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QUANTITATIVE LONG-TERM DETERMINATIONS OF THE ALVEOLAR BONE MINERAL MASS IN MAN BY ^{125}I ABSORPTIOMETRY

II. Following periodontal surgery

J. BERGSTRÖM and C. O. HENRIKSON

Periodontal surgery implies a trauma to the supporting periodontium of the teeth. Little is known about the reaction of the alveolar bone to this insult. Histology indicates, however, that an initial resorption occurs which later may be followed by the formation of new bone (WILDERMAN 1963). Any permanent loss of alveolar bone after conventional methods of periodontal surgery—gingivectomy and mucoperiosteal flap operation—is considered 'small' (FRIEDMAN & LEVINE 1964). However, the extent of bone loss and the degree of subsequent repair is not known in quantitative terms.

One way quantitatively to express alterations in bone tissue is to calculate the amount of mineral mass per unit area of the bone in question (OMNELL 1957). The principles for the measurement of changes of the mineral content of jawbone in vivo by means of radiation from ^{125}I have been presented by HENRIKSON (1967). The technique was utilized by BERGSTRÖM & HENRIKSON (1970) for

From the Departments of Periodontology and Odontologic Roentgenology, School of Dentistry, Karolinska Institutet, S-103 64 Stockholm, Sweden. This investigation was supported by a grant from the Swedish Medical Research Council, No. B-73-24x-2787-04C. Submitted for publication 22 February 1974.

Table 1

Patient data for the present material. Bone height was measured on intraoral films in per cent of the distance apex — cementoenamel junction of the lateral incisor. F = flap operation, G = gingivectomy

Case No.	Sex	Age	Bone height in per cent of root length		Interproximal pocket depth (mm) of region		Surgical procedure	
			Right	Left	Right	Left	Right	Left
1	M	42	86.7	85.7	4.5	5.0	F	G
2	M	41	68.8	70.6	4.5	4.5	F	G
3	M	42	72.5		5.0		G	
4	M	47		73.3		5.0		G
5	M	39	88.2		5.5		G	
6	F	41	76.5	76.5	5.5	5.0	F	G
7	F	54	76.5	73.3	4.5	5.0	F	G
8	F	47	85.7	71.4	5.0	7.0	F	G
9	F	42	73.7	68.4	4.0	6.5	F	G
10	M	49	70.6	85.7	4.5	4.0	F	F
11	M	49		70.6		5.0		F
Mean		44.8	77.68	75.05	4.78	5.22		

evaluating changes in interdental alveolar bone following mucoperiosteal flap surgery. The mineral content was expressed in aluminium equivalents and the measurements gave evidence of demineralization of the interdental bone from about two weeks after the operation; minimum values were observed after 3 to 6 weeks, after which a continuous increase throughout the observation period usually followed.

However, changes in volume of the soft tissue probably affected the evaluation of the changes in bone mass, especially during the first two weeks after the operation. The method was therefore improved in order to make possible measurements of the thickness of the alveolar process in the recorded area (HENRIKSON & JULIN 1971). With a knowledge of the thickness of the alveolar process in the direction of the radiation beam the influence from fluctuations of tissue volume on total transmission will be kept under control and the amount of bone mineral can be determined in terms of mass per unit of area, e.g. $mg \cdot mm^{-2}$.

The purpose of the present report is quantitatively to describe the changes in mineral mass of the interdental alveolar bone in connection with surgery of patients with periodontal disease. The postoperative swelling in the same region was recorded as well.

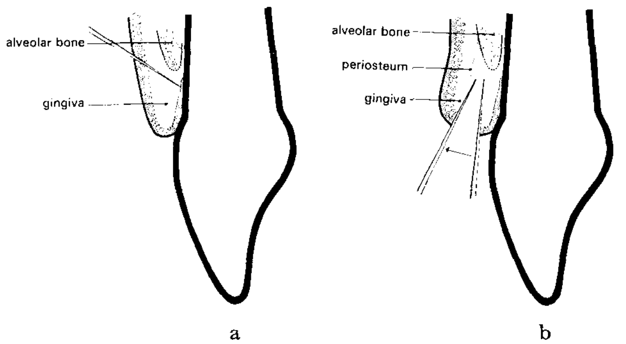

Fig. 1. a) The gingivectomy technique. b) The mucoperiosteal flap procedure.

