaining 14 per cent being rated either fair or good with no evidence of excellent results. The reason for this large discrepancy between the two sets of data is unclear and cannot be explained but in the absence of bone growth around the granules as demonstrated histologically, no evidence of increased radiodensity would be expected.

The composite radiographic tracings created by adapting the technique outlined by Rothstein et al (1984A) proved a successful way of confirming the extent of granule migration and the minimal degree of relapse (height loss in the granules) with the passage of time. The most striking aspects when the

TABLE 33

RADIODENSITY (BONE INFILTRATION)
ASSSED RADIOGRAPHICALLY

Studies	Kent et al 1982	1983	Rothstein et al 1984B	1984C	This study 1988	
No. of ridges treated	32	56	141	93	15	
Categories of assessment					OPT	LC
Poor	0	0	1	0	86	86
Fair	0	0	3	3	14	7
Good	(4) 30	(2) 42	(35) 69	(35) 66	0	7
V. Good	(26)	(40)	(34)	(31)		
Excellent	70	58	27	31	0	0

All figures in percentages.

OPT = Orthopantomogram
LC = Lateral Cephalometric

tracings are compared is the constancy of the outlined image.

Kent et al (1983) analysed the augmentation height gain in four maxillary cases with an image analysis system utilising fixed anatomical points on the radiographs. They found a mean increase in ridge height of 35 per cent but this only reflects the granular height and not the true height of the mucosal surface. In this study no definitive height measurements could be taken from the radiographs and therefore no data on height increase or relapse rates could be calculated.

It has not been possible either to compare the data from the study models with any other studies. In no previous study has more than a visual impression of the study models been attempted, apart from Rothstein et al (1984C) who measured ridge width but recorded no results. A visual impression of the models from this present study coincides with impressions gained from the composite profile tracings, namely, that the ridges increase primarily in width, only minimally in height and become more convex in profile.

The data reflecting the changes in cross-sectional area with time highlights quantitatively three aspects pertinent to ridge augmentation with HA granules. The first is that augmentation benefits the smaller ridges more substantially than the larger ones. The second is that the relapse rate (loss of area over a period of time) is not significant during the time period studied and thirdly that the degree of cross-sectional area increase achieved is not very substantial even for small ridges. However, when the increase in area is multiplied by the length of the augmented ridge there must be a significant increase in ridge size. This area increase in conjunction with the decrease in mobility must ultimately benefit the patients as evidenced by their improved experience with the dentures made on the augmented ridges.

In summary it would appear that:

- There was minimal granule and overlying soft tissue relapse during

the time of this study.

- There was an increase in width but not substantially in ridge height following augmentation.
- The ridge profile becomes more convex.
- The increase in cross-sectional ridge area is relatively small but the increase is sustained.
- Radiographs are required in different planes to accurately determine the extent of granule migration.
- Fibrous tissue rather than bone infiltrates around the majority of HA granules.
- Resorption of the underlying bone due to the presence of granules is a possibility.
- Mobility of the augmented ridge may increase with time.

2. CONCLUSION

Nothing would be done at all if a man waited until he could do it so well that no one could find fault with it.

Cardinal Newman (1801-1890)

The results of this study show that the augmentation of the anterior maxilla with the alloplastic material hydroxylapatite does have a role in the management of the hypermobile anterior maxillary alveolar ridge.

It has been demonstrated that the present range of preprosthetic surgical techniques applicable to the anterior maxilla fall short of the ideal solution to the particular problem of hypermobile tissue.

Hydroxylapatite has previously been shown, both experimentally and clinically, to be an acceptable graft material in the oral environment and the research herein reported has concentrated on its suitability in the anterior maxilla.

In the course of the present research, both the surgical technique necessary for placement of the material and the assessment of the results have been analysed and discussed. Suggested changes to the surgical protocol have been made both to simplify the procedure and reduce the postoperative complications. A new method for analysis of postaugmentation study models has been developed and used in conjunction with other recognised methods to provide a comprehensive appraisal of the surgical and prosthodontic results.

As a result of this work it is evident that:

- The clinical data from patients, prosthodontists and oral surgeon all show an improvement in the quality of the denture bearing area, a reduction in tissue mobility and a more satisfactory denture.
- Sequential study models taken at stages during treatment can reflect

the shape and profile changes of the ridge and that the changes be accurately quantified.

- Sequential radiographs can be accurately compared for evidence of both granule migration and settling in the maxilla but not for apposition of the granules or direct height measurements.
- The operative and postoperative complications associated with the use of hydroxylapatite are very low, with the prevention of granule migration being the greatest technique problem.
- The presence of hydroxylapatite in the tissues of the anterior maxilla does not appear to stimulate osteogenesis or a significant inflammatory reaction and that the reduction in tissue mobility is most probably due to the presence of the granules in combination with a surrounding matrix of fibrous tissue rather than the granules becoming encased in bone.
- The presence of hydroxylapatite within the tissues may not arrest the continuing resorption of the underlying bone and may even promote the resorption.

It can therefore be concluded that the technique of placing hydroxylapatite granules subperiosteally in the anterior maxilla to manage hypermobile tissue has the following advantages over other applicable surgical techniques:

- It is a simple, predictable outpatient procedure.
- It produces minimal operative or postoperative complications.
- There is no graft donor site morbidity.
- There is no necessity for any additional or secondary procedures.
- The patient is never aesthetically compromised and can have new dentures constructed early in the postoperative phase.

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APPENDICES

APPENDIX I

COMPANIES MANUFACTURING COMMERCIALY AVAILABLE HA AND TCP

<u>TRADE NAME</u>	<u>COMPANY</u>
Calcitek TM 4060	Calcitek Inc. 4125 Sorrento Valley Blvd. San Diego CA 92121 USA
2040	
Calcitite ^R Orthoblocks	
Calcitite ^R RM	
Integral ^R	
Alveograf ^R	Cook-Waite Laboratories Inc. 90 Park Avenue New York NY 10016 USA
Periograf TM	
Interpore 200 TM	Interpore International 18005 Skypark Circle Irving CA 92714 USA
Interpore 500 TM	
Allotropat ^R 25	Helytex Corporation 10665 Richmond Av Houston Texas 77042 USA
50	
Permagraft TM	Park Dental Research Corp. 19 West 34th Street New York NY 1001 USA
Synthograft TM	
Augmen TM	
Osteogen ^R (HA Resorb) TM	G.B.D. Marketing Group Inc. Medical Division Valley Stream NY 11580 USA
HA-1000 ^R	Orthomatrix TM 6968 Sierra Court Dublin CA 94568 USA
Ceros ^R 80 (HA)	Rob. Mathys Co. Fabrik fur Chirurgie-Instrumente CH-2544 Bettlach Schweiz
Ceros ^R 82 (TCP)	
Ostilt ^R	Howmedica ^R International Pfizer Hospital Products Ltd Staines House, 158-162 High Street Staines TW 18 4 AZ U.K.

APPENDIX II

AUGMENTATION PATIENTS

LABEL/NAME

DATE:

OLD DENTURES
NEW DENTURES

PATIENT QUESTIONNAIRE

	Excellent	Good	Fair	Poor
1) Comfort	_____	_____	_____	_____
2) Fit	_____	_____	_____	_____
3) Speech	_____	_____	_____	_____
4) Appearance	_____	_____	_____	_____
5) Ability to eat	_____	_____	_____	_____
6) Ability to taste	_____	_____	_____	_____
7) General satisfaction	_____	_____	_____	_____

Comments: _____

APPENDIX III

AUGMENTATION PATIENTS

PROSTHODONTIC ASSESSMENT

LABEL/NAME

DATE: _____
MONTHS POST OP _____
MONTHS WEARING NEW DENTURES _____

<u>RETENTION</u>	<u>PDDR</u>	<u>FAIR</u>	<u>GOOD</u>	<u>EXCELLENT</u>
OLD DENTURES				
NEW DENTURES				

<u>STABILITY</u>	<u>PDDR</u>	<u>FAIR</u>	<u>GOOD</u>	<u>EXCELLENT</u>
OLD DENTURES				
NEW DENTURES				

<u>OVERALL CLINICAL ASSESSMENT</u>	<u>PDDR</u>	<u>FAIR</u>	<u>GOOD</u>	<u>EXCELLENT</u>
PRE OPERATION				
POST OPERATION				

<u>MUCOSAL HEALTH</u>	<u>PDDR</u>	<u>FAIR</u>	<u>GOOD</u>	<u>EXCELLENT</u>
PRE OPERATION				
POST OPERATION				

COMMENTS: _____

APPENDIX IV

AUGMENTATION PATIENTS

ORAL SURGERY ASSESSMENT

LABEL/NAME

PRE OP DATE:
MEDICAL COMPLICATIONS
MUCOSAL HEALTH
MEDICATIONS
ALLERGIES

OPERATION DATE:
PROCEDURE
ANAESTHETIC
NO. HA SYRINGES USED
SUTURE MATERIAL
SURGEONS
COMPLICATIONS
MEDICATIONS
STENT

POST OP	1/52	2/52	3/52	1/12	3/12	6/12	1YR	2YR
DATE								
DEHISCENCE								
SENSORY CHANGE								
PARTICLE MIGRATION								
ULCERATION								
INFECTION								
STENT REMOVAL								

COMMENTS:

X' RAYS (3/12 POST OP)	POOR	FAIR	GOOD	EXCELLENT
RETENTION OF PARTICLES				
BONE INFILTRATION				
BONE/IMPLANT INTERFACE				
CLINICAL ASSESSMENT				

APPENDIX V

Preaugmentation image

A.R.

T.

6 months postaugmentation

Tuberosity

Anterior
ridge

12 months postaugmentation

T.

