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Advancement Genioplasty With and Without Soft Tissue Pedicle:

An Experimental Investigation

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To determine whether maintaining a soft tissue pedicle to the genial segment decreases the amount of bone resorption following an advancement genioplasty, 12 rhesus monkeys (*Macaca mulatta*) underwent advancement genioplasty of 5–6 mm. The insertion of the digastric musculature and lingual soft tissues on the genial segment was maintained in six of the animals, and six had all soft tissues stripped. Cephalometric analysis of remodeling in the anterior part of the mandible indicated that the pedicled genial segments underwent significantly less resorption than the free graft segments ($P < 0.05$). The results of this study indicate that soft tissue pedicles to the genial segments should be maintained during advancement genioplasty to minimize the amount of bone resorption in the postoperative period.

Genioplasty has become a common surgical procedure performed as either an isolated operation or in conjunction with other maxillofacial surgical procedures. Advancement of the chin by means of horizontal osteotomy of the mandibular symphysis is a popular method of increasing the prominence of the chin for persons whose chins are deficient in the anteroposterior dimension. Hofer[1] was the first to describe this procedure, which he performed through an extraoral incision. Trauner and Obwegeser[2] advocated the same osteotomy via an intraoral approach. Several variations to horizontal osteotomy of the mandibular symphysis have been described in an attempt to tailor the operative procedure to the particular deformity.[3–8]

One technical aspect of the horizontal osteotomy that has never been investigated experimentally is the necessity of maintaining a soft tissue pedicle (the digastric musculature and periosteum of the inferior border and lingual surface) to the advanced genial segment. Most clinicians believe this is of paramount importance, surmising that a pedicled graft maintains its vascularity and thereby decreases chances of infection or aseptic necrosis and the amount of the postoperative resorption.[3–6,8–11] Evidence for that supposition is offered in a clinical report by Mercuri and Laskin,[12] in which an advancement genioplasty was performed without soft tissue attachments (i.e., a free graft) and in which the genial segment subsequently became necrotic and partially sequestered. Similar results following pedicled advancements of the genial segment have not been reported. However, Behrman[13] and Caldwell and Gerhard[14] maintain that the genial segment may be used as a totally free graft.

Preliminary results of an experimental study by

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Carlson and coworkers[15] reported that suprahyoid myotomy may lead to greater resorption of bone along the labial symphysis due to compromise of blood supply. However, additional evidence for the supposition that postoperative resorption is less with a pedicled graft is unavailable. Although several authors believe this to be the case, no controlled studies have compared the amount of postoperative resorption of the genial segment following advancement genioplasty using a pedicled versus a free-graft.

This study was performed to determine the amount, the area, and the chronology of osseous remodeling of the genial segment and anterior mandible following advancement genioplasty with and without lingual soft tissue pedicles in adult rhesus monkeys (*Macaca mulatta*). Histochemical and biochemical analyses of adaptations in the suprahyoid musculature after advancement genioplasty were published previously.[16] This paper will present the results of the cephalometric analysis of hard tissue changes.

Materials and Methods

Experimental Groups

Six male and six female rhesus monkeys (*Macaca mulatta*) were used in this experiment. According to scales of tooth eruption, these animals were at least four to four and a half years of age at the beginning of the study. The animals were considered young adults in that all permanent teeth, including third molars, were in occlusion.

Tantalum bone implants were placed aseptically throughout the craniofacial complex of each animal using the method developed by Björk[17] and modified by McNamara[18] for use in the rhesus monkey. Additional bone implants were placed in the anterior region of the mandibular corpus.

The 12 animals were divided equally into two experimental groups. Animals in Group A underwent advancement of the inferior border of the mandible with the attachments of the anterior digastric muscle left intact. Animals in Group B underwent advancement of the inferior border of the mandible with detachment of the anterior digastric muscle and lingual soft tissues. The genial segment was essentially a free graft.

Surgical Procedure

Animals were sedated with an intramuscular injection of phencyclidine hydrochloride (Sernylan®) at a dosage of 1.5 mg per kg, and general anesthesia was induced by intravenous administration of pentobarbital sodium in a dose of 5 mg per kg. Subsequently, smaller doses were administered as needed to maintain the anesthetized state. The animal was prepared and draped to allow aseptic access to the submental and submandibular areas bilaterally. A vertical midline incision was made through skin, subcutaneous tissues, and platysma extending from the mandibular symphysis to the hyoid bone. The flaps were undermined to approach the inferior border of the mandible. The lateral aspect of the mandible was exposed subperiosteally by incising the periosteum along its lateral–inferior aspect. A Stryker saw was used to perform a horizontal osteotomy approximately 6 mm above and parallel to the inferior border of the mandible extending to the second molar area bilaterally. The osteotomy was then carried to the inferior border, creating a horseshoe-shaped segment of mandible. In Group A, all of the insertions of lingual soft tissues were left intact on the genial segment. In Group B the soft tissues were stripped from the genial segment, creating a free graft. In both groups of animals, the horseshoe-shaped segment in the inferior border was advanced approximately 5 mm. The segment was wired in place using 26-gauge stainless steel wires placed through holes in the intact mandible and around a groove in the inferior border of the advanced genial segment. Two wires were placed on each side of the mandible. The tissues were then closed in layers.

