Soft tissue management

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Critical review of soft tissue healing

The healing capacity of oral tissues is excellent. Only seldom are there serious postsurgical complications, such as tissue necrosis, nerve damage, profound bleeding or serious infections. When general basic rules are followed, fair healing of the soft tissues can be expected. Recession is a frequent sequel to healing after periodontal surgery. Its extent and differences in terms of recession location have not been studied extensively. The goal of periodontal surgery is to alter and treat and heal diseased gingival tissues and crestal bone through a host of invasive measures, thereby removing selected areas that are not retainable (52,77,78). The healing behavior of tissues, where attachment has been lost, but that are healthy, has only been studied in recent years, with the development of periodontal plastic surgery. This treatment of healthy periodontal tissue mainly involved restoration of lost attachment and augmentation procedures (28,79). The goal has increasingly shifted, towards restoration of the natural shape, position, color and appearance of soft tissues as present before trauma, disease or treatment induced changes of the tissues (27,79).

When a lesion resulting of endodontic pathology develops on a specific tooth and needs surgical intervention, frequently marginal soft tissues may be healthy (53). With the aid of contemporary techniques such as magnification under a microscope, suitable materials and the use of microinstruments, endodontic surgery has evolved to microsurgery and will result in a predictably successful outcome in teeth treated (14,21,30,48).

Healing process

Healing takes place in several phases that overlap and coexist: wounding, clotting and inflammation, epithelial healing, connective tissue healing, proliferation, maturation and remodeling (53,59,78,80). While a multitude of immune defense mechanisms exists, and the details of intercellular communication pathways and interdependent signaling processes during hemostasis and wound healing are beyond the scope of this article, the main events are described below. Within 24h, polymorphonuclear leukocytes and macrophages start migrating into a blood clot. Stimulated macrophages play a central role in angiogenesis and new collagen synthesis (58,76,78,80,81). Inflammatory and reparative cells migrate along fibrin strands, followed by capillary buds. The microvascularization in the flap itself remains patent, providing nutrition for the mucogingival flap, in concert with contributions from remaining periosteal, periodontal and bone microvascular networks (60). Parallel fibrin strands after wound compression and a thin hiatus between wound edges accelerate this process (20,59,76). Epithelial streaming as a sheet or as fingers is observed after 2 days, eventually resulting in a multilayered seal (74,82). After 4 days an epithelial barrier has formed (76). Other authors described complete epithelial healing in the sulcus at 14 days and after 28 days the wound healing process was accomplished (59,60,83). Healing and reattachment of an elevated flap to cortical bone is a slower procedure, the periosteum does not survive reflection (58). Granulation tissue replaces the thin fibrin clot between the flap and cortical bone after 4 days, and fibrous connective tissue replaces granulation tissue by 14 days (58). Due to early epithelial bridging, suture removal is therefore advocated after 2-3 days (76). Initial resistance to rupture forces is attributed to regeneration of epithelial attachment to tooth surfaces (20,74,82). Other authors do not recommend suture removal before 4d, as stainable collagen content in granulation tissue, which determines tensile wound strength, is only present after 3d (59). While healing wounds that are subject to small amounts of mechanical stress, demonstrate an increase in collagen strength and formation, excessive forces disrupt the neovasculature and collagen fibers and delay healing (80).

More and more variables of wound healing, including patient nutritional status, bacterial infection, wound care and available tissue oxygen, are being researched. Consequently, novel therapies are evolving, such as growth factor therapy (84). Growth factors may lead to new strategies in improvement of soft tissue healing, including skin, mucosa, and nerve tissues (85).

Strategies and procedures

The choice of flap designs should allow maintenance of optimal blood perfusion during surgery. This implies using a design where vertical releasing incisions run vertical, parallel to the tooth axis and to supraperiosteal blood vessels in the mucosa and gingiva, resulting in minimal vascular disruption (30,31,43,45,53). Paramedian rather than mid-axial releasing incisions are recommended in order to minimize recession risks (Fig.8) (43). Healing is influenced by flap shrinkage and the resulting difficult reapproximation with more sutures than usually necessary. This is true in particular for submarginal flap types. A vertically oriented releasing incision and secondary blood supply from the crestal bone to papillae and attached gingiva can avoid sloughing of unreflected tissue (43,86). Unlike horizontal incisions further apically, an incision severing the anastomosis between gingival and periodontal vasculature as used in every full mucoperiosteal flap or sulcular flap showed no effect on the circulation in free and alveolar gingiva (45). Tissue trauma through stretching, distorting or tearing a flap can be avoided through appropriate magnification and careful manipulation with microsurgical instruments (72,79).