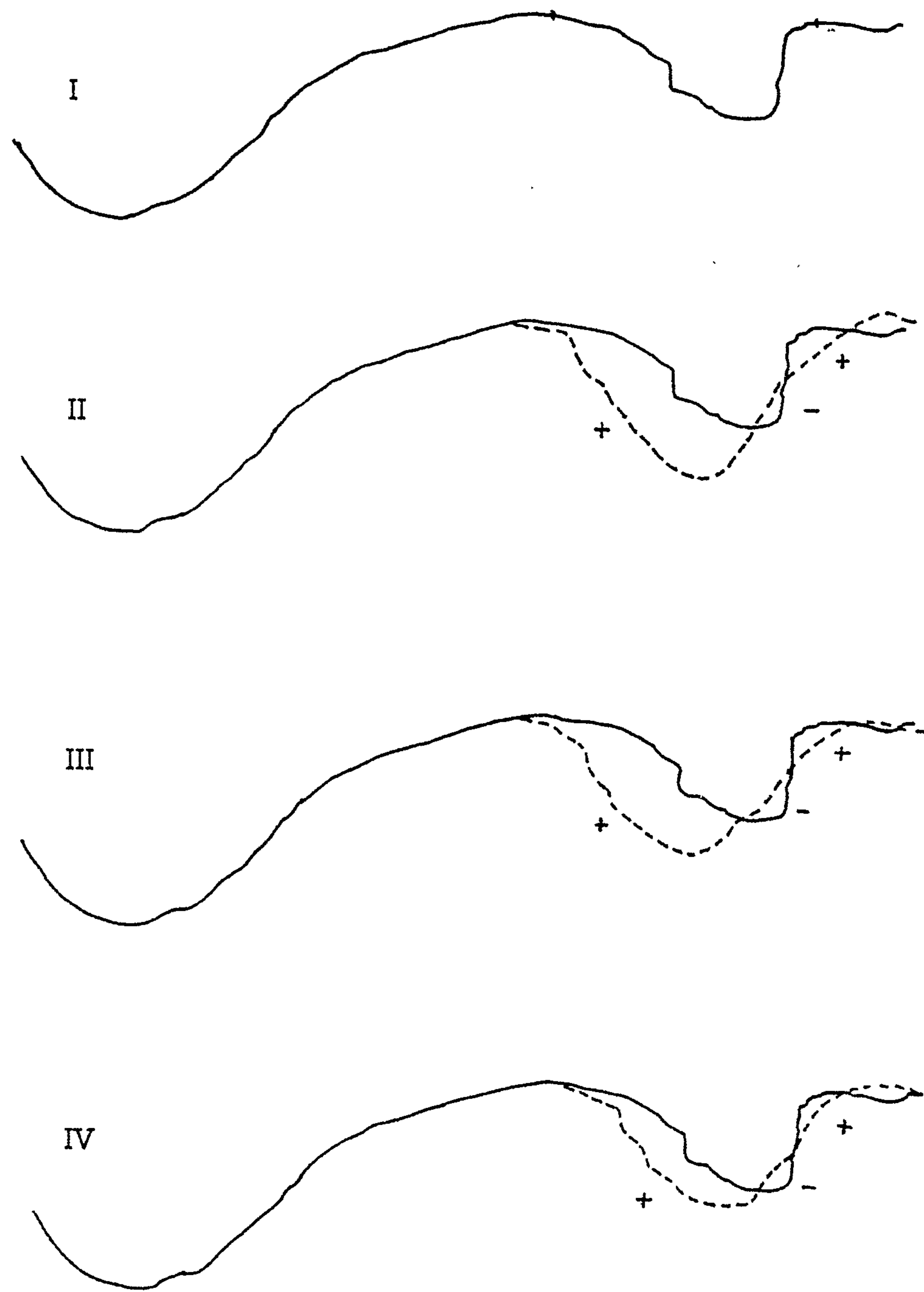
A.R.

18 months postaugmentation

T.

A.R.

APPENDIX VI



Tracings for patient 4 (EF) drawn from the images of Appendix V. The continuous line is the preoperative tracing and the broken line the profile following augmentation at 6 months (II), at 12 months (III), and at 18 months (IV). Plus indicates increases and minus decreases in area.

APPENDIX VII

PATIENT QUESTIONNAIRE SUMMARY
(RESPONSES EXPRESSED AS PERCENTAGES)

PARAMETER		ASSESSMENT			
		Poor	Fair	Good	Excellent
Ability to Eat	PA	73	27		
	IPA	7	7	36	50
	SPA		10	40	50
Speech	PA	7	40	46	7
	IPA		14	43	43
	SPA		15	30	55
Denture comfort	PA	46	40	7	7
	IPA	7	7	36	50
	SPA			35	65
Denture fit	PA	53	40	7	
	IPA	7	14	21	57
	SPA		10	30	60
Appearance	PA	33	20	47	
	IPA	8		42	50
	SPA		15	40	45
Taste	PA	13	27	60	
	IPA		21	36	43
	SPA		5	40	55
General Satisfaction	PA	60	33	7	
	IPA		14	29	57
	SPA		10	35	55

PA - Pre-augmentation Assessment

IPA - Initial Postaugmentation Assessment (one to three months)

SPA - Subsequent Postaugmentation Assessment (three to fourteen months)

APPENDIX VIII

PROSTHODONTIC QUESTIONNAIRE SUMMARY (RESPONSES EXPRESSED AS PERCENTAGES)

PARAMETER		ASSESSMENT			
		Poor	Fair	Good	Excellent
Clinical Assessment	PA	67	33		
	IPA		8	75	17
	SPA		10	74	16
Retention	PA	73	27		
	IPA		25	75	
	SPA			79	21
Stability	PA	80	20		
	IPA		42	58	
	SPA	5	21	58	16
Mucosal health	PA	20	53	27	
	IPA	8	8	67	17
	SPA	5	21	69	5

PA - Pre-augmentation Assessment

IPA - Initial Postaugmentation Assessment (one to three months)

SPA - Subsequent Postaugmentation Assessment (three to fourteen months)

APPENDIX IX

ORAL SURGERY ASSESSMENT SUMMARY (expressed as a percentage)

Time	Assessment			
	Poor	Fair	Good	Excellent
Preoperative	60	40		
Postoperative				
3 months		20	53	27
6 months		13	60	27
1 year		10	60	30
18 months		17	50	33

ENCLOSURE I

HYDROXYLAPATITE AND ITS ROLE IN RIDGE AUGMENTATION AND PRESERVATION

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ABSTRACT

A review of the current literature concerning the research and clinical applications of the alloplastic augmentation material hydroxylapatite is presented. Included are indications for atrophic ridge augmentation and the characteristics of a number of commercially available hydroxylapatites. A description of the surgical technique and subsequent prosthodontic care together with a review of published results to date are also included. Finally the possibilities for preventive prosthodontics utilising hydroxylapatite root implants in extraction sockets are discussed.

Key words: Augmentation, Hydroxylapatite, Pre-prosthodontic surgery, Root implants.

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dental implant materials and procedures"
conducted under the auspices of the
University of Sydney Postgraduate
Committee in Dental Science, Sydney,
17-20 November 1986

INTRODUCTION

Surgery to assist the wearing of dentures has as long and distinguished a history as the provision of the dentures themselves, (Starshak 1980). Traditionally, surgery has been of a minor corrective nature following the removal of teeth, or procedures such as the elimination of undercuts or the removal of hyperplastic tissue. The more extensive pre-prosthetic surgical procedures have commonly been viewed with more suspicion by prosthodontists. A recent survey showed 25% of specialist prosthodontists had no experience of maxillary augmentation and 9% no experience with mandibular augmentation (Meador et al. 1986). This suspicion may have arisen because the emphasis by surgeons has largely been on creating an environment for greater retention without equal consideration being given to denture stability and the quality of the attached mucosa (Castleberry 1982). Meador et al. (1986) concluded that no consensus existed in many areas relating to the surgical management of the prosthodontic patient, including what constituted an adequate ridge height. Taylor (1986) in his comprehensive article wrote,

"it may be that there has not been enough co-operation between oral surgeons and prosthodontists. Perhaps this is the reason that so many earlier attempts at augmentation failed."

The continuous resorption of the edentulous mandible seems inevitable with only the rate of resorption varying (Atwood 1971). This raises the spectre that many patients with full dentures could at some stage require alveolar augmentation. The skills of prosthodontists keep these numbers down to manageable levels; however, of the nearly 38 million denture wearers in the United States, five million (13%) have insufficient alveolar bone height (Boyne 1982, Rothstein et al. 1984A).

Many surgical techniques have been proposed for the improvement of the denture base (Table 1).

Table 1
Surgical alternatives for the atrophic ridge

(1)	Metallic implants
	Subperiosteal
	Endosseous
	Osseointegrated
	Magnetic
	Transosseous (staple)
(2)	Vestibular extension
	Buccal vestibuloplasty
	(with or without grafts)
	Mylohyoid ridge reduction
	Lowering mouth floor
(3)	Augmentation
(a)	Onlay (free) bone graft — mandible
	Superior border
	Inferior border
(b)	Pedicle bone flap — mandible
	(with or without grafts)
(c)	Skeletal base osteotomy — maxilla
(d)	Alloplastic graft — maxilla mandible

Recently the emphasis has been on the merits of various implants such as the transosseous or osseointegrated systems. Such methods effectively bypass the problem of the grossly resorbed alveolar ridge and rely on the mechanical strength of the implants and their bond to bone.

The more traditional techniques can be divided into two groups: Those which seek to increase the relative height of the ridge by increasing the depth of the surrounding vestibules (vestibuloplasties) and those that add absolute height to the alveolar ridge by augmentation. Various vestibuloplasty procedures have been developed but all have the major disadvantage that they require at least 15 mm of residual basal bone measured at the mandibular symphysis on a lateral cephalometric radiograph. Ridges which measure less than 15 mm should primarily be considered for augmentation. Other conditions where augmentation should be considered include young patients undergoing rapid alveolar resorption, a large inter-arch distance and prominent mental nerves. In the maxilla an indication for augmentation is a hypermobile (flabby) ridge where the close proximity of the nasal floor and nares precludes an anterior vestibuloplasty.

When pre-prosthodontic surgical augmentation is contemplated, a

joint consultation between the prosthodontist, surgeon and patient is mandatory.

"It is critical that surgeon and prosthodontist jointly diagnose and treatment plan augmentation procedures, especially when using hydroxylapatite" (Taylor 1986).

Examination of the patient's motivation, health and prosthetic history with a discussion of the surgical alternatives will create a greater degree of patient satisfaction at the culmination of treatment; but the comments by Lawson (1972) should be heeded:

"There is no advantage in having surgery for surgery's sake and bad surgery is worse than none at all" and "pre-prosthetic surgery is only of value if a better prosthesis can be constructed as a consequence."

