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A Comparative Study of the Wound Healing of Three Types of Flap Design Used in Periapical Surgery

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The clinical and histological features of wound healing of three common types of surgical flap designs used in periapical surgery were evaluated. A semilunar incision of alveolar mucosa, a submarginal incision of attached gingiva, and an intrasulcular incision of the attachment apparatus and papillae of the teeth were performed on beagles and observed at intervals of up to 60 days. Inflammatory changes persisted longer in the semilunar and intrasulcular incisions and retarded healing of the wound. Loss of alveolar bone occurred with the intrasulcular incision. Visible scarring occurred in the submarginal and semilunar incisions.

Periapical surgery has become an integral part of comprehensive dental treatment. Since its primary purpose is the treatment of the bony lesion at the periapex of the tooth, little attention has been given to the treatment of the gingival tissues that must be incised and reflected to surgically gain access to the lesion. The design of the surgical flap in most cases has been determined by clinical convenience, even though it may influence the healing process.

The surgical flap designs can be described according to their geometric shape (1), as well as by the location of the horizontal portion of the incision. A review of the endodontic literature and texts reveals considerable disagreement relative to the indications and contraindications for each particular flap design (2–8). The criteria for the flap design selected appear to be based upon empirical factors and clinical experience. They include marginal gingival recession, contraction or necrosis of the gingival papilla, hemostasis, ease of access, visibility, maintenance of an adequate blood supply, presence of a dehiscence or fenestration, minimal trauma to the wound margins, and scarring.

Because of these implications and the clinical conditions present, the selection of a particular surgical flap design should be based on available information of the postoperative healing of the incisional wound.

The purpose of this study was to evaluate the clinical and histological features of healing of three common types of surgical flap designs used in periapical surgery. These designs include the semilunar incision of alveolar mucosa, the submarginal incision of attached gingiva, and the intrasulcular incision of the attachment apparatus and papillae of the teeth.

MATERIALS AND METHODS

Six pure bred female beagles, ranging in age from 13 to 34 months, served as the test animals for this experiment. These kennel-bred dogs were fed a diet of dry dog food ad libitum. For ease in identification, their teeth were numbered from 1 to 42, as shown in Fig. 1.

Calculus accumulations and gross staining of the teeth were removed by prophylaxis with a Cavitron (Dentsply, Inc., York, PA) 2 wk before surgery. For this procedure, each dog was weighed and anesthetized with an i.v. injection of sodium pentobarbital at a dosage of 1 ml/5-lb body wt. A marker was placed on the buccal surface of tooth #25, approximately 2 mm from the crest of the free marginal gingiva. A 33½ inverted cone bur and a high-speed handpiece with water spray were used to make a shallow cavity preparation approximately 3 x 4 x 2-mm, which was then restored with a color-enhanced resin. The purpose of this marker was to aid in the measurement of gingival recession and alveolar bone loss in the quadrant where the intrasulcular incision was to be made.

On the day of surgery, each dog was again anesthetized with sodium pentobarbital i.v. Each surgical site was infiltrated with 1.8 ml of lidocaine HCl (2%) with 1:50,000 epinephrine for vasoconstriction and was injected into the buccal mucosa and gingival papillae until blanching of the tissues occurred.

In the upper right quadrant, a semilunar incision, approximately 2.5 cm in length, was made in the alveolar mucosa by a single cut with a scalpel (Fig. 1). A full-thickness surgical flap was reflected with a periosteal elevator exposing the underlying cortical bone. To simulate the procedures involved in an apicoectomy, the cortical plate of bone was perforated in the area of the apex of a tooth with #10 round bur and a high-speed handpiece with water spray.