On the day of the operative procedure and for ten days postoperatively, the animals received procaine penicillin G intramuscularly (40,000 U/kg). The animals were observed daily for signs of infection and weight loss.

Analytical Procedures

The protocol included taking lateral cephalograms immediately preoperatively, immediately postoperatively, and at one, four, eight, 12 and 24 weeks postoperatively. Each radiograph was enlarged three times using Kodak® translite film.

The number of animals in each group decreased as the postoperative interval increased, since one animal from each group was killed at intervals of four weeks, eight weeks, and 12 weeks postoperatively, and three animals from each group at 24 weeks postoperatively for histologic analysis of adaptations within the anterior digastric muscles.[16] The six animals alive at 24 weeks were all female.

Analytical procedures were performed to determine differences between the two experimental groups in dimensions of the anterior mandibles and genial segments and in area occupied by osseous tissues in the symphyseal region. Numerical values were modified to correct for the 3× enlargement of

the radiographs so that measurements were of the actual scale of the animals.

Analysis of Linear Dimensions

The occlusal plane was determined from the preoperative cephalogram of each animal. A perpendicular line to this plane was then drawn through a bone marker in the proximal segment of the posterior mandible (posterior vertical reference line; Fig. 1). A second vertical reference line was constructed for each cephalogram by dropping a perpendicular line from the preoperative occlusal plane (which was transferred to each succeeding cephalogram by computer) through a bone marker in the genial segment (anterior vertical reference line; Fig. 1). Three measurements were obtained for each cephalogram (Fig. 2).

Position of the Genial Segment. This position was determined by measuring the distance between the posterior and anterior vertical reference lines. This measurement quantified anteroposterior changes of the mobilized genial segment.

Remodeling at Anterior Segmental Point. Remodeling of the most anterior aspect of the advanced genial segment was assessed by measuring the perpendicular distance between the anterior vertical reference line and the most anterior aspect of the advanced genial segment (anterior segmental point). This measure allowed quantification of the anteroposterior remodeling of the advanced genial segment regardless of changes in its position.

Remodeling at Anterior Corpus Point. Remodeling in the area of the anterior aspect of the mandibular symphysis between the proximal and distal mandibular segments was monitored by measuring the perpendicular distance between the posterior vertical reference line and the point of intersection of the superior aspect of the advanced genial segment and the stable anterior portion of the mandibular symphysis. The most posterior aspect of this junction was digitized as the anterior corpus point. This measure quantified the anteroposterior remodeling of the junctional area between the advanced segment and the stable mandible.

Analysis of Area Measures

The Area of Osseous Tissue within the Mandibular Symphysis. The area of osseous tissue within the mandibular symphysis was calculated in an attempt to quantify the total amount of osseous change occurring in the mandibular symphysis. A vertical line was drawn perpendicular to the occlusal plane and tangential to the most posterior aspect of the mandibular symphysis in the translite enlargement of the preoperative cephalogram. A horizontal line, parallel to the occlusal plane, was constructed 30 mm above the inferior border of the mandible (Fig. 3). The resulting quadrant was transferred to succeeding cephalograms of the same animal by superimposition of bone markers within the stable portions of the mandible. The area of the mandibular symphysis outlined by this quadrant was then calculated in each translite enlargement of the cephalograms using an X–Y digitizer. A digitizing pen was used to outline the contour of the anterior aspect of the mandibular symphysis and the two intersecting lines, thus completing the circuit. A computer program then calculated the area within the outlined circuit for each tracing. The differences between the areas of successive tracings were tabulated for both experimental groups.

Statistical Analysis

Differences from the preoperative to postoperative interval in the two measures, 1) position of the genial segment, and 2) area of osseous tissue within the mandibular symphysis, were subjected to the Student's t test to determine the significance of differences between the two experimental groups. A two-way analysis of variance was performed on all four measured variables on the three animals from each group who were alive at 24 postoperative weeks to detect changes over time and differences between groups.