Finally if any implant material is considered for use it must fulfil the guidelines laid down by the Harvard Consensus Conference on dental implants which stated that to be successful a dental implant should provide satisfactory functional service for five years in 75% of cases (Schnitman 1979).

Alloplastic materials — Hydroxylapatite

Ridge augmentation was initially developed using as an augmenting material autogenous bone harvested either from a rib or the iliac crest. The long-term results have been disappointing due to the degree of resorption experienced irrespective of the surgical technique used or the donor site from which the bone was taken (Baker et al. 1979, van Sickels et al. 1984). This has led to a search for an alloplastic material which would become the ideal bone substitute. An alloplastic material is an inert foreign body that can be implanted into living tissue without provoking an adverse tissue response.

An ideal material should be non-toxic and non-antigenic, biologically inert, as strong and flexible as bone and directly interface with the living bone surface without any

interposing material. Absence of this ideal material has lead to experimentation with a multitude of substances ranging from various metals and polymers to ceramics (Topazian et al. 1971, Harle et al. 1984). None has proved satisfactory in the long-term but the recent experience and results with hydroxylapatite have been very encouraging.

Hydroxylapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$), (herein referred to in the text as HA), is the predominant crystal in human calcified tissue.

It is physically and chemically identical to the mineral phase of bone. It has, however, only been successfully synthesised and purified for implantation in the last decade, having been licenced for use in humans in the USA in 1981 and Australia in 1986 (Jarcho et al. 1977, 1979, Griffiths 1985).

Since the introduction of HA it has found diverse use in surgery such as Van Blitterswijk (1984) but it is the specialties of dentistry which have been the most diligent in both research and clinical applications. Periodontists have used HA to good effect in periodontal osseous defects (Forrest 1986), and maxillo-facial surgeons have applied it to a range of procedures, such as orthognathic surgery (Kent et al. 1986A, Waite 1986); filling pathological defects (Allard et al. 1982, Block et al. 1986A, Zide 1986); with soft tissue surgery (Shafer et al. 1984) and ridge augmentation, either alone (Kent et al. 1982, 1983); as an adjunct to pedical grafts (Stoelinga et al. 1986, Frame et al. 1984); or with free grafts (Lew et al. 1986A, Kraut 1985).

HA has no innate osteogenic potential but acts as a space filling matrix forming a crystalline framework for the ingrowth of soft tissue components. It can be successfully sterilised, is radiopaque and for clinical purposes, non-resorbable. The merits of having a non-resorbable material for augmentation are obvious following the experience with autogenous bone which has shown a marked capac-

ity for resorption over time when used for ridge augmentation.

Tricalcium phosphate (TCP), a material chemically close to HA has been produced for ridge augmentation (AugmenTM)†, but no clinical results have been published of its use. Swart et al. (1985) used TCP in conjunction with a sandwich osteotomy with disappointing results, and the author has experience of an augmentation case in which TCP and cancellous bone were used to produce a satisfactory result only for the implant to completely resorb within six months. A clinically insignificant degree of resorption also takes place with HA. This resorption is dictated by the implant surface area (macroporosity), the material's calcium/phosphate ratio and the density (microporosity) which is a product of the manufacturing process. Resorption appears to be partly by chemical dissolution and in part by phagocytosis.

HA is commercially produced by means of a sintering process (heat and pressure applied either to a powder or a wet precipitate of HA). The surface can be either rough or smooth. Following implantation it provides a matrix allowing the ingrowth of osteoprogenitor cells.

Both HA granules and blocks are produced for augmentation and each possesses certain advantages and disadvantages. Granules are technically easier to place, and cannot be overcontoured. They remodel under stress initially but are less stable and have a tendency to migrate from the area in which they were deposited. To minimise this problem precise periosteal stripping is required to confine the granules to their desired location.

It is unclear if rough granules are more liable to cause a dehiscence through soft-tissue (Alveograf)‡ or whether smooth granules are more prone to migrate (Calcitite)¶. Both tend to settle with time. Given this

degree of uncertainty the choice of material depends on operator preference.

Replamineform HA (Interpore)* is a recent material developed as an alternative to the sintered granules (the name is derived from "replicated life forms"). The material is produced from a coral (Genus *Porites*) which is chemically altered from aragonite (CaCO_3) to HA without destroying the macroporosity inherent in the coral shape (Piecuch et al. 1983). The pore size of 140 to 160 microns has been found to be ideal for the ingrowth of osteoprogenitor cells. It is available as either porous granules or blocks.

Blocks require exact fitting, a time consuming procedure necessitating multiple adjustments in shape. They are liable to be overcontoured producing lingual undercuts and reduction of the buccal sulcus depth. The ingrowth of bone tissue into the porous blocks provides more stability but soft tissue dehiscence, particularly at the block edge, can lead to infection necessitating block removal. Neither can they adjust to changes in masticatory forces.

Non-porous blocks have also been produced but are difficult to carve to shape and they have found more favour for implantation into post-extraction sockets in an attempt to discourage resorption of the alveolar ridge.

In summary, the HA products available for augmentation include: ALVEOGRAFTM(18-40 mesh) non porous irregular granules (Fig. 1) CALCITITETM(2040-20) non porous smooth granules (Fig. 2) INTERPORETM(200) porous blocks or granules (Fig. 3a, b)

Augmentation technique using HA

The 'tunnel' technique has become the most universally accepted means of introducing HA granules subperiosteally (Alling 1984, Harle 1985, Kwon 1984, Roth-

†AugmenTM — Park Dental Research Corporation, New York

‡AlveografTM — Sterling-Winthrop Research Institute, Rensselaer, New York.

¶CalcititeTM — Calcitek Inc., San Diego, California.

*InterporeTM — Interpore International, Irvine, California.



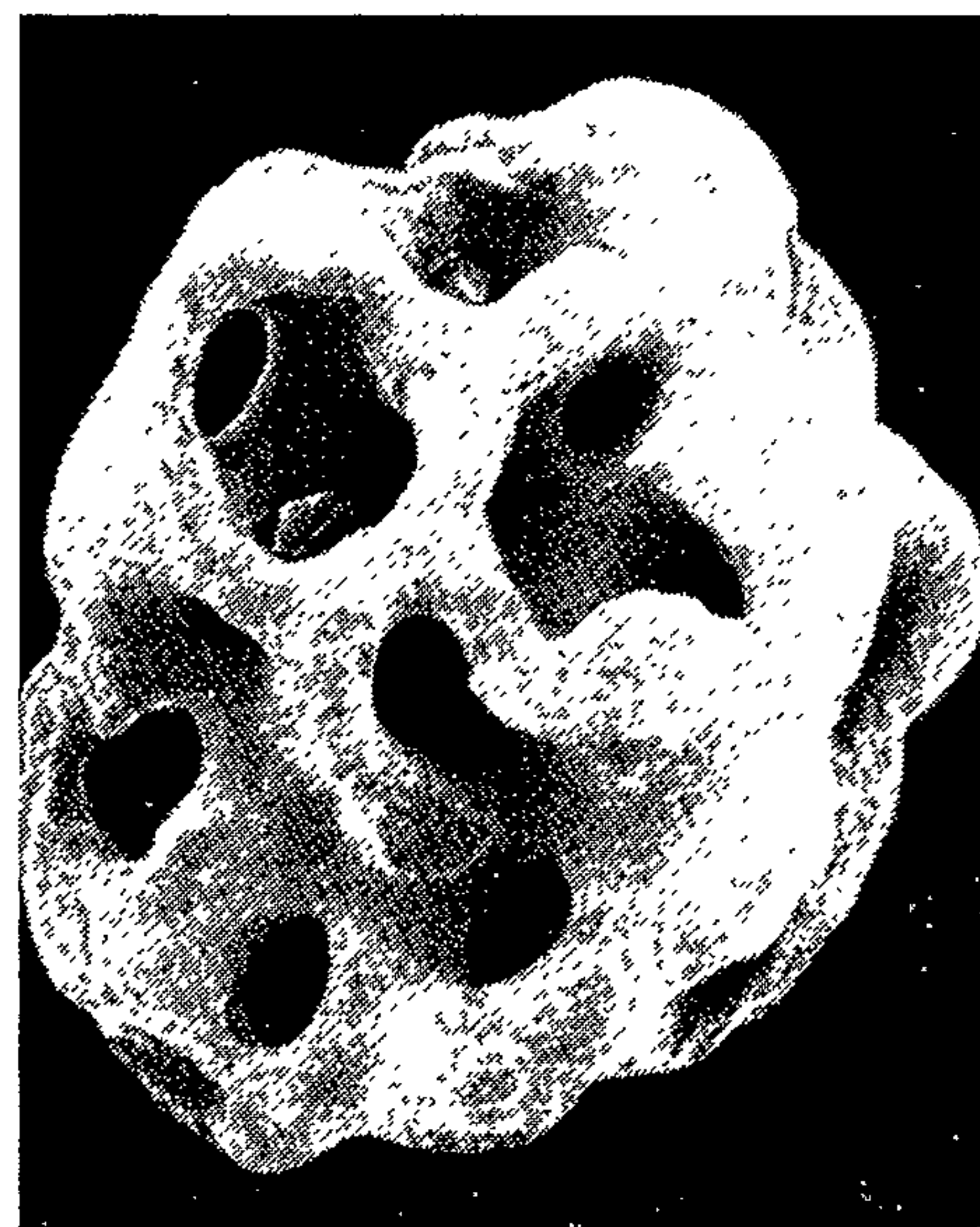
Fig. 1 A scanning electron photomicrograph of Alveograf granules. Note the irregular fractured surfaces and uniform microstructure with minimal porosity.



Fig. 2 A scanning electron photomicrograph of Calcitite granules. Note the smooth surfaces and minimal porosity.



Fig. 3a A closeup photograph of an Interpore block showing the regular distribution of the pores (from the Interpore literature).



3b A scanning electron photomicrograph of an Interpore granule (from the Interpore literature).

stein 1984A, B). It was pioneered by Kent and associates (1982, 1983) at the University of Louisiana, where it has now been in use for eight years. They also developed a simple classification of alveolar ridge deficiencies. Four classes of deficiency were identified (Table 2). Initially Class I and Class II were treated with HA alone and Class III and IV with a combination of HA and cancellous bone, usually harvested from the iliac crest. However, it has become apparent that HA alone can suffice in cases of Class III and IV deficiencies, thus eliminating the need for a general anaesthetic and surgical donor site (Kent et al.