The material consists of 11 patients, 4 female and 7 male, referred to the Department of Periodontology, for treatment of periodontal disease. Their periodontal condition, though not advanced to such a degree as the tooth mobility was notably increased, indicated surgery. Data for the total material are given in Table 1. All patients had a sufficient number of teeth in the upper jaw to guarantee necessary stability of the measurement apparatus.

Before any measurements, dental plaque and calculus were removed. The patients were also instructed in oral hygiene and informed of its importance. Only those who cooperated in this respect were included in the material. The oral hygiene of the patients was continuously supervised during the observation period. The patients were observed during a six-month period and observations were made mainly according to the following schedule: on 2 to 3 occasions before operation with at least one week's interval, at weekly intervals during the first postoperative month, every second week during the next two months, and every third week during the remaining three months of the observation period.

Methods

Surgical procedure. Two types of periodontal surgery were used: in nine instances a gingivectomy was performed and in nine instances a mucoperiosteal flap operation. Most patients were operated on by gingivectomy in one area and by flap operation in the contralateral (Table 1). Both methods are conventional modalities of surgery for the elimination of periodontal pockets, the principal difference being that the flap procedure involves temporary bone exposure while the gingivectomy does not.

In areas where gingivectomy was performed the diseased gingiva labially, lingually and interdentally was eliminated. The surface of the subjacent marginal alveolar bone was not exposed but was covered by a remaining layer of soft tissue. The treated area was covered with a surgical dressing for one week (Fig. 1 a).

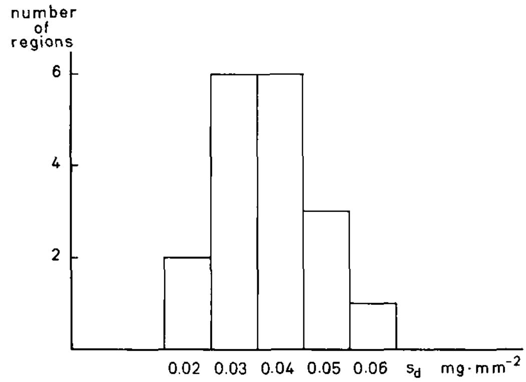

Fig. 2. Distribution of precision values, s_d, for eighteen regions.

The mucoperiosteal flap method implied a deflection by blunt dissection of the labial gingiva in the area. This was accomplished by an internal bevelled incision along the gingival margin and from the margin down to the crest of the alveolar bone, followed by elevation of a flap containing mucosa and periosteum (Fig. 1 b). Lingual pockets were removed by curettage. The epithelial lining of the pocket wall as well as granulation tissue and subgingival plaque were removed. No correction of the alveolar bone was made. The flap was replaced and sutured interdentally and the treated area was covered with surgical dressing for at least one week. (For a more detailed explanation of the surgical techniques the reader is referred to standard textbooks, e.g. GLICKMAN 1972, GOLDMAN & COHEN 1968.)

Recording procedure. With the apparatus used it is possible to measure the transmission of ^{125}I radiation through a certain part of the alveolar process and also to measure the thickness of the same part of the alveolar process. The apparatus and the measurement technique have been described by HENRIKSON & JULIN (1971) and HENRIKSON & BERGSTRÖM (1974). The measurement of bone mineral mass and thickness refer to the interdental region between a canine and a lateral incisor or between a medial and a lateral incisor of the upper jaw.

The transmission was measured in two positions, the interdistance between such measurement points being 0.3 to 0.5 mm. The position of a measurement point in relation to adjacent teeth was controlled on a series of roentgenograms of the area by projection of steel balls (1 mm in diameter) at the points of entrance and exit of the radiation beam on lingual and labial gingiva.