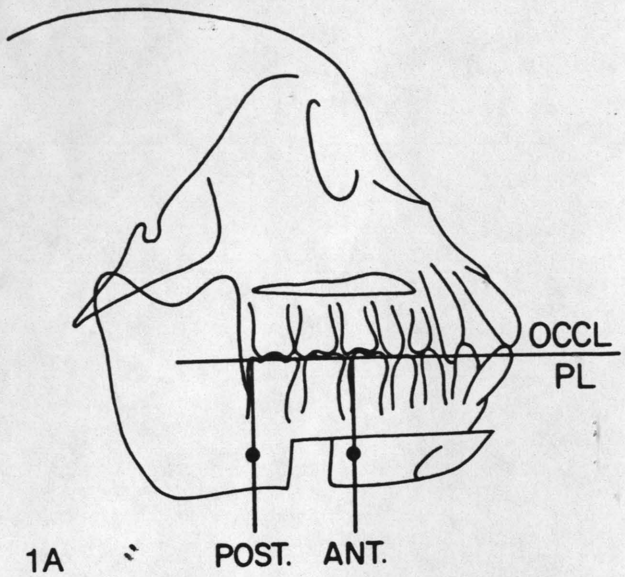
Results

No animal had intraoperative or postoperative complications, all withstood the surgical procedures without difficulty and there were no postoperative infections.

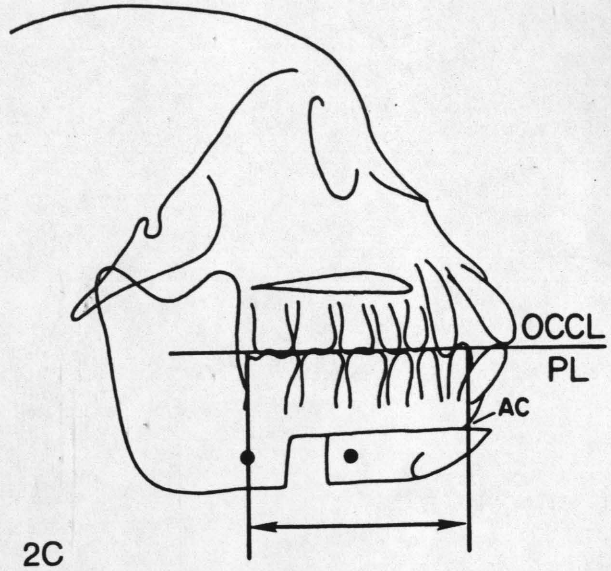
Stability of the Genial Segment

In Group A (soft tissue pedicle), the segment, as indicated by the movement of the implants, was advanced 5.2 mm (SD = 1.3 mm). In Group B (free graft), the segment was advanced 6.5 mm (SD = 2.5 mm). There was no statistically significant difference in the amount of advancement between the groups ($t = -1.1$; $P = 0.29$).

Measurement of the distances between the implants in the advanced osseous segment and the implants in the proximal mandible did not reveal a greater relapse in Group A than in Group B. In fact, in our analysis of the data from the six monkeys that were followed for 24 weeks, the opposite was found—two-way analysis of variance (Table 1) revealed no significant changes over time and moderate differences between groups ($P < 0.05$). For



1A



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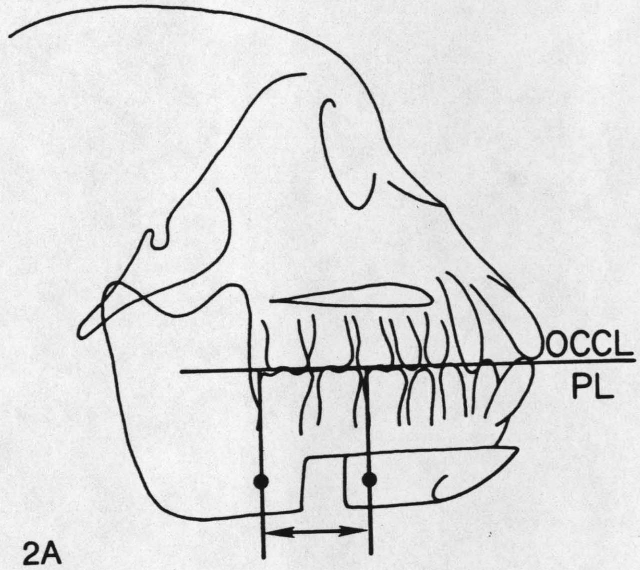