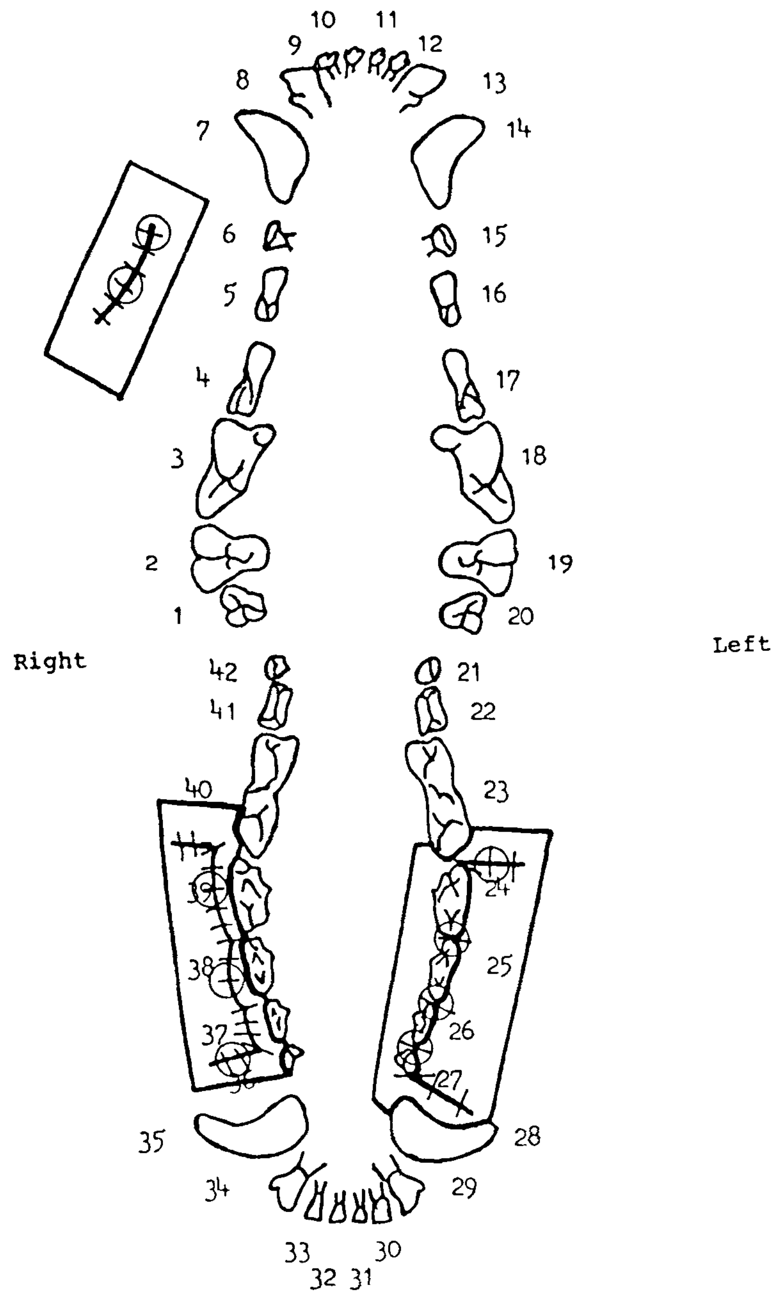

FIG 1. Diagram illustrating sites of surgical incisions, placement of sutures, tissue samples removed from test animals, and representatives samples used for histological evaluation.

Thereafter, the edges of the wound were approximated and sutured with 4-0 black silk and CE-2 needle. The number of interrupted sutures placed was dependent upon the length of the incision. The sutures were placed in such a manner as to prevent gaping of the wound site, thereby promoting healing by primary intention. Gentle pressure with a warm sterile water-soaked gauze pad was applied for 3 min to the surgical flap to minimize hematoma formation subperiosteally and to enhance reattachment of the flap to the underlying bone.

The upper left quadrant was used as the control in which no surgical procedures were performed.

In the lower left quadrant, a horizontal intrasulcular incision was made in the attachment apparatus and around the necks of the teeth indicated in Fig. 1. Vertical relaxing incisions were made at the distal line angle of tooth #24 and the mesial line angle of tooth #27. Tissue retraction, preparation of the cortical bone, and postoperative pressure adaptation were performed in a manner similar to that described for the semilunar surgical flap. After retraction of the full-thickness surgical flap, the distance from the composite marker to the crest of the alveolar bone adjacent to the tooth was measured and recorded. One interrupted silk suture was placed in each gingival papilla to immobilize the flap. A sufficient number of sutures were placed in the relaxing incisions to prevent gaping of the wound.