1986B). The most conductively shaped ridges for augmentation with HA particles are broad with either a flat or concave profile, a situation which is often found distal to the mental foramen in atrophic mandibles. The material once placed can be likened in behaviour to wet sand and its ability to heighten different bases is demonstrated in Fig. 4. The degree of augmentation achievable is a product of the width and cross section of the bone base. A further advantage of a concave ridge form is that once the periosteum is raised a more substantial tunnel is created.

The technique is a straightforward procedure that can satisfactorily be completed under local anaesthesia. It permits the periosteum to be lifted from the alveolar process just in the area to be augmented and is usually combined with a submucous vestibuloplasty (Obwegeser 1964), to prevent the loss of vestibular depth after augmentation. Many modifications have been suggested with most research directed towards the problem of granule migration.

Following adequate local anaesthesia, a vertical mucosal incision is placed bilaterally in the

Table 2
Classification of alveolar ridges

Class I	Alveolar ridge adequate in height but inadequate in width, usually with lateral deficiency or undercut areas.
Class II	Alveolar ridge deficient in both height and width and presents a knife-edge appearance.
Class III	Alveolar ridge resorbed to level of the basilar bone, producing concave form on posterior areas of the mandible and a sharp, bony, ridge form with bulbous, mobile soft tissue in the maxilla.
Class IV	Resorption of the basilar bone, producing pencil-thin, flat mandible or flat maxilla.

(Adapted from Kent JN, Quinn JH, Zide MF, Guerra LR, Boyne PJ. Alveolar ridge augmentation using nonresorbable Hydroxylapatite with or without autogenous cancellous bone. *J Oral Maxillofac Surg* 1983; 41: 629-642.)

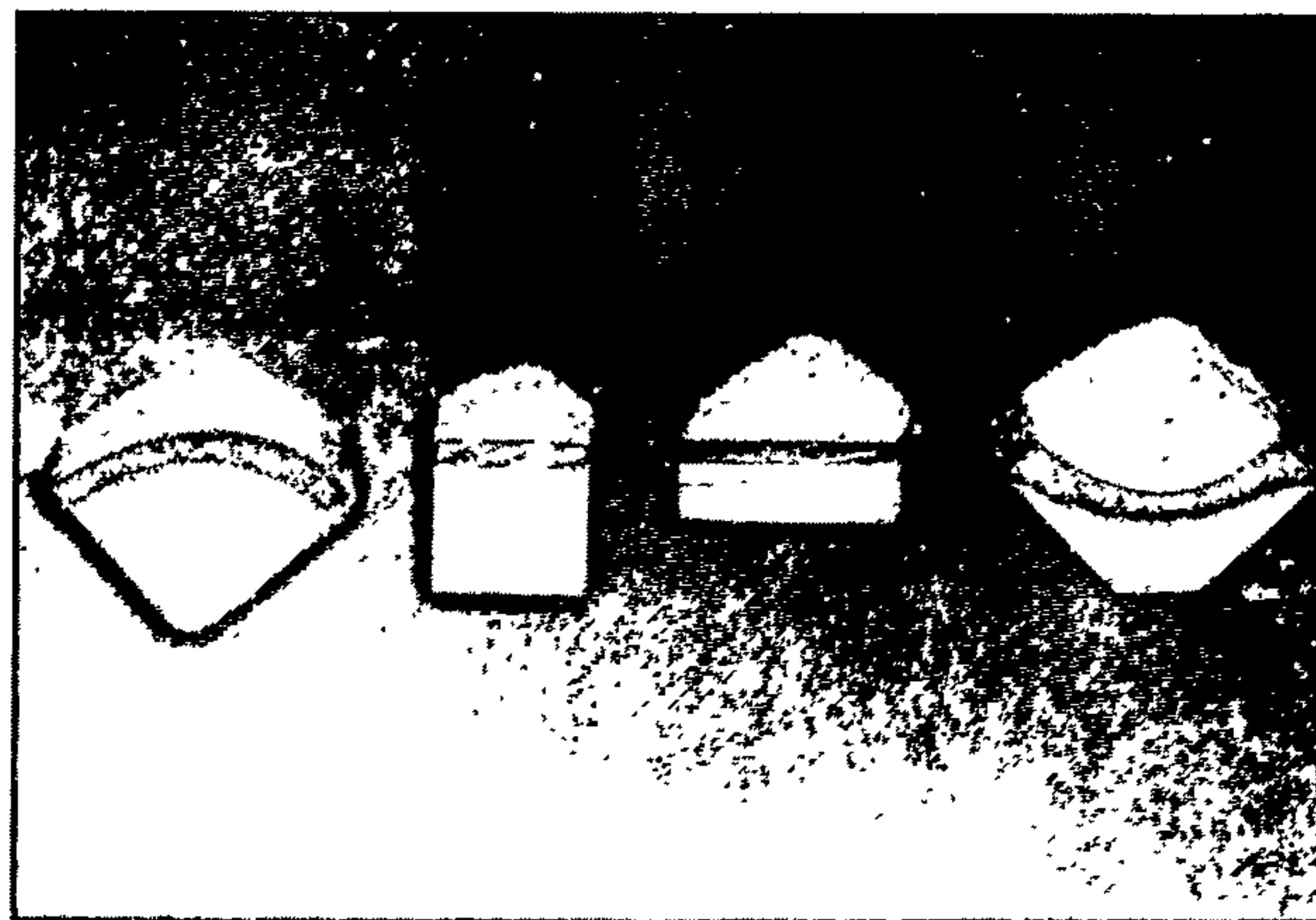


Fig. 4 Sand balanced after being poured onto different cross sections to illustrate that augmentation height is dependent on the width and cross sectional shape. Convex (left) being the least successful. Concave (right) being the most successful.

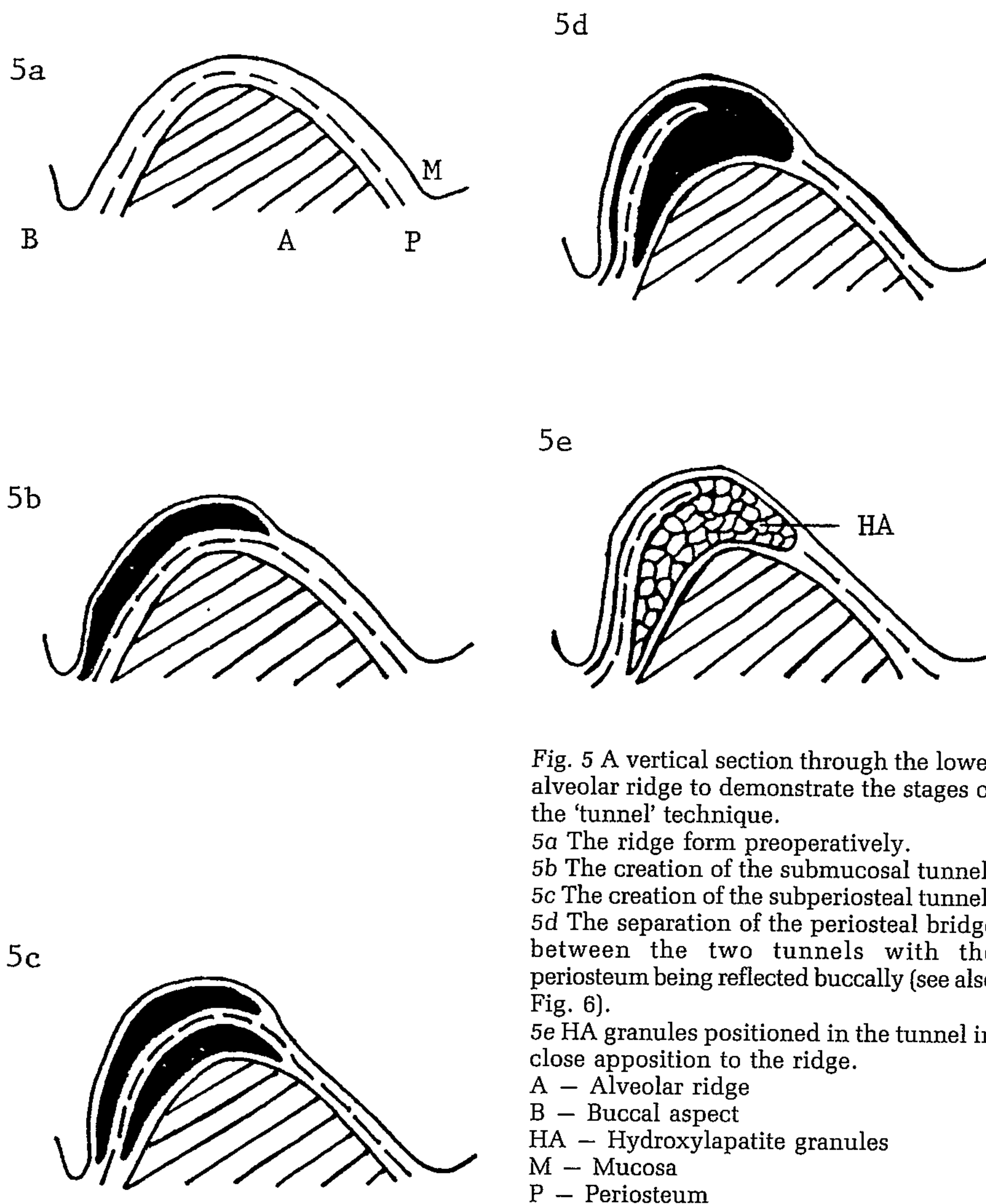


Fig. 5 A vertical section through the lower alveolar ridge to demonstrate the stages of the 'tunnel' technique.

5a The ridge form preoperatively.

5b The creation of the submucosal tunnel.

5c The creation of the subperiosteal tunnel.

5d The separation of the periosteal bridge between the two tunnels with the periosteum being reflected buccally (see also Fig. 6).

5e HA granules positioned in the tunnel in close apposition to the ridge.

A — Alveolar ridge

B — Buccal aspect

HA — Hydroxylapatite granules

M — Mucosa

P — Periosteum

canine regions of the mandible and/or in the midline of the maxilla. A suprapariosteal tunnel is then created using blind dissection with blunt ended scissors (Fig. 5b).