All values of mineral mass obtained were corrected for the 'shorter wave length' of the radiation (HENRIKSON & BERGSTRÖM 1974).

The precision of the method, s_d, was determined on the basis of replicate determinations according to the formula

Table 2

Values of bone mineral mass in mg · mm^{-2} for regions treated by flap operation. The preoperative value (0) is the mean of 2 to 3 observations before the operation

Case No.	Week								
	0	1	2	3–4	6–8	10–12	14–16	18–20	24–26
1	4.16	4.20	4.14	4.02	4.00	4.15	4.00	4.02	4.01
2	4.37	3.88	3.66	3.72	3.80	4.02	4.08	4.14	4.16
7	4.50	4.42	4.25	4.19	4.15	4.13	4.32	4.37	4.29
11	2.09	2.04	1.62	1.74	1.90	1.82	2.48	(2.49)*	2.50
6	4.15	4.16	3.58	3.27	3.48	3.79	3.81	3.98	4.09
8	3.17	3.07	2.73	2.81	3.04	3.13	(3.18)*	(3.18)*	3.22
10	3.91	3.92	3.77	3.66	3.78	3.67	(3.82)*	3.97	(3.97)*
10	0.56	0.60	0.37	0.37	0.42	0.38	0.40	0.41	0.39
9	4.47	4.28	4.23	4.10	4.12	4.08	4.38	4.53	4.58
M	3.4866	3.3966	3.1500	3.0977	3.1877	3.2411	3.3855	3.4544	3.4677
SD	1.3445	1.2909	1.3431	1.2819	1.2553	1.3052	1.2681	1.3038	1.3132
SE	0.4481	0.4303	0.4477	0.4273	0.4184	0.4350	0.4227	0.4346	0.4377
N	9	9	9	9	9	9	(9)	(9)	(9)

* Value found by inter- or extrapolation

$$s_d = \sqrt{\frac{\sum d_i^2}{2\,n}}, \text{ where}$$

d_i = difference between two replicate determinations
n = number of differences

The mean value of the precision for the 18 regions examined was 0.038 mg · mm^{-2}, the range being 0.02 to 0.06 mg · mm^{-2} (Fig. 2). No significant differences were noted as regards the mean precision value for the first four postoperative weeks as compared to that of the subsequent observation periods, 6 to 12 weeks and 14 to 26 weeks, or to the preoperative mean precision value.

The thickness of the alveolar process has been determined separately in connection with the transmission measurements. The mean precision of the thickness determinations as expressed by the standard deviation of repeated settings and readings throughout the observation period was 0.13 mm for the total material.

Results

Changes in interdental bone mineral mass. The values of the bone mineral mass for the present material during the period of observation are given in Tables 2 and 3. As a mean for all areas treated the preoperative value of bone

Table 3

Values of bone mineral mass in mg · mm^{-2} for regions treated by gingivectomy. The 0-value represents the mean of 2 to 3 observations before the operation

Case No.	Week								
	0	1	2	3–4	6–8	10–12	14–16	18–20	24–26
1	4.48	4.48	4.25	4.18	4.38	4.64	4.60	4.55	4.54
2	4.20	4.03	4.06	3.75	3.85	4.25	4.61	4.66	4.48
7	2.69	2.53	2.31	2.47	2.47	2.58	2.63	2.50	2.56
4	4.45	3.98	3.69	3.86	3.83	4.28	4.46	4.50	4.43
6	4.00	3.63	3.72	3.65	3.78	3.87	3.88	3.90	4.07
5	1.62	1.15	0.83	0.90	1.18	1.22	1.50	1.64	(1.57)*
3	3.98	3.97	3.99	3.95	3.97	4.00	(4.06)*	(4.06)*	4.12
8	2.30	2.28	2.11	2.05	2.06	(2.17)*	(2.17)*	2.27	2.42
9	3.59	3.50	3.62	3.59	3.65	(3.74)*	3.82	4.48	4.43
M	3.4788	3.2833	3.1755	3.1555	3.2411	3.4166	3.5255	3.6177	3.6244
SD	1.0288	1.0746	1.1589	1.1035	1.0747	1.1546	1.1425	1.1581	1.1245
SE	0.3429	0.3582	0.3863	0.3678	0.3582	0.3848	0.3806	0.3860	0.3748
N	9	9	9	9	9	(9)	(9)	(9)	(9)