In the lower right quadrant, a horizontal submarginal incision was made in the attached gingiva. It was necessary to ascertain that a minimum of 2 mm of attached gingiva was present (9). This horizontal incision extended from the mesial line angle of tooth #37 to the distal line angle of tooth #39, where vertical relaxing incisions were placed (Fig. 1). Tissue retraction, preparation of the cortical bone, and postoperative pressure adaptation were performed in a manner similar to that described for the semilunar surgical flap. One interrupted silk suture was at each of the two corners of the approximated surgical flap. A sufficient number of sutures was placed in the horizontal and vertical incisions to aid healing by primary intention.

The time during which the surgical flap was retracted and the bone was exposed varied from 5 to 7 min for each procedure. No surgical pack was placed over the surgical sites postoperatively.

The dogs were not fed on the day of surgery because prior feeding could cause problems with anesthesia and trauma to the wound from postoperative feeding had to be avoided. On the first postoperative day, each dog was weighed and fed a soft diet of one can (66 g) of dog food.

This routine of weighing and feeding was continued for 10 days after surgery. One crushed tablet of Tylenol #3 (300 mg of acetaminophen and 30 mg of codeine) was added to the dog food for the first 3 postoperative days to minimize any discomfort that may have resulted from trauma to the wound and/or from premature loss of sutures. The sutures were removed on the 7th postoperative day. The dogs resumed their normal diet after 10 days and their weight was monitored at each visit when photographs were taken.

Photographs were taken of the wound sites preoperatively, immediately postoperatively, and at 1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30, 40, and 60 days after surgery, or until the dogs were sacrificed. One milliliter of Acepromazine (Ayerst Laboratories, Inc., New York, NY) was injected intramuscularly to tranquilize the dog so that photographs could be taken without causing undue trauma to the surgical sites.

Of the six dogs used, two were sacrificed at 48 h after surgery and one dog was sacrificed at 7, 15, 30, or 60 days after the surgical procedure. The dogs were sacrificed with an overdose of sodium pentobarbital administered i.v.

Tissue samples were removed immediately from each of the surgical sites for histological examination in order to evaluate wound repair. An incision was made so that the entire previous wound with a border of 1 cm or more of normal tissue would be included in the sample. The tissue was reflected from the bone with the periosteal elevator and stored in 15% formalin for 72 h. The samples taken from the dogs sacrificed at 48 h and 7 days after the operative procedures included the suture materials in place.

Measurements were made from the composite marker on tooth #25 to the height of the alveolar bone adjacent to it, to determine if any bony changes had occurred in the region of the intrasulcular incision.

The samples were trimmed to provide representative areas for viewing the cross-section through the incisional wound of each surgical flap design. The sections were embedded in paraffin and sectioned so that the approximated edges of the wound could be viewed. Successive sections of each specimen were stained with either hematoxylin and eosin, Van Gieson stain, or Wilder's reticulin stain. Each section was examined for progression of wound repair, as described by Peacock and van Winkle (10), according to the following criteria: presence of fibrin, hyperemia (distended capillaries), type of inflammatory cell infiltrate, edema, epithelial cell changes, proliferation of fibroblasts, changes in collagen, increased vascularization, keratinization, and the return of normal appearance of the epithelial layers and rete pegs.

Comparisons of the distances from the composite marker to the height of the adjacent alveolar bone at the time of incision and at the time of sacrifice were used to assess the bony changes that took place in the alveolar crestal bone with the intrasulcular incision.

Criteria for the clinical evaluation of the surgical wounds were: color, swelling, closure, marginal gingival recession, and residual scarring.

RESULTS

Histological Evaluation

The data presented in Table 1 are based on evaluation of histological sections of the incision sites for the three surgical flap designs removed from dogs sacrificed at the time intervals indicated.

A well-established fibrin clot was present in each incision site at 2 and 7 days after surgery, but was no longer present at 15 days in any of the dogs. In each case, the clot extended from the epithelium down to the periosteum and was observed subperiosteally in that area in which the surgical flap was reflected.

Hyperemia was evaluated by the presence of distended, blood-filled capillaries and arterioles in the tissues adjacent to the incision. The submarginal incision exhibited less vascular distention and engorgement during the early stages of healing. By 15 days, the hyperemia was resolving in every dog and at 30 days normal vessels were observed.