The incisions are then continued through the periosteum, and a subperiosteal tunnel created, preferably using a sharp, thin bladed periosteal elevator such as a Freer's. Care must be taken to identify and protect the mental nerve (Fig. 5c).

The two tunnels are then joined by cutting the periosteum over the ridge crest (Fig. 6) and reflecting the free periosteum buccally (Fig. 5d). This increases the tunnel size without placing the mucosa under tension. If the overlying ridge is mobile and fibrous, cuts can be made into the fibrous tissue from below to further expand the tunnel space. Care must be taken at this stage not to incise through the full thickness of the fibrous tissue (Fig. 7). By holding the fibrous ridge between finger and thumb and palpating the moving scalpel blade, a perforation can be avoided. This additional step greatly improves the stability and shape of the ridge post-operatively. If necessary the anterior nasal spine can be resected at this stage.



Fig. 6 The intraoperative cutting of the periosteum between the submucosal and subperiosteal tunnels.



Fig. 7 The intraoperative reverse incision used to 'fillet' maxillary hypermobile tissue prior to HA augmentation. Note the controlling fingers (bottom right).

The HA granules are prepared by wetting with normal saline (blood is not required). Some products are supplied pre-packed in sterile syringes, others in a vial from which the syringe can be filled. Complaints that the syringes are too bulky have led to the use of other dispensers such as a sterilised amalgam gun.

Problems may be experienced inserting the syringe under the flap and placement of a suture to retract the tunnel should be considered. Once in position, the syringe is slowly discharged. Tissue tension palpated over the syringe can serve to gauge the quantity to be discharged at any position. Care is needed to ensure the granules are in direct contact with the bone (Fig. 5e), (Chang et al. 1983).

Difficulty can be experienced in assessing the quantity of HA that is required for a procedure. The pre-packaged syringes contain from

0.75 to 0.8 grammes and 2-4 syringes are usually required for the maxilla, and 2-6 in the mandible, depending on whether the anterior ridge area is being augmented in conjunction with the posterior.

It is vital that the tunnel not be overfilled.

"The premise that if a little is good, a lot is better does not apply." (Desjardin 1985).

Overfilling the tunnel creates the most common postoperative complications such as dehiscence, undercuts and ridge mobility. A more precise but time consuming solution for assessing quantity is to construct a clear acrylic dressing plate on a duplicated model after the ridge has been idealised with the addition of wax (Fig. 8). The dressing plate can be tried in position and areas underfilled or blanching from overfilling can be identified (Fig. 9).

The incision is then closed, using Nylon or long acting dissolvable suture material. Final remodelling between finger and thumb at this stage allows the granules to migrate to beneath the incision line. If this is not done a cleft in the ridge will eventuate. The exception is to keep the granules clear of the mental nerve and foramen.

It is vitally important that the granules remain in a stable position during healing as they have a tendency to move up the face of the maxilla or on to the lingual surface of the mandible, producing irregular ridges and undercuts. Many ingenious solutions have been put forward to counteract this (Table 3). The most popular at present appear to be an overcontoured stent in the maxilla which is secured by screws into the palatal vault and the placement of horizontal mattress suture through the base of the tunnel in the mandible (Fig. 10). Both constrict the base of the augmented ridge. The use of soft tissue expanders could be the technique of the future (Lew et al. 1986B), but they require placement as an initial procedure, so lengthening and complicating treatment

A 'direct tunnel' technique for the mandible has been described by Barsan et al. (1985) in which the buccal mucosa is raised on a

Table 3
Techniques for limiting particle migration

Surgical stent	Barrett (1985)
Fibrin adhesives	Bochlogyros et al. (1985)
Preliminary periosteal scarring	Brook et al. (1985)
Collagen tubes	Shen et al. (1986)
Vacuum drain	Hall et al. (1985)
Two piece surgical splint	Lambert (1986)
Soft tissue expander	Lew et al. (1986B)
Open splint	Pham (1986)
Horizontal mattress sutures	Propper (1985)
Soft vinyl stents	Torres et al. (1986)

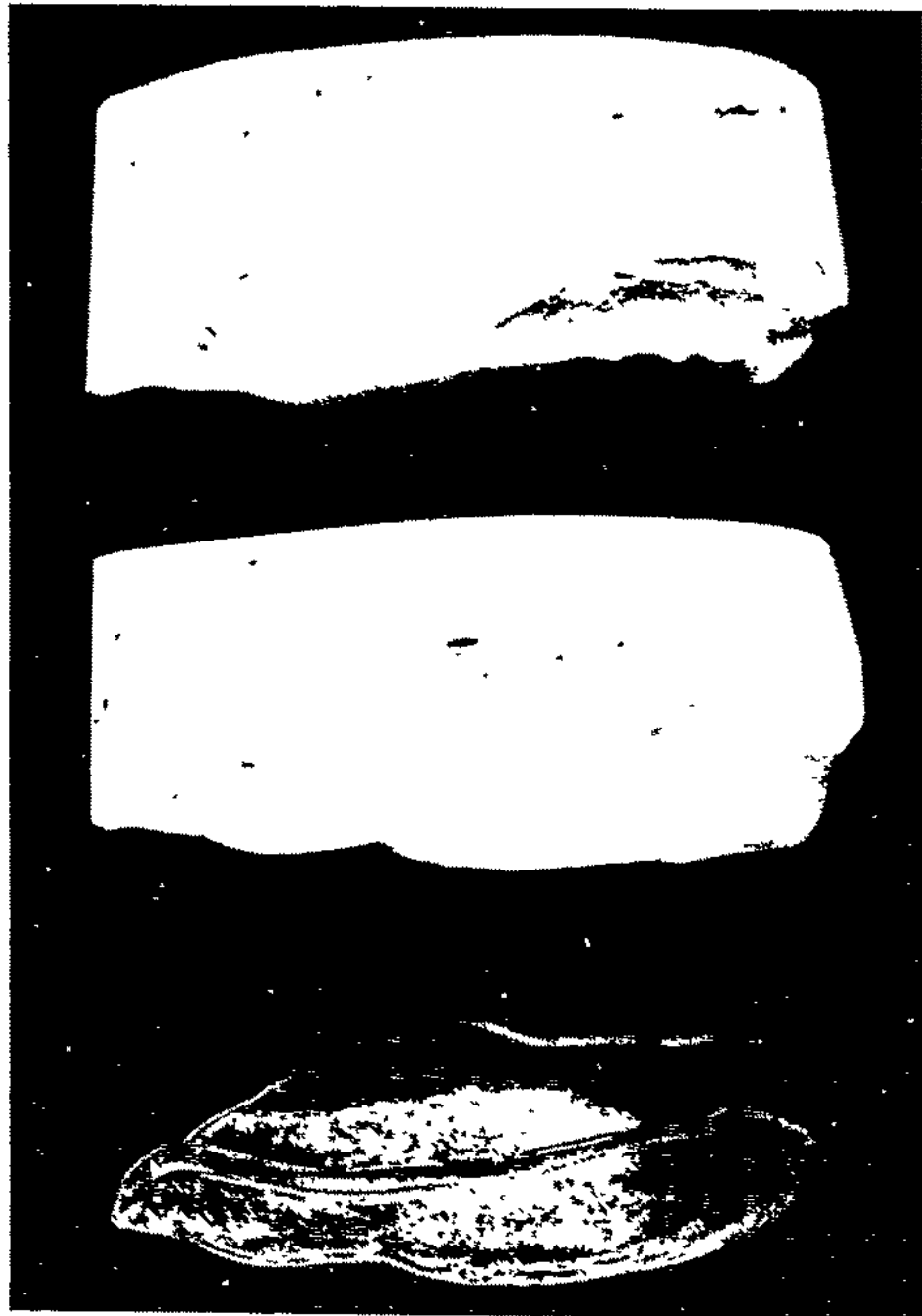


Fig. 8 A lateral view of the preoperative model (upper), the idealised ridge augmented with wax (middle) and a clear vinyl temporary stent for assessing the post-operative ridge form (lower).

lingual base from an incision in the buccal mucosa extending from right to left molar region. The dissection is made supra-periosteally to the crest of the ridge where the periosteum is then incised along the full length of the ridge and reflected buccally (Fig. 11a). The cut ends of mucosa and periosteum are then sutured together to form a spacious tunnel which is packed with HA particles (Fig. 11b). The area denuded of mucosa in the sulcus is allowed to heal by secondary intention. Jensen (1985) described a similar technique except that the periosteum was transposed into the buccal defect and the mucosa sutured into the sulcus. Another technique for the maxilla using palatal mucosa has been described by Lew (1985).

RESULTS

HA granules

The success of any new development in treatment can only be assessed by the long-term results obtained, particularly in the case of implants where the Harvard