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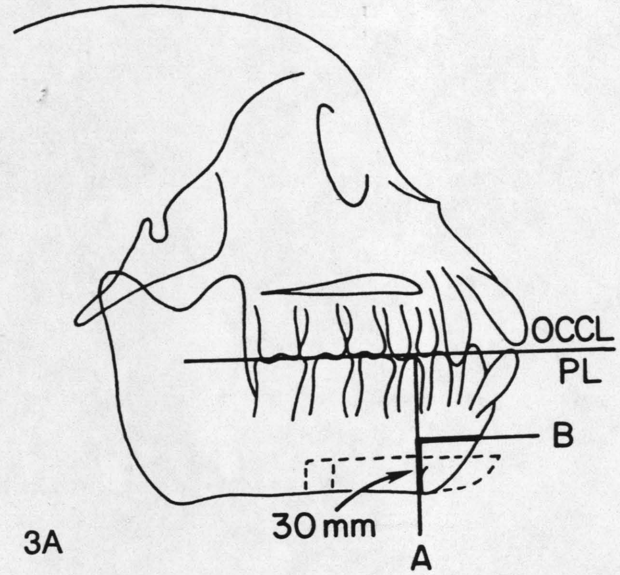
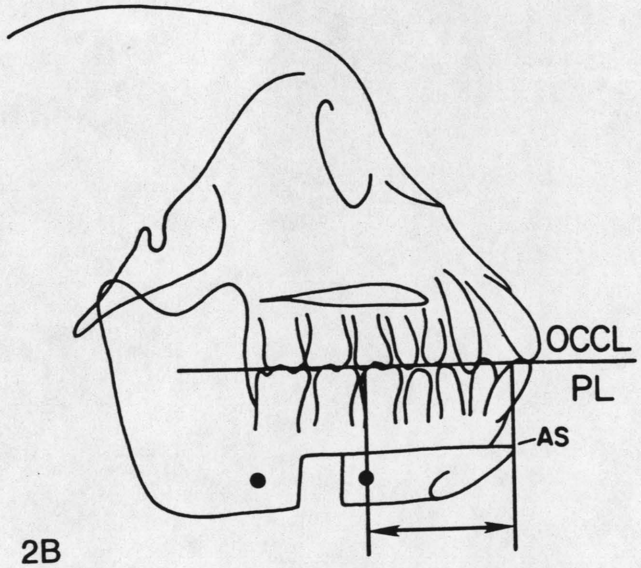


3A



2B

FIGURE 1. *A*, illustration showing the occlusal plane and the two vertical reference lines. The posterior vertical reference line is a line drawn through a bone marker in the posterior aspect of the mandible perpendicular to the preoperative occlusal plane. The anterior vertical reference line is a line drawn through a bone marker in the mobilized genial segment perpendicular to the preoperative occlusal plane.

FIGURE 2. Three linear measurements used to analyze changes occurring following advancement genioplasty. *A*, the distance between the posterior vertical reference line and the anterior vertical reference line was used to assess the anteroposterior changes in the genial segment. *B*, the perpendicular distance between the anterior vertical reference line and the anterior segmental point was used to assess the anteroposterior remodeling of the anterior aspect of the genial segment. *C*, the perpendicular distance between the posterior vertical reference line and the anterior corpus point was used to assess the anteroposterior remodeling at the most anterior area between the proximal and distal segments.

FIGURE 3. *A*, method used to assess the area of osseous tissue within the mandibular symphysis. A line was drawn tangential to the posterior aspect of the mandibular symphysis and perpendicular to the occlusal plane on the translite enlargement of the preoperative cephalogram (line A). Another line, parallel to the occlusal plane, was drawn 30 mm above the inferior border of the mandible (line B). The resultant quadrant was copied to subsequent tracings by superimposition on stable bone markers within the mandible. The quadrant, along with the contour of the mandible it outlined, was digitized to obtain the area lying within it.

instance, by four postoperative weeks, the advanced segment relapsed by an average of 0.50 mm (SD = 0.49) in the B group and 0.12 mm (SD = 0.09) in the A group. On the other hand, when the six animals that were followed for a shorter term were additionally considered, a difference between the groups was not found (Fig. 4). Instead, there was a large amount of variation in the postoperative response of the Group A animals (0–2.1 mm of relapse) compared with that of the Group B animals (0–1.0 mm of relapse).

Remodeling at Anterior Segmental Point

In Group A, an average of 1.3 mm of bony resorption of the advanced segmental point was seen over the 24-week postoperative interval, compared with 2.5 mm of bony resorption in Group B. Two-way analysis of variance (Table 2) revealed that not only was the difference in the amount of total resorption between groups significant ($P < 0.05$), the amount of bony resorption also changed significantly over time ($P < 0.01$). Assessment of the data for individual animals plotted over time (Fig. 5) further revealed that the rate of resorption of the shorter term animals was similar to that of the 24-week animals in both groups, and that both groups underwent resorption at a similar rate for the first eight to 12 weeks postoperatively. For instance, by eight weeks, Group A showed an average of 0.84 mm (SD = 0.29) of resorption compared with 1.15 mm (SD = 0.62) for the B group. Conversely, from the twelfth to twenty-fourth week, the Group A exhibited little additional resorption, while two of the remaining three animals in Group B continued to show a more rapid rate of resorption of the advanced segmental point.