* Value found by inter- or extrapolation

mineral mass was 3.48 mg · mm^{-2} (3.487 and 3.479 mg · mm^{-2} in flap and gingivectomy areas, respectively) and the range was 0.56 to 4.47 mg · mm^{-2}.

The response of the alveolar bone to the surgery as reflected by the values of mineral mass is similar in the two groups. It is characterized by an initial decrease, most marked 3 to 4 weeks after the operation. Intraindividual differences were determined between the alveolar bone mass value obtained before and 3 to 4 weeks after surgery. The mean value of these differences was 0.389 $\pm$ 0.078 mg · mm^{-2} (M $\pm$ SE) and 0.322 $\pm$ 0.079 mg · mm^{-2} (M $\pm$ SE) for the flap operation and gingivectomy areas, respectively. These mean differences are significant ($t = 4.99$ and 4.06, respectively, $p < 0.01$).

The values of mineral mass during the period of observation expressed in per cent of the preoperative value are given in Fig. 3. The average decrease at the three to four week observation was then 13.67 and 11.52 per cent for the flap operation and gingivectomy areas, respectively. These percentage changes are statistically significant ($t = 4.33$ and 2.64, respectively, $p < 0.01$).

After the initial period of decreasing mineral mass increasing values were again encountered in both types of treatment. For the total material the preoperative level is reestablished after about 16 to 18 weeks. The process of return is somewhat faster in the gingivectomy treated areas.

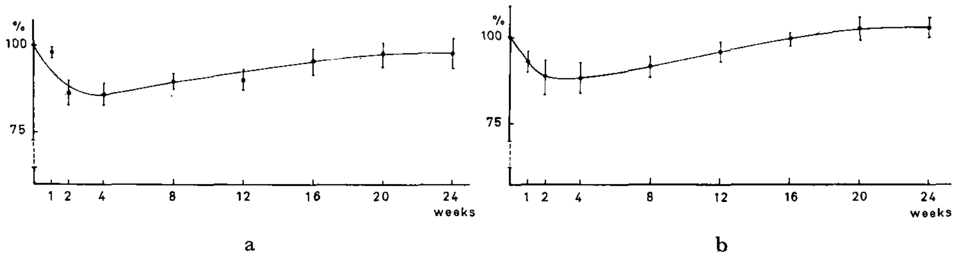

Fig. 3. Percentual changes with time in relation to preoperative values of bone mineral mass. Mean and SE for a) nine regions treated with flap operation and b) nine regions operated upon with gingivectomy.

Changes in the thickness of the alveolar process in relation to the preoperative level during the period of observation are given in Fig. 4 as averages for the two groups. It is evident from the graph that the thickness increased immediately after operation in both groups and more so for the flap operation group. At the one-week postoperative observation the mean increase was 1.24 ± 0.21 mm (M ± SE) for the flap operations and 0.66 ± 0.17 mm (M ± SE) for the gingivectomies. The changes are statistically significant ($t = 5.91$ and 3.88, respectively, $p < 0.01$).

During the subsequent period of observation this increase declines towards the preoperative level in both groups. As for the gingivectomy group the preoperative value is reattained after two to four weeks and from about eight weeks after operation the alveolar thickness is less than preoperatively, significantly so at the end of the observation period ($t = 2.82$, $p < 0.05$).

The subsiding of the postoperative swelling is slower in the flap operated areas and a return to the preoperative level does not occur completely during the period of observation.