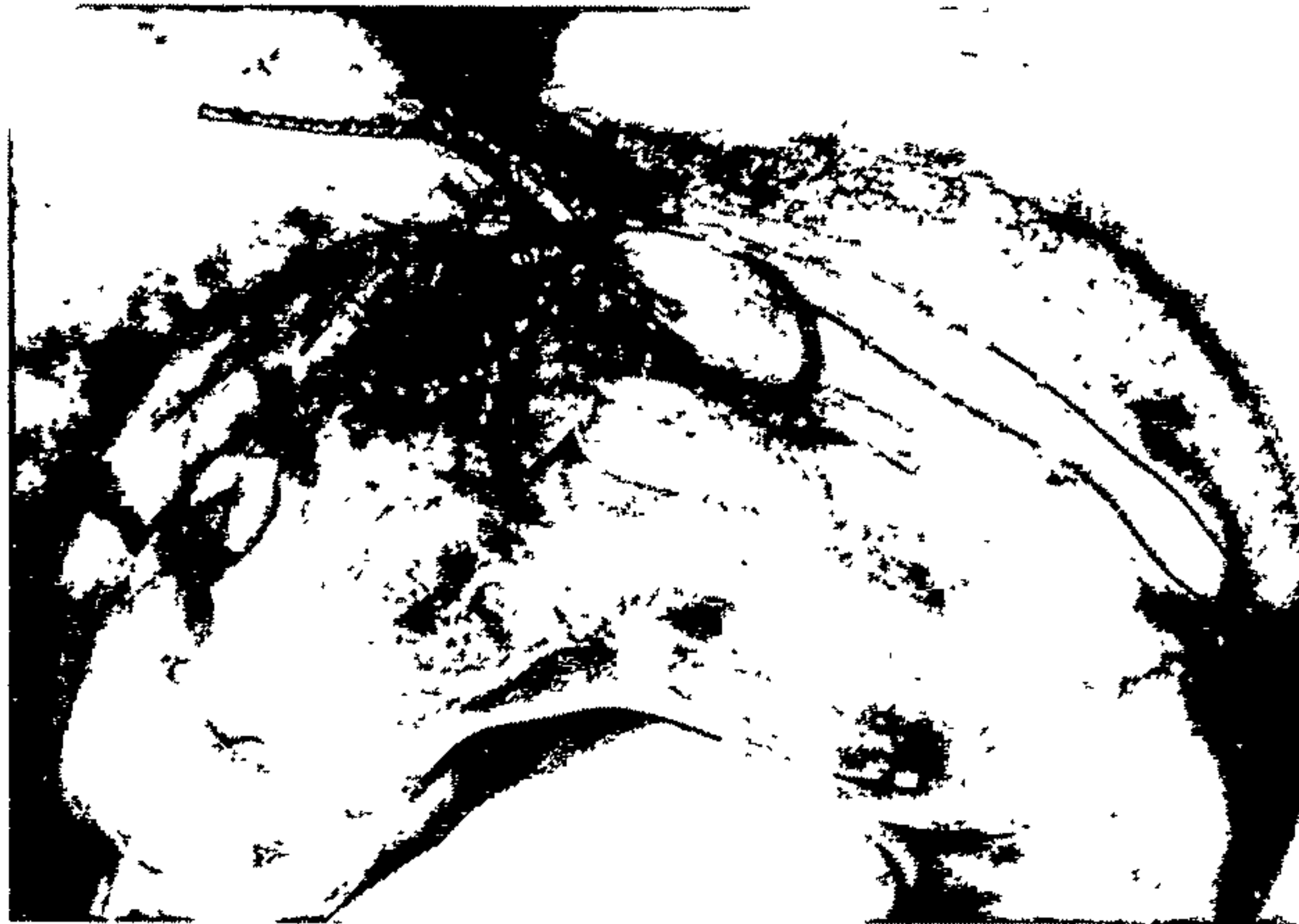


Fig. 9 A clear acrylic stent held in place over an augmented anterior maxilla to assess ridge form and signs of overpacking. (Note blanching in premolar region but not in the augmented area).

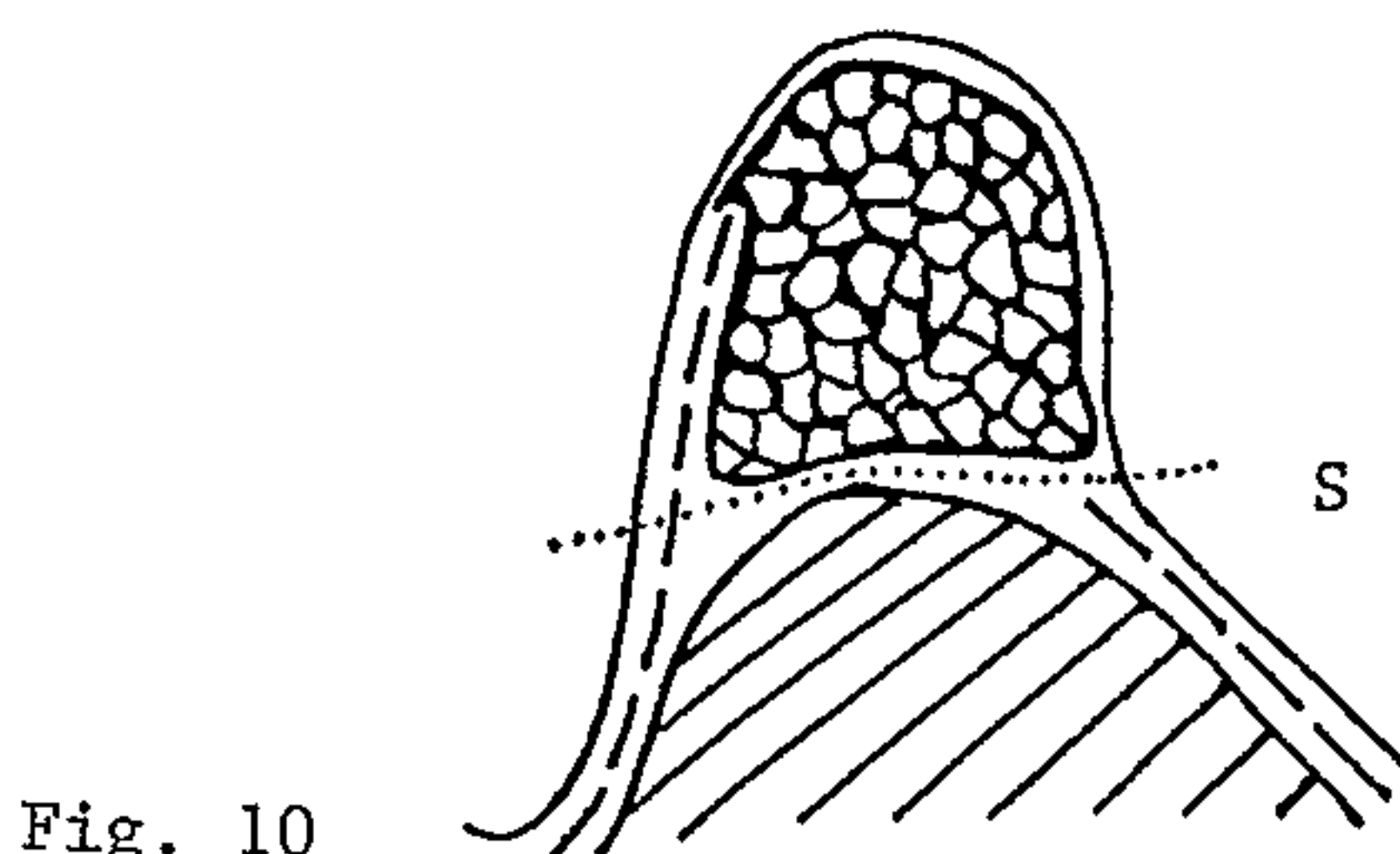


Fig. 10

Fig. 10 A vertical section through the lower alveolar ridge to show the position of the horizontal mattress suture used to control particle migration.
S — Suture

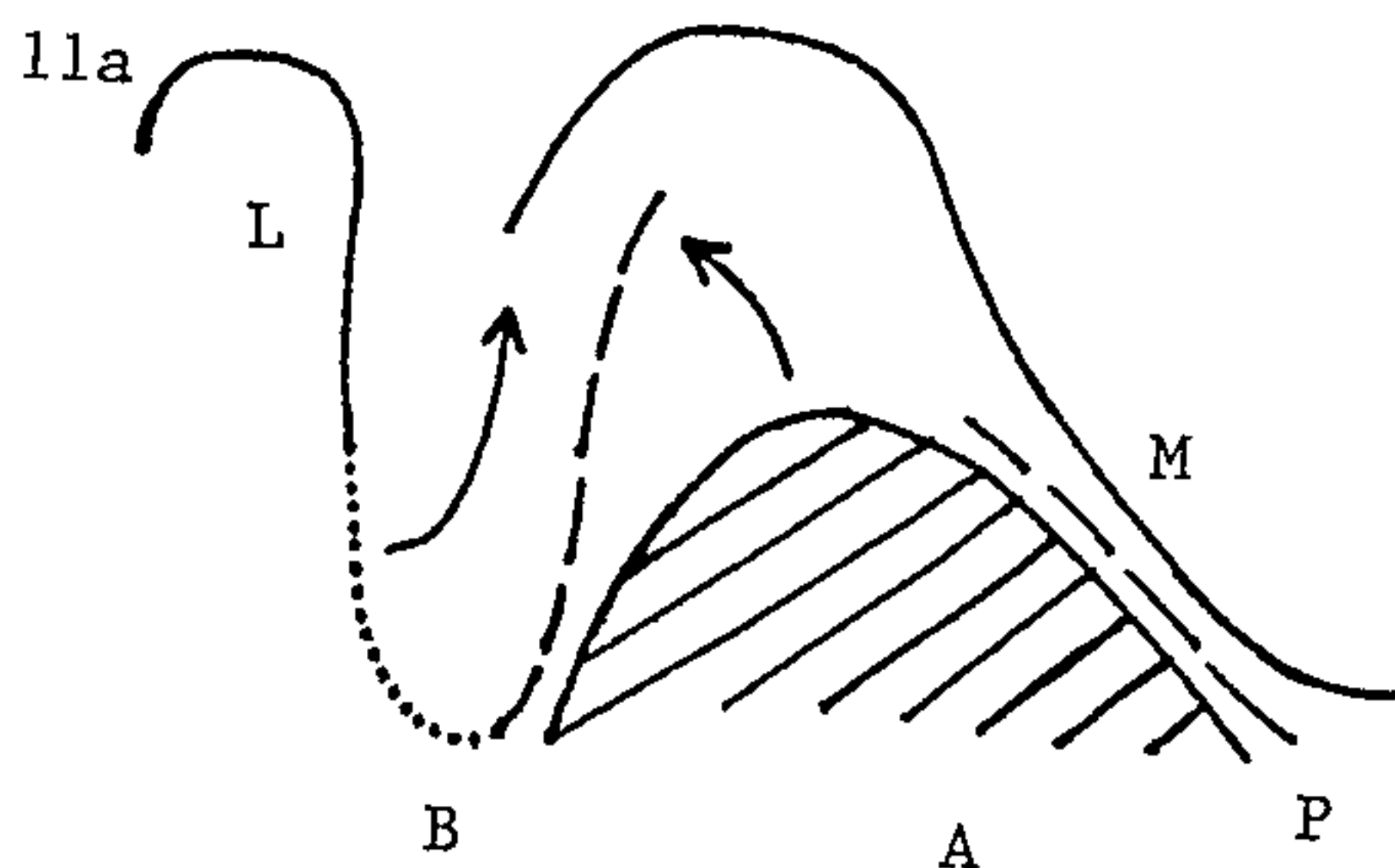
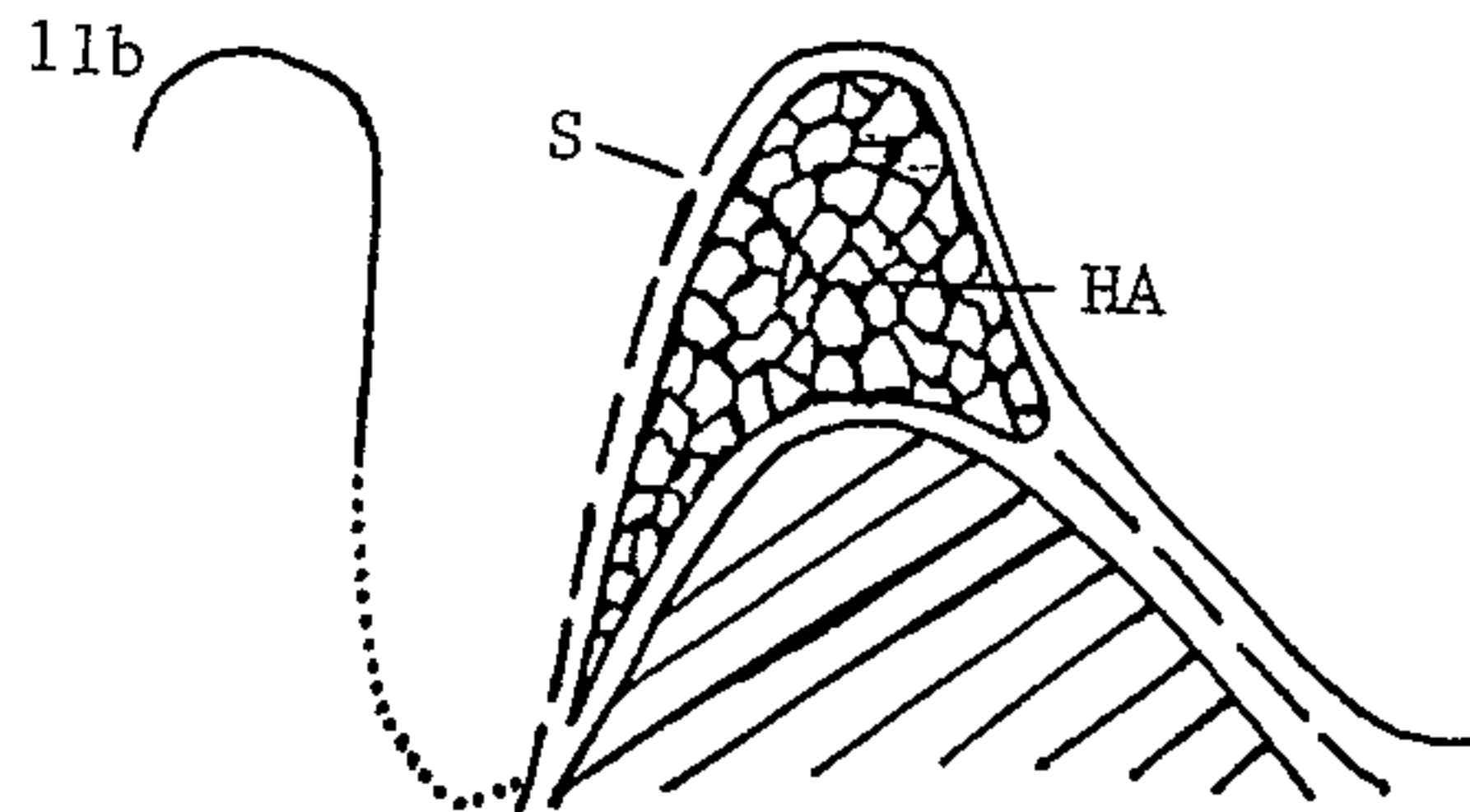