Remodeling at Anterior Corpus Point

The anterior bony remodeling in the area between the two mandibular segments demonstrated a similar response in both of the groups, although differences in magnitude were found. In Group A, the average amount of anterior remodeling of the anterior corpus point was 3.79 mm (SD = 0.35) over the 24-week postoperative interval, while in Group B the average amount was 2.31 mm (SD = 0.46). Two-way analysis of variance (Table 3) showed that this difference was significant ($P < 0.01$) and that there were significant ($P < 0.01$) changes in the absolute amount of remodeling at different postoperative time periods. Additionally, the graphic presentation of the data for individual animals (Fig. 6) showed that the responses of the shorter-term animals were similar to the initial responses of the 24-week animals. The majority of the remodeling took place by eight to 12 weeks postoperatively, with little change thereafter in either group.

Table 1. Analysis of Variance of Changes in Position of the Genial Segment versus Postoperative Weeks

	df*	SS†	MS‡	Fs§	Sig¶
Source of variation					
A (postoperative weeks)	4	0.14	0.04	0.33	ns
B (groups)	1	0.58	0.58	4.83	$P < 0.05$
A × *B* (interaction)	4	0.17	0.04	0.33	ns
Within subgroups (error)	20	2.40	0.12	—	—
TOTAL	29	3.29	—	—	—

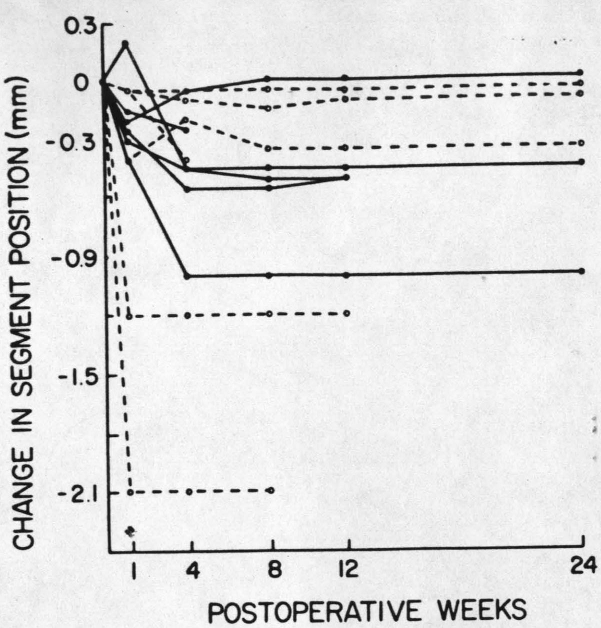
* Degrees of freedom.
† Sum of squares.
‡ Mean square.
§ F statistic.
¶ Significance level (ns = not significant).

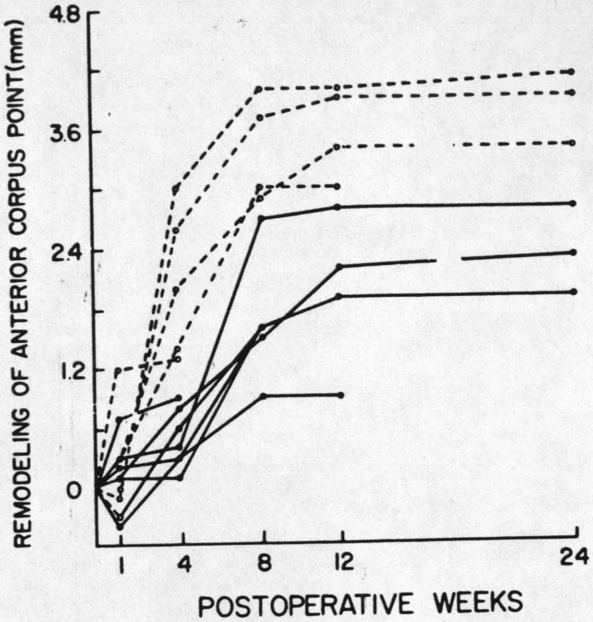
Analysis of the Area of the Mandibular Symphysis