Discussion

The general course of the postsurgical reaction of the alveolar bone for both groups of treated areas is rather uniform, characterized by an initial loss of alveolar bone mass followed by a gradual recovery. At the end of the observation period the alveolar bone mass approximates the preoperative level. This course of events gives further support to earlier findings on a similar patient material (Bergström & Henrikson 1970) when the changes of the alveolar process were expressed in aluminium equivalents. Converting these latter values to $mg \cdot mm^{-2}$ hydroxyapatite, it will be seen that for both of these materials, altogether 25 treated regions, the magnitude of the initial decrease was approximately 0.3 $mg \cdot mm^{-2}$.

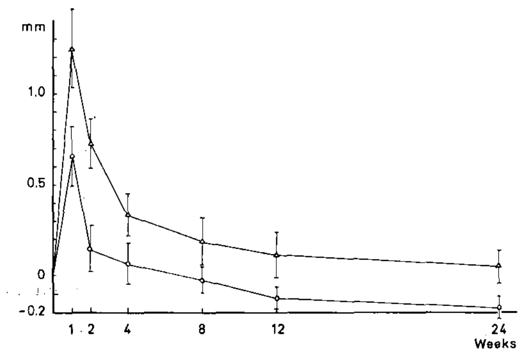

Fig. 4. Changes in thickness with time in relation to preoperative values. △ mean and SE for nine flap operations and ○ for nine gingivectomies.

Compared to the initial changes characterized by bone loss the recovery phase is a rather slow process. On an average for the total material the preoperative level of bone mineral mass is reestablished after about six months.

Histologic observations on the reaction of the alveolar bone following periodontal surgery have been made both in animals (WILDERMAN et coll. 1960, STAFFILENO et coll. 1962, 1966, WILDERMAN 1963, CAFESSE et coll. 1968) and in man (RAMFJORD & COSTICH 1963, 1968, PFEIFER 1963, 1965). The severity of the reaction is dependent upon the surgical technique and to which extent the bone has been exposed. Experimental periodontal flap procedures in animals (WILDERMAN et coll. 1960, WILDERMAN 1963) indicate that bone resorption as reflected by the osteoclastic activity was most extensive six to ten days after surgery, while histologic criteria of bone regeneration seem to suggest that this process would be completed within 2 to 3 months after surgery (WILDERMAN 1963, CAFESSE et coll. 1968). In comparison with this histologic information—although not fully adequate, as the histologic findings are mostly based on animals with healthy periodontia—the present results would indicate that the processes of initial demineralization, and particularly that of the later remineralization, seem to be slower than and lag behind histologically evidenced stages of bone resorption and bone formation.

The present results are in concordance with recent concepts of bone tissue dynamics (FROST 1964, URIST 1969, HAM & HARRIS 1971, RASMUSSEN & BORDIER 1973). After injury to the tissue, mesenchymal cells will be activated to form osteoclasts, producing resorption. This phase lasts one or a few weeks. At the end of this phase osteoblasts are produced (FROST 1964, RASMUSSEN & BORDIER 1973). Once the osteoblasts are formed, a new organic matrix is produced which subsequently becomes mineralized (PRITCHARD 1972). According to FROST (1964) mineralization begins one to two weeks after the matrix is formed and is completed after 3 to 4 months.

Therefore, using a time scheme for alveolar bone healing in terms of mineral mass analogous to that of WILDERMAN (1963), it seems appropriate to call the initial reaction, 0 to 30 days, the demineralization stage (corresponding to the preparatory, osteoclastic and osteoblastic stages of WILDERMAN) and consequently the period 30 to 180 days after the injury the remineralization stage (corresponding to the maturation stage).

The quantitative analysis of mineral mass changes of the alveolar bone reported was performed in its marginal interdental part. The height of the remaining margin was reduced by, on an average, 15 per cent compared to normal, which is generally regarded to be about 90 per cent of the root length (Table 1).

These regions varied in mineral mass within rather wide limits (0.56 to 4.48 $mg \cdot mm^{-2}$). Such interindividual variation may in part be qualitative but may also represent the orientation of the radiation beam within the subject on passage through the alveolar process, and particularly its relation to the alveolar margin.