Fig. 11 A vertical section through a lower alveolar ridge showing the key stages of the 'direct' technique.

11a The arrows indicate the position and direction the mucosal and periosteal flaps are raised.



11b The enlarged tunnel created by the suturing of the raised mucosal flap to the periosteal flap is demonstrated. The denuded vestibule heals by secondary intention.

A — Alveolar ridge
B — Buccal aspect
HA — Hydroxylapatite granules
M — Mucosa
P — Periosteum
S — Connecting suture

consensus guidelines should act as the minimum acceptable requirement. In the case of HA augmentation it is hard to measure the success rate objectively, and matters are further complicated when the published results are reviewed and show that some patients have been involved in more than one survey.

Larsen et al. (1983) used a subjective questionnaire and objective radiographic study to assess a two year follow-up of 55 augmented ridges in 50 patients. In all criteria the post-augmentation ridges were superior when compared to pre-augmentation irrespective of the original ridge defect. Radiographs showed after two years a 10% loss of ridge height.

Utilising a similar comprehensive questionnaire, Rothstein et al. (1984A, 1984B), evaluated the results of augmentation in two groups of patients. In the first survey (1984A) 110 patients who had undergone a total of 115 augmentations were assessed over a 33 month post operative period. In the second survey (1984B), 198 patients who had undergone 207 augmentations two years previously were assessed.

The cases were from six different centres and included patients with all classes of ridge deficiency (Table 2), treated by either HA alone or combined with cancellous bone. The subjective nature of the questionnaire was complemented by an objective clinical and radiographic assessment by the patient's prosthodontist and oral surgeon.

The patients were asked to grade their pre- and post-implant dentures for comfort, fit, speech, appearance, ability to eat, ability to taste and general satisfaction. The collective data in both surveys showed that the augmented ridges had improved the patients' perception of their dentures in every category. Assessed prosthodontically the post-implant dentures were found to be more retentive, aesthetically pleasing and stable due to the mucosa being firm and immobile.

The overall clinical assessment made by prosthodontists and oral surgeons also indicated a substantial improvement (the surgeons being the more optimistic of the results).

Data on postoperative complications in the two groups were also included. These showed a relatively low incidence of problems with no long-term adverse effects. Wound dehiscence varied between 19% and 26% of the patients, mental paraesthesia between 23% and 29% (the majority of which had resolved within six months), particle migration between 14% and 16%, soft tissue sloughing 6%, particle extrusion 5% and denture ulceration 5%.

"It was concluded that Hydroxylapatite particles placed through a sub-periosteal tunnel offered a highly successful method of ridge augmentation and eliminated the most serious problems associated with the use of autogenous or banked bone, namely, morbidity, risk, costliness and poor results."

It will be interesting to see if similar opinions are expressed when the patients are re-assessed five and 10 years postoperatively.

Block et al. (1984) studied 74 patients who had undergone ridge augmentation using HA with or without the addition of cancellous bone. Over four years they measured the alveolar ridge height reduction following augmentation using panoramic radiographs and found an average reduction of 4% in the ridges augmented with HA alone, and 10% in the ridges where HA was combined with cancellous bone. This compares very favourably with a resorption rate of between 60% and 89% by the third year using either rib or iliac crest bone alone (Wang et al. 1976, Baker 1979).

Beirne et al. (1986) studied a small group of nine women who had undergone mandibular augmentation with HA. There was an improvement in all aspects of the post-implantation dentures, however, there was a high incidence of mental paraesthesia (four

of nine) and difficulty in confining the particles. Concurrent work in rats with localising the particles by mixing with collagen showed that the migration was limited without the bone infiltration being affected.

Kent et al. (1986B) in a review of 228 HA augmented ridges in 208 patients found that 16% suffered transient lip paraesthesia, 7% some particle migration and 9% dehiscence of particles via the incision. Technical modifications to the tunnelling procedure were suggested to overcome these complications. The resultant ridge forms were found to be convex with a wider zone of non-mobile mucosa and this coupled with a retained sulcus depth was more important for successful denture construction than any absolute height gain (Fig. 12a, b).

This sentiment is echoed by Terry et al. (1984) when they wrote:

"These alterations present an improved ridge form and a greater surface area for denture support, resulting in a larger zone for distribution of functional forces and increased denture stability. The broad, convex-ridge form appears to be more important for successful prosthetic rehabilitation than the overall absolute height."

Interpore

To date there have been very few published trials on the use of Interpore for augmentation. Hupp et al. (1985) reported on the placement of 42 mandibular and five maxillary Interpore blocks. The blocks were shaped preoperatively on study models and held in place postoperatively with a stent. Four of the mandibular and one of the maxillary blocks had to be prematurely removed and one implant had migrated, no dehiscence or resorption was noted. Using the same material Ponichtera et al. (1985) augmented four maxillary and eight mandibular ridges. Four dehiscenced with the subsequent loss of two blocks. Other problems included loss of the buccal sulcus, lingual undercuts and discomfort



Fig. 12a A preoperative view of a hypermobile maxillary ridge showing the unacceptable distortion ridge.



12b A postoperative view of the same maxillary ridge three months after HA augmentation. Note the lack of distortion under pressure.

over the implant edge. Frame et al. (1987) have reported early encouraging results using 10 pre-shaped porous blocks for five patients with mobile pre-maxillary ridges, despite the removal of one block and dehiscence of a second. All the ridges showed a diminished mobility and an improvement in shape with overlying non-mobile mucosa. It would appear at present that blocks are not yet ideal for ridge augmentation, requiring more clinic time and with an increased percentage of complications. Indications are that the porous non-resorbable Interpore granules will be more successful.

The prosthodontic follow-up and provision of post-augmentation dentures has been outlined by Grisius et al. (1984). Denture construction can commence four to six weeks post-implantation. There should be minimal anterior contact with the posterior teeth being cuspless to decrease lateral forces and, in centric relation there should be simultaneous bilateral contact. The majority of dentures will require at least one reline within the initial 18 months.

HA root replacement implants — Preventive Prosthodontics

The prevention of alveolar resorption after tooth extraction would be a major advance for prosthodontics providing a long-

term stable base. The research using HA blocks and granules within the sockets of extracted teeth is an attempt to achieve this.

Boyne et al. (1984), using dogs, demonstrated that 30% of endosteal root implants formed a complete bony cover after placement and concluded that the material was capable of long-term alveolar bone maintenance. Quinn et al. (1984) placed shaped HA blocks in extraction sites of baboons and dogs, 2 mm-3 mm below the alveolar bone crest. An average of 2 mm more bone was preserved on the implanted, when compared to the non-implanted, control site. Quinn et al. (1985) then placed 81 root implants in 42 patients and on review 31 months post implantation found twice the amount of bone on the implanted side compared with the unimplanted contralateral side.