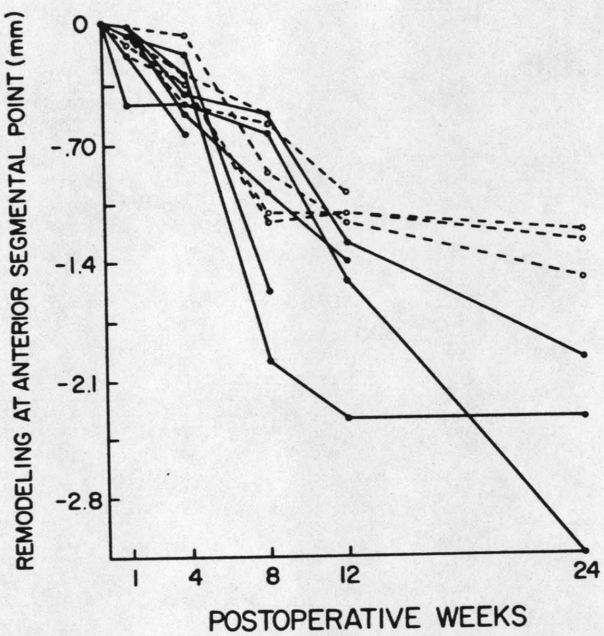
The average immediate postoperative increase in osseous tissue within the outlined quadrant was similar ($t = -0.82$; $P < 0.43$) for both groups, with a value of 21.56 mm^2 (SD = 3.36) in Group A and 23.27 mm^2 (SD = 3.87) in Group B. During the first postoperative week, both groups showed a similar decrease of approximately 2.5 mm^2. Thereafter, differences between the groups were apparent over the 24-week experimental period. Group B showed an average total decrease in the amount of osseous tissue present within the outlined quadrant of 13.21 mm^2 (SD = 1.75), whereas Group A showed a slight average increase of 0.91 mm^2 (SD = 3.79). Two-way analysis of variance (Table 4) revealed that the differences between Groups A and B were significant ($P < 0.01$). Additionally, there was a significant interactive effect ($P < 0.01$) between time and change in osseous area. These results were further supported by the plot of the data for individual animals (Fig. 7). This plot illustrates that the shorter-term animals, with the exception of one Group A animal, were similar to the 24-week animals for this measurement. Likewise, the Group A animals showed little change in osseous area over the 24-week experimental period, whereas all Group B animals showed a decline that was more rapid in the first eight weeks and started to level off from the eighth to twenty-fourth week.

Overview of Results

Figure 8 shows tracings of the anterior portion of the mandible at several postoperative intervals for animals that were typical of Group A and Group B. Following an initial advancement of the genial segment, osseous resorption along the anterior aspect of the segment (anterior segmental point) and osseous deposition along the interface of the segment with the stable portion of the mandible (anterior corpus point) could be observed. With time, the two







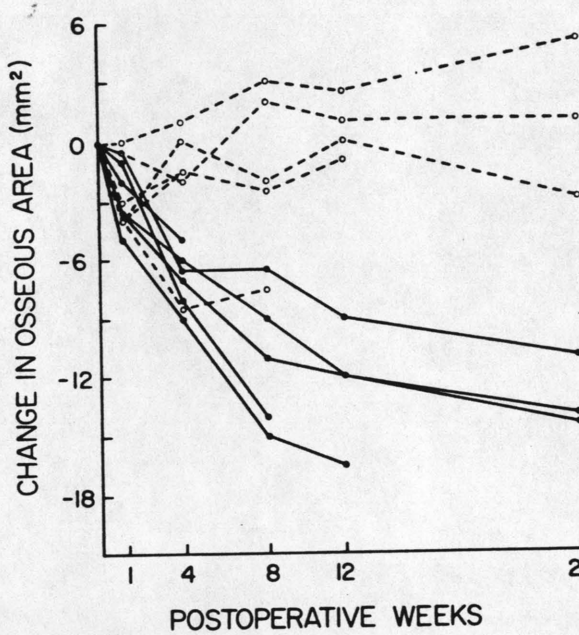


FIGURE 4. *Top left,* anteroposterior movement of the advanced genial segment over time for individual animals in the two experimental groups. Animals in Group A are indicated by a dashed line; Group B, by a solid line.

FIGURE 5. *Bottom left,* anteroposterior remodeling of the advanced genial segment (anterior segmental point) over time for individual animals in the two experimental groups. Animals in Group A are indicated by a dashed line; Group B, by a solid line.

FIGURE 6. *Top right,* anteroposterior remodeling of the area between the proximal and distal segments (anterior corpus point) over time for individual animals in the two experimental groups. Animals in Group A are indicated by a dashed line; Group B, by a solid line.

FIGURE 7. *Bottom right,* changes in the area of osseous tissue within the mandibular symphysis over time for individual animals in the two experimental groups. Animals in Group A are indicated by a dashed line; Group B, by a solid line.

began to merge until, in the Group B subject, they became the same point. The Group A animal, in contrast, retained much of the genial protuberance.