Dense concentrations of polymorphonuclear leukocytes were present in the semilunar and intrasulcular wounds at 2 days, but were not seen in observations made at longer time intervals. The concentration of polymorphonuclear leukocytes was accompanied by a dense infiltration of mononuclear cells that did not begin to decrease until after 30 days and was still observed to some degree after 60 days. The submarginal incision in the attached gingiva exhibited a mild, diffuse polymorphonuclear and mononuclear cellular infiltration at 2 days and showed some resolution after 15 days. By 30 days, there was a relative absence of inflammatory cells in the submarginal incision wound.

Edema was also more evident in the semilunar and intrasulcular wounds than in the submarginal wound during the early stages of repair. Edema was still in evidence in the intrasulcular incision at 30 days.

The epithelial changes that would normally be observed in an incisional wound were found to occur in each surgical flap design. They include flattening of the basal cells, migration of the basal cells along the dermis to close the wound, flattening of the adjacent rete pegs, and mitosis of basal cells in areas adjacent to the wound site. However, the resultant inverted epithelial cleft formed by this migrating epithelium appeared to be narrower in the submarginal incision than in the semilunar and intrasulcular incision, respectively.

The amount of fibroblastic proliferation was judged to be similar in each experimental group.

Wilder's reticulin silver stain demonstrated the later appearance of immature collagen fibrils in the intrasulcular incision, and their abundance in the 30- and 60-day samples of the intrasulcular surgical flap demonstrated a slower maturation of these connective tissue elements.

A relative increase in vascularity was observed in each wound throughout the observation period. However, an earlier decrease was observed in the submarginal incision at 60 days, though not a return to a state of normal vascularity. These observations were demonstrated by the use of Van Gieson stain.

The submarginal wound was judged to be the best for epithelial closure of the wound inasmuch as complete closure of the wound by more than a single epithelial layer was observed after 2 days. The semilunar incision exhibited closure by only a single layer of cells after 2 days, while the dermal tissues of the intrasulcular wound were not covered by epithelium until 7 days had elapsed.

The histodifferentiation of the epithelium occurred in a similar order by exhibiting keratinization or, in the case of alveolar mucosa, development of the characteristic multicellular layering approximately 1 wk after epithelial closure.

The final stages of repair of the connective tissue of the wound was determined by the change of the collagen from a fine, fibrillar appearance to a coarse, bundle form, as demonstrated by Van Gieson stain and Wilder reticulin silver stain.

Epithelial islands were found entrapped in the wound site in the intrasulcular incision.

Cicatrization, another facet of tissue repair after injury, involves the orderly arrangement of connective tissue elements, particularly collagen bundles, along predesigned planes or along lines of stress (11). This change in orientation was evident to some extent in all of the surgical flap designs by 15 days, although to a more advanced state in the submarginal incision during the later stages of repair.

The final step of wound repair at a histological level is the return of the normal appearance of the rete peg. This was more evident in the semilunar and submarginal incisions than in the intrasulcular incision.

TABLE 1. Histological evaluation

Day	2	2	2	7	7	7	15	15	15	30	30	30	60	60	60
Incision	SL*	IS	SM	SL	IS	SM	SL	IS	SM	SL	IS	SM	SL	IS	SM
Fibrin clot	++	++	++	++	++	++	0	0	0	0	0	0	0	0	0
Hyperemia	++	++	+	++	++	+	+	+	+	0	0	0	0	0	0
Polymorphonuclear cell infiltration	++	++	+	0	0	0	0	0	0	0	0	0	0	0	0
Mononuclear cell infiltration	++	++	+	++	++	+	++	++	+	+	+	0	+	+	0
Edema	++	++	+	++	++	+	+	+	+	0	+	0	0	0	0
Epithelial changes															
Basal cell shape	++	++	++	++	++	++	+	+	+	0	0	0	0	0	0
Flattening of rete pegs	++	++	++	++	++	++	++	++	++	+	+	+	+	+	+
Basal cell mitosis	++	++	++	++	++	++	++	++	++	+	+	+	+	+	+
Basal cell migration	++	++	++	++	++	++	0	0	0	0	0	0	0	0	0
Fibroblastic proliferation	0	0	0	++	+	++	++	++	++	++	++	++	+	+	+
Epithelial closure	+	0	++	++	+	++	++	++	++	++	++	++	++	++	++
Abundance of capillaries	++	++	++	++	++	++	++	++	++	++	++	+	++	++	+
Keratinization	0	0	0	0	0	+	0	+	++	0	++	++	0	++	++
Collagen															
Fibrillar form	0	0	0	+	0	+	++	+	++	+	++	+	+	++	0
Bundle form	0	0	0	0	0	0	0	+	+	++	++	++	++	++	++
Entrapment of epithelial islands	0	+	0	0	0	0	0	0	0	0	+	0	0	+	0
Cicatrization	0	0	0	0	0	0	+	+	+	+	+	++	+	+	++
Return of rete peg to normal appearance	0	0	0	0	0	+	0	+	+	0	0	+	+	0	+