Veldhuis et al. (1984) placed 212 implants in 24 patients and on review five years post-implantation found that only two had been lost. Thirty per cent had shown dehiscence at some stage but were easily treated by reduction of the implant height and advancement of a mucosal flap. The dehiscence was seen as a sign of continuing resorption despite the implants. Conversely in 70% of implants not showing dehiscence resorption was assumed to have been arrested.

Kangvonkit et al. (1986) placed 96 HA cone implants in anterior mandible sockets of 15 patients and compared them with non-implanted patients. After two years six implants had been lost and 17 had shown dehiscence but after reduction in their height the mucosa rehealed. There was significantly less vertical resorption and better ridge shape noted in the implanted cases. Advantages noted over the technique of vital submerged roots included simplicity and ease of placement with no necessity for a mucoperiosteal flap.

Kwon et al. (1986) inserted 70 solid HA cones 1 mm below the alveolar crest and used lateral cephalometric radiographs taken over a 24-month period to measure resorption against control subjects. Fifty-two per cent of the cones eventually became exposed and 27% had to be removed. It was concluded that HA cones did not significantly preserve the alveolar bone.

Block et al. (1986B) compared the use of particles and solid root forms of HA in extraction sockets in dogs. Neither form of HA prevented post-extraction resorption but the particles were simpler to use and could be placed level with the alveolar crest, whereas the root forms had to be placed 2 mm-3 mm below the crest. They concluded

that neither particles nor solid root forms preserved alveolar bone. Bell (1986) also compared particles and solid HA in extraction sockets. The particles were easier to place and involved much less chairside time. The solid root forms also created post-implantation problems including dehiscence, implant loss, migration, and sub-mucosal prominence. The preservation of alveolar bone was not assessed.

An early initial report (Denissen et al. 1979), of a 100 dense HA root implants placed into 20 patients was encouraging and a five year post implantation review (Denissen et al. 1985), concluded that the physical presence of the HA implants prevented collapse of the cortical plates creating a more advantageous alveolar ridge shape in 95% of cases. Thus implants do not appear to prevent physiological resorption but act as space maintainers between the plates preventing horizontal resorption.

Studies do tend to concentrate on the absolute ridge height, not width, and the benefit of HA implants in extraction sockets could be the improved ridge shape when compared to a non-implanted ridge despite a similar rate of vertical resorption. There seems no doubt that there will be a role for HA implants in fresh extraction sockets in selected cases, but the long-term results need to be assessed, particularly as the resorption of the alveolar ridges is both long-term and not a linear progression. To quote Denissen et al. (1985), root implants are:

"a valuable and practical contribution to preventive prosthetic dentistry."

Conclusion

There appear to be many promising features associated with hydroxylapatite. Its properties make it close to the ideal alloplastic material for augmentation. No donor site is required and it can be placed under local anaesthetic with minimal surgery, a great advantage when treating older, frail patients.

The range of suitable clinical applications is likely to expand as more research is completed but already it has been used in many pre-prosthetic situations either alone or in conjunction with vestibuloplasties, pedical grafts or as an adjunct to metal implants.

The exciting possibilities for the preservation of ridges using HA in extraction sockets could fundamentally alter prosthodontic treatment planning. Discussions on the retention of periodontally involved teeth or the necessity to preserve decoronated roots for overdentures could acquire a new dimension.

Experience also shows the beneficial effect of HA on the overlying soft tissue via the fibrous growth into the most superficial aspects of the implant. The resulting mucosa is firm and not mobile, well suited to the rigours of denture loading.

It is foreseeable, however, that the very attraction of HA as an answer to many problems may also produce a negative side. The ease with which it can be placed may tempt its use either in inappropriate circumstances or in large volumes leading to failure and a dissatisfaction with the material itself. There is also still no complete understanding of the effect that dentures have on the mechanism of ridge resorption and therefore their long-term influence on a ridge augmented with HA. Possibly the remaining alveolus will be protected from resorptive influences or possibly the underlying bone will continue its resorption unchecked.

There is no doubt that HA has worthwhile potential in the management of preprosthodontic surgical cases. Unlike many other materials that have come and gone it has many of the desirable characteristics needed for augmentation but only the continuing publication of long-term data of its use in a clinical setting will prove its acceptability.

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ENCLOSURE II



The Australian & New Zealand Association
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**XIIITH CONFERENCE - BRISBANE
AUG 29 - SEPT 2 1988**

**SUPERIOSTEAL TISSUE EXPANDERS AS AN
ADJUNCT TO ALVEOLAR AUGMENTATION WITH
HYDROXYLAPATITE**

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Surgery, University of Sydney.

Hydroxylapatite augmentation of the atrophic
ridge is becoming recognised as an advantageous
preprosthetic surgical technique.

Placing the hydroxylapatite granules under a local
anaesthetic is technically straightforward, how-
ever, subsequent particle migration is a potential
complication.

This display demonstrates the use of Subperiosteal
Tissue Expanders (S.T.E.) to counter this
complication.

The expanders are placed in a subperiosteal tunnel
created on the ridge crest three weeks prior to
the proposed augmentation. Their inflation with
sterile saline allows the mucosa to stretch and
the tension dissipate and also for fibrous
healing to take place along the line of the
periosteal reflection.

Short term review of the technique shows
encouraging results.

ENCLOSURE III

A description of the surgical technique for HA augmentation of the anterior maxilla based on the conclusions reached in this thesis:

- 1) The patient must be sufficiently fit to withstand a minor oral surgery procedure of approximately 30 minutes' duration, preferably under local anaesthetic. They must have an upper denture and relevant radiographs and, ideally, preoperative study models and photographs.
- 2) Prior to the operation, sufficient local anaesthetic to anaesthetise the surgical area, including the palatal vault, should be administered and the denture adjusted for use as a surgical splint by relieving the fitting surface over the proposed area of augmentation (Plate 14, page 174). A countersunk mid-palatal hole is also created to accommodate the bone screw which secures the splint following surgery. The converted denture is then soaked in aqueous chlorhexidine solution until required.
- 3) With an assistant retracting the upper lip, a midline incision, using a No.15 scalpel blade, is made (Plate 15, page 176). The incision is advanced down to the alveolar crest and onto the palatal aspect of the ridge if no submucous vestibuloplasty is planned. However, it is initially only taken submucosally if a submucous vestibuloplasty is to be performed.

Note: a submucous vestibuloplasty is indicated only where (i) the buccal aspect of the maxilla as measured in the midline from piriform aperture to alveolar bone crest is at least 10 mms, and (ii) where there is minimal buccal attached mucosa (in combination with muscle or frenal attachments close to the ridge crest).

If a submucous vestibuloplasty is required, a submucosal pocket is created within the vestibule using sissors and blunt dissection (Plate 16, page 177). The tissue remaining attached to the periosteum is then displaced superiorly with a periosteal elevator to allow the submucosal surface to lie directly on the periosteum (Fig. 26, page 177).

- 4) A Freer's periosteal elevator is then inserted under the periosteum in the midline palatal to the ridge crest and bilateral subperiosteal tunnels created, extending to the distal aspect of the mobile tissue. Care must be taken to keep the tunnel narrow and as close to the ridge as possible (Plate 17, page 180).
- 5) Repeated incisions into the overlying fibrous ridge are then made with a scalpel from within the tunnel, allowing the tissue to be expanded (Plate 19, page 182). This manoeuvre creates a larger tunnel which is technically no longer subperiosteal because the overlying periosteum has been divided.
- 6) The required HA syringes are then prepared by suffusing the granules with sterile normal saline solution, the excess being discarded (Plate 20, page 185). The volume of HA required is dictated by the elasticity and quality of the overlying tissue as well as the tunnel size. Excessive augmentation (overfilling) leads to dehiscence and ulceration with loss of granules and a reduction in any augmentation benefit. Three syringes (2-3g) are sufficient for the majority of anterior maxillary augmentations.
- 7) The HA containing syringe is then introduced into the depths of the tunnel and the granules discharged as the syringe is withdrawn (Plate 21, page 184). This is repeated with more syringes until the tunnel is filled bilaterally. The midline incision is then closed in one layer, preferably with a resorbable suture material such as 3/0 VicrylTM (Plate 23, page 187). The ridge is then manipulated and moulded into the correct position using finger pressure. The granules are now contained buccally, occlusally and palatally by the overlying fibrous tissue and mucosa while being supported by the residual alveolar bone just palatal to the ridge crest (Fig. 30, page 184).
- 8) The anterior aspect of the surgical splint (old denture) is then dried, filled with Coe-pak and inserted. The excess Coe-pak is moulded

- within the buccal vestibule and allowed to set (Plate 24, page 187).
- 9) A tungsten carbide fissure bur is then used to drill a hole through the palate using the surgical splint as a guide. A self-tapping metal screw, sufficiently long to penetrate through to the nasal floor is then inserted (Plate 25, page 188). To avoid inhalation of the screw a gauze square is placed in the oro-pharynx and the screw held in an artery forceps. The splint must be held securely but not tightly against the palate. A small amount of splint movement reduces ulceration at the flanges, minimises pressure over the augmented ridge and avoids constriction of palatal mucosal circulation. Some movement also acts to relieve stresses on the screw which would lead to its loosening and displacement.
 - 10) The patient can then be discharged with advice on postoperative care and the likely postoperative sequelae, a prescription for suitable antibiotics, analgesics and mouthwash, together with a recall appointment.

Monitoring both the short- and long-term sequelae of HA augmentation must be conducted by regular reviews. Contraction of the enveloping fibrous tissue, granule settling and granule migration will all cause some degree of relapse, particularly in the first postoperative year. The amount varies between patients and is not predictable, however, an overall expansion in size of the ridge is not critical to success. A combination of increased ridge stability with a more convex ridge profile will lead to improvement in denture stability and retention.

The difficulties encountered in objectively qualifying the degree of augmentation achieved by this procedure (ref. in thesis) means that, for practical purposes, the degree of improvement attained must be measured by clinical results. Thus, it is concluded that success should be measured by the

patient's ability to comfortably wear the new denture which should function without the discomfort or symptoms previously present.

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