Figure 9 shows the differences in the remodeling patterns of the two groups from superimposed tracings of the genial area in the preoperative, postoperative, and 24-weeks postoperative cephalograms of a typical Group A and Group B animal. Deposition of bone along the anterior corpus area was much more prominent in Group A, whereas resorp-

Table 2. Analysis of Variance of Remodeling at Anterior Segmental Point versus Postoperative Weeks

	df*	SS†	MS‡	Fs§	Sig¶
Source of variation					
A (postoperative weeks)	4	13.32	3.33	22.20	$P < 0.01$
B (groups)	1	1.09	1.09	7.27	$P < 0.05$
A × *B* (interaction)	4	1.37	0.34	2.27	ns
Within subgroups (error)	20	2.98	0.15	—	—
TOTAL	29	18.76	—	—	—

* Degrees of freedom.
† Sum of squares.
‡ Mean square.
§ F statistic.
¶ Significance level (ns = not significant).

tion along the anterior segmental area was more prominent in Group B.

Discussion

The results of this study indicate that maintenance of a soft tissue pedicle is associated with less osseous resorption of the genial segment following advancement genioplasty. In the group that underwent advancement genioplasty with the lingual soft tissues attached (Group A), resorption at the most anterior portion of the genial segment was less than it was in the group where the soft tissues were detached (Group B).

Deposition of osseous tissue anteriorly between the genial segment and the stable portion of the mandible (anterior corpus point) was also more marked in Group A animals. When three animals in each group were followed to 24 weeks postoperatively, a significantly greater change was found in Group A (mean = 3.8 mm) over Group B (mean = 2.3 mm).

Analysis of the changes in area of the labial aspect of the mandibular symphysis provided the most enlightening and definitive differences between the two experimental groups. The results of this analysis showed a preservation of existing osseous tissue in Group A animals. This was a highly significant difference between the two experimental groups (Table 4). In fact, from immediately postoperatively to 24 weeks, the three Group A animals showed a slight average increase of 0.91 mm^2 in osseous tissue in the symphyseal area, while Group B animals showed a large average decrease of 13.21 mm^2.

The reason for the differences observed between animals in Group A and Group B is most likely the fact that the blood supply of genial segments of Group A animals was maintained by way of the lingual soft tissue pedicles. Bell[19,20] demonstrated very clearly that segments of bone attached to mucoperiosteum maintain their blood supply by perforating vessels within the periosteum. Bell and Schendel[21] also found that attached muscle tissue can supply blood to the underlying bone via the same mechanism. The digastric musculature was left attached to the periosteum of the genial segments in Group A animals, and it was most likely this that caused adequate blood supply to be maintained, allowing preservation of much of the osseous bulk. The dramatic remodeling of the anterior corpus point in the Group A animals with deposition of osseous tissue may be due to the fact that this point was located in a vertex of bone, and was surrounded on two sides by vital bone from the genial segment and the stable portion of the mandible. This may have allowed deposition from the osseous walls as well as from the overlying periosteum. The genial segment in Group B animals, however, had no soft tissues attached and were essentially free bone grafts. As such, they had no inherent blood supply and were subjected to the same process of

Table 3. Analysis of Variance of Remodeling at Anterior Corpus Point versus Postoperative Weeks

	df*	SS†	MS‡	Fs§	Sig¶
Source of variation					
A (postoperative weeks)	4	40.56	10.14	56.33	$P < 0.01$
B (groups)	1	13.32	13.32	74.00	$P < 0.01$
A × *B* (interaction)	4	3.06	0.77	4.28	$P < 0.05$
Within subgroups (error)	20	3.58	0.18	—	—
TOTAL	29	60.52	—	—	—

* Degrees of freedom.
† Sum of squares.
‡ Mean square.
§ F statistic.
¶ Significance level.

Table 4. Analysis of Variance of Changes in the Area of the Osseous Tissue in the Mandibular Symphysis versus Postoperative Weeks

	df*	SS†	MS‡	Fs§	Sig¶
Source of variation					
A (postoperative weeks)	4	59.28	14.82	2.61	ns
B (groups)	1	530.79	530.79	93.45	$P < 0.01$
A × *B* (interaction)	4	171.10	42.78	7.53	$P < 0.01$
Within subgroups (error)	20	113.60	5.68	—	—
TOTAL	29	874.77	—	—	—

* Degrees of freedom.
† Sum of squares.
‡ Mean square.
§ F statistic.
¶ Significance level (ns = not significant).