* SL, semilunar incision; IS, intrasulcular incision; SM, submaringal incision; ++, very evident; 0, absent; +, present.

TABLE 2. Clinical evaluation

Appearance	Day / Incision	2 SL*	2 IS	2 SM	7 SL	7 IS	7 SM	15 SL	15 IS	15 SM	30 SL	30 IS	30 SM	60 SL	60 IS	60 SM
Dog A																
Color		++	++	+	++	++	+	+	+	0						
Swelling		++	++	+	++	+	0	+	0	0						
Closure		0	0	+	+	+	++	++	++	++						
Recession		0	0	0	0	+	0	0	+	0						
Scarring		0	0	0	0	+	+	+	0	+						
Dog B																
Color		++	++	+												
Swelling		++	++	++												
Closure		0	0	+												
Recession		0	+	0												
Scarring		0	0	0												
Dog C																
Color		++	++	+	++	+	+	+	0	0	0	0	0	0	0	0
Swelling		++	++	+	+	+	+	+	+	0	0	0	0	0	0	0
Closure		0	0	+	+	++	++	++	++	++	++	++	++	++	++	++
Recession		0	0	0	0	+	0	0	++	0	0	++	0	0	++	0
Scarring		0	0	0	0	+	+	+	0	+	++	0	++	++	0	++
Dog D																
Color		+	++	+	+	+	0	0	0	0	0	0	0			
Swelling		+	++	+	+	+	0	0	0	0	0	0	0			
Closure		+	0	+	++	+	++	++	++	++	++	++	++			
Recession		0	0	0	0	0	0	0	0	0	0	0	0			
Scarring		0	0	0	0	0	+	++	+	++	++	0	+			
Dog E																
Color		+	+	+												
Swelling		+	0	+												
Closure		+	+	++												
Recession		0	0	0												
Scarring		0	0	0												
Dog F																
Color		+	+	+	0	0	0									
Swelling		++	+	+	+	0	0									
Closure		+	+	++	++	++	++									
Recession		0	0	0	0	0	0									
Scarring		0	0	0	0	0	0									

* SL, semilunar incision; IS, intrasulcular incision; SM, submaringal incision; ++, very evident; +, present; 0, absent.

Clinical Evaluation

The data presented in Table 2 are based on the clinical evaluation of the sites for each of the three surgical flap designs at the time intervals indicated. Alteration of color, presence of swelling, recession of marginal gingiva, and extent of scarring were evaluated on the basis of: 0, none; +, slight; ++, moderate to severe. Closure of the wound site was evaluated as: 0, an open wound with only a clot present; +, some epithelial closure of the incision; ++, complete epithelial closure throughout the length of the wound.

The inflammatory changes of redness and swelling were more severe during the early wound repair with the semilunar and intrasulcular incisions. Their return to normal appearance was delayed when compared with the submarginal incision wounds.

Epithelial closure progressed much more quickly and more predictably with the submarginal incision, although closure was complete with each flap design by the 15th day.

Recession of the marginal gingiva occurred in the intrasulcular incision, but not to a predictable degree. The amount of recession varied from 0 to 1.2 mm. No recession was observed with the other two incisions, since injury to the epithelial attachment apparatus was avoided.

Very little, if any, scarring was evident with the intrasulcular incision. However, scarring was quite evident in each of the other two surgical flap designs from the day the sutures were removed to the end of the observation period.