It has been reported (WILDERMAN et coll. 1960, WILDERMAN 1963, WOOD et coll. 1972, TAVTIGIAN 1970) that the margin is especially sensitive to resorptive changes after surgery. In the present material no significant correlation was found between the presurgical amount of the alveolar bone and the severity of the initial reaction (expressed as loss of mineral mass). Further measurements, however, should be made to evaluate the magnitude of such changes for bone layers at different distance from the margin.

On the other hand there was rather close conformity of the type of reaction between the two measurement positions within a certain region and at the given height level. This indicates that possible erroneous influences due to a contribution to attenuation from dentine and cementum of adjacent teeth were limited, if at all present. As the apparatus was constructed also for film exposure by the extremely collimated radiation, the tissue structure at the positions selected for recording could be examined. Bone structure was demonstrated in the films of all areas.

As was demonstrated by FORSBERG & HÄGGLUND (1957) the trauma from periodontal surgery will result in an at least temporarily increased mobility of the teeth. The increased tooth mobility may affect the reliability of the value of mineral mass obtained during the first postoperative period. However, judging from the fact that the precision of the method was not notably altered during this period it was concluded that by the measurement technique used such a possible effect did not interfere with the reliability of data obtained.

As was anticipated from earlier observations (BERGSTRÖM & HENRIKSON 1970) the influence from gingival swelling on total attenuation has to be taken into consideration when evaluating the changes pertaining to the mineral mass in vivo. This is particularly true during the first four postoperative weeks and when the procedure is a flap operation. As is reported elsewhere (BERGSTRÖM 1974) the oedema after surgery is more marked at a distance from than near the margin. The magnitude of such changes in the transverse thickness is thus dependent, among other things, also on the vertical height level of the measurement position.

To conclude, the present results reveal that periodontal surgery, whether gingivectomy or periosteal flap operation, brings about an average of 10 to 15 per cent loss of mineral mass in the interdental alveolar bone tissue. This is an insult to an already fragile bone tissue due to chronic periodontitis. In general, however, the tissue seems to repair within a six-month period. Whether this process of regeneration will continue in time to produce a more mineralized bone as a final result of the treatment demands further investigation.

SUMMARY

The influence on the alveolar bone mineral mass of two common techniques of periodontal surgery, mucoperiosteal flap operation and gingivectomy, was investigated in patients with periodontal disease. The bone reaction, similar with respect to type of treatment, was characterised by a loss of mineral mass during three to four weeks after surgery. The maximum loss was 0.3 mg · mm^{-2} on an average (10 to 15 per cent). A remineralization of the alveolar bone followed towards the presurgical level, which was reattained after four to six months.

ZUSAMMENFASSUNG

Es wurde der Einfluss von zwei gewöhnlichen Techniken der periodontalen Chirurgie, die mukoperiosteale Lappenoperation und die Gingivektomie, auf den alveolaren knöchernen Mineralgehalt bei Patienten mit einer periodontalen Erkrankung untersucht. Die Knochenreaktion, die ähnlich im Hinblick auf den Typ der Behandlung war, zeichnete sich durch einen Verlust des Mineralgehalts während drei bis vier Wochen nach der Operation aus. Der maximale Verlust betrug im Durchschnitt 0,3 mg · mm^{-2} (10—15 %). Es erfolgte eine Remineralisation des alveolaren Knochens bis zum präoperativen Gehalt, der nach vier bis sechs Monaten wieder erreicht war.

RÉSUMÉ

L'influence sur la masse minérale de l'os alvéolaire de deux techniques courantes de chirurgie périodontale, l'opération du volet mucopériosté et la gingivectomie, a été étudiée chez des malades atteints de maladie du périodonte. La réaction osseuse, semblable quelque soit le type de traitement, a été caractérisée par une perte de la masse minérale pendant trois à quatre semaines après l'intervention. Le maximum de perte a été de 0,3 mg · mm^{-2} en moyenne (10 à 15 pour cent). La reminéralisation de l'os alvéolaire fait à l'opération et atteint le niveau préopératoire au bout de quatre à six mois.

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