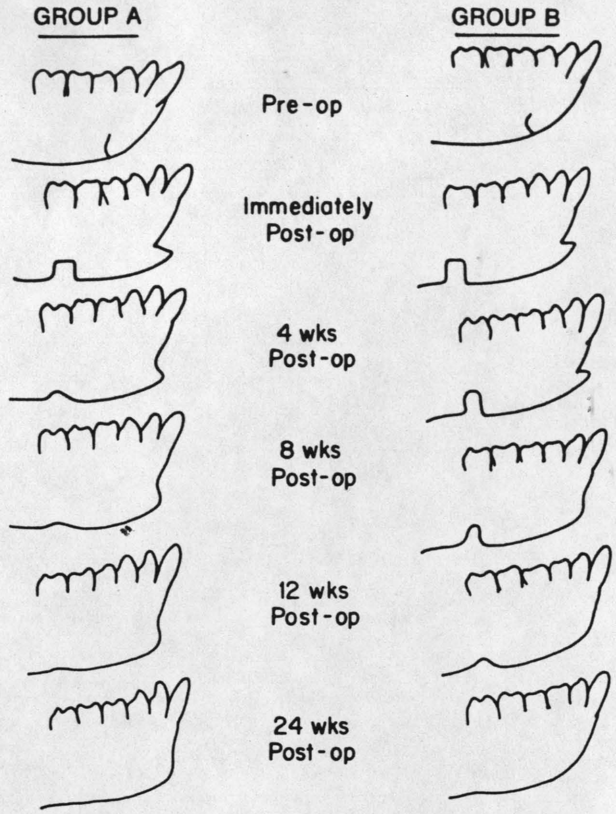


FIGURE 8. Tracings from a typical Group A and Group B animal for several intervals of time. Note the deposition of osseous tissue at the inferior border of the mandible in the area between the advanced genial segment and the remainder of the mandible. Also note the maintenance of a genial prominence in the Group A animal.

revascularization as is any bone graft, a process involving resorption and replacement of the graft and, finally, bone remodeling.

Our findings suggest an important reason for maintaining a soft tissue pedicle to the mobilized genial segment. However, one possible detrimental effect of this procedure is the stretching of the attached digastric musculature. Stretching of this musculature may increase the tension generated within it and cause posterior displacement of the advanced genial segment.[22] The results of this study indicate a slightly greater relapse in the 24-week Group B animals (0.50 mm) than in the 24-week Group A animals (0.12 mm). Although this difference was statistically significant, we do not think that it is biologically significant. Rather, we found that when our shorter-term animals were additionally considered, there was greater variation in the response of the Group A animals (0–2.1 mm of relapse) compared with that of the Group B animals (0–1.0 mm). This greater variation in relapse in animals with a soft tissue pedicle is similar to results of a previous study from our laboratory.[23] We found much greater variation of response in monkeys with a mandibular advancement without suprahyoid myotomy than in those with suprahyoid myotomy.

The clinical effects of increased tension are probably insignificant in an advancement genioplasty performed alone or in combination with a mandibular setback procedure. However, when an advancement genioplasty is performed with mandibular advancement surgery, the effect of these two procedures on the tension within the digastric musculature may be detrimental to the stability of the postoperative result. Ellis and Carlson[23] demonstrated that the suprahyoid musculature exerts significant adverse forces on the mandible following mandibular advancement surgery of 4–5 mm in adult rhesus monkeys. Combining these procedures may lead to more postoperative relapse of the mandibular skeleton. Although partial stripping of the attached digastric musculature may be a means of alleviating some of this increased tension while maintaining adequate soft tissue pedicle for nourishing the genial segment, this has not been proved clinically.

Whether maintaining a soft tissue pedicle to the advanced genial segment will decrease the likelihood of postoperative infection was not clear from the results of this study. While none of the 12 animals developed an infection, the results of the osseous analyses clearly demonstrated that the pedicled grafts underwent less resorption and probably maintained their viability. One can only surmise that the chances of postoperative infection would be decreased in a viable graft vs a free bone graft.

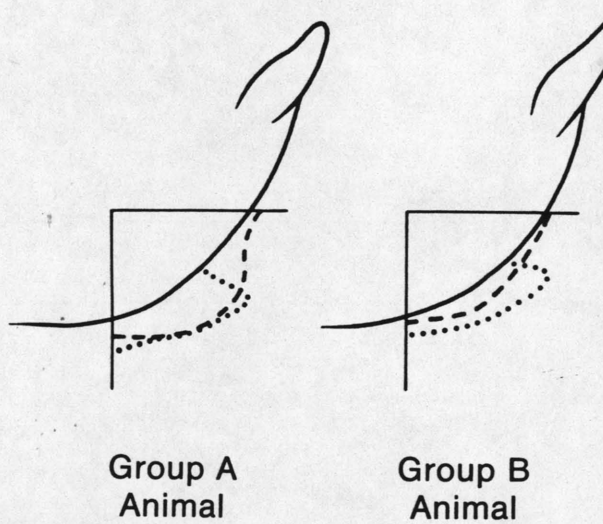


FIGURE 9. Composite of the preoperative (solid line), postoperative (dotted line), and 24-week postoperative (dashed line) tracing for a typical Group A and Group B animal.

Acknowledgment

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