Evaluation of Osseous Changes

The data presented in Table 3 are based on measurements taken from the composite marker to the adjacent alveolar bone at the time of surgery and at the time of sacrifice. The results revealed that some bone loss had occurred as anticipated, but the amount of loss could not be predicted. The greatest amount of

Table 3. Distance between the composite marker and the height of the alveolar bone adjacent to tooth taken at the time of surgery and at the time of sacrifice

Dog	B	E	F	A	D	C
Day	2	2	7	15	30	60
Distance (mm) on day of surgery	2.8	3.0	2.9	3.2	2.5	2.8
Distance on day of sacrifice	2.9	3.0	3.4	3.8	3.7	3.8
Difference	0.1	0.0	0.5	0.6	1.2	1.0

bone loss occurred between the 2nd and 30th day after surgery.

DISCUSSION

In this study the design of the surgical flaps was chosen so that an evaluation could be made regarding the rate and quality of healing of the incisional wound in three different types of tissue, i.e., loose alveolar mucosa, attached gingiva, and crevicular and papillary gingiva. Vertical relaxing incisions were used in the submarginal and intrasulcular incisions to minimize tugging or tearing of the wound margin during retraction.

Local anesthetic with a vasoconstrictor was used to aid in hemostasis. Studies (12) have shown the detrimental effects of poor hemostasis and hematoma formation on the adaptation of the surgical flap to the underlying bone and the resultant retardation of healing of the incisional wound, whereas no research has investigated the effects of a vasoconstrictor on the healing of the wound margins.

The work of previous researchers (13–16) can be cited to defend the use of dogs as test animals in assessing the wound healing of gingival tissues. The periodontium of the beagle is quite similar to the human periodontium on both the gross anatomical as well as the ultrastructural level (17–19). The microvascularization and collagen synthesis and maturation of the dog have been studied extensively and compared favorably with primates (13, 16, 20, 21). The normal sulcus depth in beagles is similar to that in the human periodontium (average of 2.4 mm) (22). An added advantage for the use of the dog, though different than humans, is that they are capable of synthesizing vitamin C endogenously, ensuring adequate levels for collagen synthesis in which it plays a vital role.

Since nutrition plays such a vital part in wound healing, the amount of food ingested by the dogs, as well as their weight, was monitored daily. No significant weight loss or gain (±2 lb) was observed over the experimental time.

Histological and clinical evaluation of the incisional wounds would lead us to conclude that a submarginal incision in the attached gingiva will progress toward the final stages of repair more quickly, with fewer signs of prolonged inflammation and more scarring.

In each surgical flap design, the initial steps of wound repair occurred in the usual sequence; however, the size of the clot which formed and the epithelial closure of the wound were affected by how closely the edges of the incisional wound could be reapproximated after surgery.

The friable nature of the tissue of the alveolar mucosa makes it difficult to gain complete closure and healing by primary intention. The fragility of this tissue causes an inversion of the edges into the wound site. The pulling action of the surrounding musculature tends to cause some separation of the wound edges, even after suturing has been completed.

With the intrasulcular incision, the anatomy of the papillae makes reapproximation of the wound edges less than ideal. Once again, inversion of the epithelial layers is seen so that primary healing is not easily accomplished. This surgical flap design is used extensively in periodontal therapy where healing by first intention is seldom achieved. Healing by second intention, union by adhesion of granulating surfaces, is the common finding when this flap design is utilized (21).

The submarginal incision in the attached gingiva produced a situation very similar to that described by Mittelman et al. (23). Here, the surgical flap can be very closely repositioned and sutured to place with little tension placed on the postoperative wound. In this situation, healing by primary intention rather than by granulation is allowed to proceed.

The increased and prolonged hyperemia and edema present in the semilunar incision were probably the result of the greater vascularity of the alveolar mucosa, as observed in the control samples. This greater vascularity was evident during the surgical procedure when this surgical flap design was found to present the most problems in maintaining hemostasis. The increased and prolonged hyperemia and edema present in the intrasulcular incision might have resulted from greater trauma received by the papillary tissues during mastication and parafunctional oral habits. There are no contact areas between the posterior teeth of dogs to protect the sutures placed interproximally in this surgical flap design. This might account for the chronic inflammation. However, it has not been shown that open interproximal contacts can be related statistically to alveolar bone loss or gingival recession (24). The submarginal incision, placed in less vascular tissue than the semilunar incision and in an area protected by masticatory trauma, was able to progress more rapidly through the early stages of wound repair.

A similar judgment could be made regarding the mononuclear cellular infiltrate. Chronic lesions maintain this inflammatory cell population. A prolonged inflammatory state retards healing, since the macrophages and lymphocytes present are known to release factors that inhibit synthesis of metabolites necessary for repair, or, in fact, are destructive to the surrounding tissue.

The ease of reapproximation of the edges of the wound also affected the epithelial cellular changes found in wound repair. Since the submarginal incision could be reapproximated better and held in place more securely than the semilunar or intrasulcular incisions, epithelial migration appeared to close the wound more quickly and was able to proceed more quickly to cellular maturation and histodifferentiation.

A similar pattern is observed in the connective tissue elements adjacent to the wound. A relative increase in vascularity is seen in each incision site to provide the nutrients necessary for wound repair. Some decrease could be observed in the submarginal incision at the end of the observation period. This could probably be anticipated because this incision had proceeded to the final stages of repair most rapidly.

The latter appearance and slower maturation of collagen fibrils can also be related to the longer chronic inflammatory state that existed in the semilunar and intrasulcular incision wounds (25, 26). This maturation of the collagen is important when we consider the ability of the wound to resist rupture. Tensile strength and extension or pliability of the wound are the determinants of the energy absorption necessary to rupture a healed wound (11).

From Forrester's work (11), we can see that maturation of collagen into bundle form and the alignment of collagen fibers are important determinants of final wound strength. The presence of epithelial islands entrapped along the incision line also adversely affects the tensile strength, since epithelial bonding is weaker than that of connective tissue.

The submarginal incision at 60 days exhibited the most advanced collagen bundle formation, an orientation of the collagen bundles comparable to adjacent normal tissue, and the lack of entrapped epithelial islands. This leads to the conclusion that the tensile strength of the submarginal incision wound will be greater at 60 days than the semilunar and intrasulcular incision wounds.

From a clinical standpoint, the submarginal incision demonstrated better results than the semilunar or intrasulcular incisions, except in the areas of scar formation. Inflammation resolved more quickly, macroscopic epithelial closure occurred more quickly, no marginal gingival recession occurred, and no alveolar crestal bone was lost. After 60 days, the basic differences were the amount of scarring that occurred with the semilunar and submarginal incisions and the altered periodontal attachment from the intrasulcular incision. The clinical implications of these results should be considered.

As a result of the greater vascularity of the alveolar mucosa, a semilunar incision in that tissue will usually result in increased hemorrhage. The geometric shape of the surgical flap necessitates overextension of the incision or risks excessive trauma to the wound margins in order to provide adequate access and visibility. These disadvantages contradict one of Halsted's (27) and Davis' (28) basic surgical principles, i.e. minimal trauma to the wound edges and avoidance of hematoma formation. The difficulty in reapproximating two wound margins, neither of which are firmly attached to underlying bone, provides another reason for avoiding this surgical flap design.

The choice between the intrasulcular and the submarginal must first be based on the anatomical location of the pathological lesion requiring the surgical therapy. It is considered to be good clinical practice not to place an incision over an area where a lesion is present, since the cortical bone will usually be removed and primary coverage of the bony lesion would be difficult to attain. If the edges of the wound are closely reapproximated and trauma to the wound is avoided, closure of the wound with epithelium and connective tissue should occur by primary intention. The only requisite is that a fibrin clot be established and maintained into which the tissue elements are able to migrate. However, since postoperative trauma cannot always be avoided, it is prudent to place the incision over healthy bone so that intact periosteum can provide a firm base for suturing the surgical flap into place.

When this anatomical feature is not a prime consideration, the advantages and disadvantages of these two surgical flap designs can be evaluated. From the literature and this study (12–15, 29–36), we know that the intrasulcular incision with retraction of a full-thickness surgical flap will expose alveolar crestal bone, causing some loss of that bone, possible recession of the marginal gingiva, or, at the least, lengthening of the epithelial attachment. These are consequences that should be avoided unless osseous recontouring of periodontal defects is being done at the same time.

The presence of a dehiscence has been cited by different authors as either an indication or contraindication for both the submarginal and intrasulcular incisions. In a situation where a dehiscence is present, but is not detectable clinically because probing of the sulcus is within normal limits and no mucogingival problem is apparent, a fibrous attachment of the gingiva to the root surface of the tooth is usually found to exist. If an intrasulcular incision is made to reflect a full-thickness flap, this epithelial attachment will be injured and reattachment will most probably occur at a more apical level (13, 20). Some degree of alveolar bone loss will predictably occur once the periosteum is reflected. With these events occurring, the probability of a gingival cleft resulting is increased. The most severe consequences would be severe gingival recession (especially if the remaining cortical plate is extremely thin along the remainder of the exposed tooth root), altered aesthetics, hypersensitivity of adjacent teeth, and root caries (H. C. Crossetti, personal communication).

Such complications can be avoided with the submarginal incision. When the incision is placed in firmly attached gingival tissue, even if that tissue is epithelial in nature, healing occurs without the previously mentioned sequellae. Excellent tissue reapproximation and fixation with fine sutures placed without tension will allow repair to occur without an altered gingivo-dental relationship. The dehiscence may increase, due to the reflection of periosteum, however, collateral circulation will maintain the integrity and vitality of the marginal epithelium (37–40).

The scarring that occurs with the submarginal incision should be of concern, though, in practice, the location of the scar is usually not easily visible. Its extent is dependent upon the ability of the operator, the tension placed on the wound margin and on the sutures, and the host's state for connective tissue remodeling (41, 42).

In this study, catgut, chromic gut, or polyglycolic acid sutures would have caused less of an inflammatory response and, because of their resorbable nature, less downgrowth of epithelium into the suture tracts (43–51). The epithelial ingrowth and chronic inflammation from the suture tracts were often confluent with the incision site and caused some difficulty in evaluation. However, after a review of endodontic texts and a survey of a number of practicing endodontists, silk was chosen as the test material to provide relevance of the results to everyday practice. For the same reason, the interrupted suture technique was used rather than the continuous suture technique, although the latter is more efficient, allows better placement of the tissues, and keeps the knots from being placed over the incisional wound (41). This last point is of special concern because the constant irritant of the knot and the debris that it accumulates deter healing.

The requirement of a minimum of 2 mm of attached gingiva is of great importance in the prevention of more severe mucogingival problems (9). In a situation where sufficient attachment is not present and the periapical surgery is not of an emergency nature, procedures for gaining more attached gingival tissue are recommended prior to periapical surgery (38–40, 52–55).

Triangular surgical flap designs are acceptable if adequate access can be achieved without trauma to the margins of the wound. Trapezoidal flap designs are not necessary, since the possibility of embarrassing the blood supply to the surgical flap is virtually impossible if proper surgical technique is used and the tissues are not badly traumatized (56). Adequate circulation has been maintained, even in long, thin pedicle flaps (55, 57, 58) when Halsted's (27, 28) surgical principles are followed: (a) a single, clean incision; (b) minimal trauma to the wound margins; (c) prevention of hematoma formation under the surgical flap; (d) use of small gauge sutures and needles; (e) minimal tension of the sutures; and (f) asepsis.

CONCLUSIONS

Within the scope of this study, the following conclusions can be drawn:

1. Inflammatory changes persist for longer time in the semilunar and intrasulcular incisions than in the submarginal incisions. This chronic inflammation retarded healing of the incisional wounds.
2. When compared with the submarginal incision, the semilunar and intrasulcular incisions demonstrated a delay in histologically observable mature collagen fibers and its realignment with adjacent tissues. Entrapped epithelial islands were observed in the intrasulcular incisions.
3. Loss of alveolar bone, accompanied by gingival recession or an increase in the length of the epithelial attachment, will occur with the intrasulcular incision.
4. Scar formation occurs with the submarginal and semilunar incisions, while very little, if any, visible scarring occurs with the intrasulcular incision.

From the evidence presented, it would appear that the submarginal incision is the flap design of choice in periapical surgery when not contraindicated by the anatomical location of the lesion or by insufficient attached gingival tissue.

It should be pointed out that this study was carried out under nonpathological conditions, the size of the sample was limited, and the conclusions were drawn from observations in dogs. It would be unwise to make definitive clinical statements; however, the results demonstrate clinical concepts that should be evaluated in further studies, particularly on primates.

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