After reflecting a mucogingival flap, scaling of root-attached tissues and tissue tags on cortical bone should be avoided in order to allow rapid reattachment and protection against bone resorption (31,53,58). Preservation of the papilla in the col area during elevation and refection is another key point for healing by primary intention (76). Careful handling, undermining elevation and retraction using the groove technique are helpful in order to avoid unnecessary injuries to the reflected tissue (21,30,52). Keeping the flap moist at all times helps avoids shrinkage and dehydration (76).

Patient related factors

Both the type of tissue involved and the type of surgical wound determine the healing process (78). Patients with a “thick” tissue biotype tend to display coronal soft tissue regrowth to the former level in crown lengthening procedures, whereas patients with a thin tissue biotype do not (71,87). Next to thickness and width of the gingival tissue, the integrity and thickness of underlying bone plays a role in mucogingival stability (79).

Macrosurgical versus microsurgical outcome

As stated before, healing results using a macrosurgical approach are generally regarded as fair. Figure 9 shows a representative result of flap closure using traditional techniques; in this case, a trapezoidal mucogingival flap was raised. Wound closure was accomplished using polyamide 4/0 single knot sutures. The vertical releasing incisions were closed with three sutures each and the papilla with a single knot suture. Wound margin adaptation was considered as sufficient at that time. The healing result after 1 week postsurgically displayed acceptable healing without any complications and was described as good. Figure 10 shows the surgical site before and directly after suture removal. When the surgical area is examined more carefully and critically, following observations can be made: At 7 days, the vertical incision displays complete closure of the wound edges in the apical part. A discrete tissue indentation in the entire extent of the vertical incision is clearly distinguishable. This indentation becomes more pronounced at the marginal level and ends in a wound dehiscence, which is esthetically the most critical area. This comes as no surprise as at the time of conclusion of the surgery the wound edges in the marginal portion were not properly reapproximated. The healing process requires closure of the hiatus between the reflected and the unreflected tissue with connective tissue and epithelium (76). When adaptation of the tissue edges is ideal and the tissues are positioned in very close proximity in the vertical and horizontal dimension to each other, only few cells need to be generated to bridge the gap. Close adaptation will expedite wound closure, epithelial cells being the fastest (see section wound healing). Healing of the vertical incision (Fig. 10b) must be judged as by secondary intention, specifically in the marginal area, resulting in scar tissue formation and tissue defects. The area of the papilla seems to be well preserved during the surgical procedure and sutured at its proper position. However, the most coronal portion of the papilla has shrunk, resulting in a rounded papilla shape and loss of height.

In another case, a submarginal incision was performed using microsurgical techniques and instruments. Flap closure was performed with polyamide 6/0 sutures. At suture removal after 4 days (Fig. 11) areas with better healing are visible and the incision is barely recognizable, just adjacent to a poorly healed portion with a tissue dehiscence and some areas with fair healing. In this clinical example, there are

incision sections with perfect and poor healing results directly adjoining to each other. As the surgical technique was the same, and the same types of tissues were manipulated it must be assumed that the different healing patterns were a consequence of varying degrees of tissue adaptation after the suturing process. It is obvious in this example that there is potential for improved healing even after very short periods of time. Wound closure seems to be quite critical in terms of healing outcome. Considerable understanding has been generated from research in mucogingival surgery, specifically in recession coverage and soft tissue grafting procedures, as well as in general plastic surgery (22,35,36,88).

It has been also pointed out, that if periodontal plastic surgery is performed, esthetic outcome is often the only important factor and function becomes secondary for example in recession coverage or papilla reconstruction (27). Incision design and suturing technique critically influence the postoperative wound healing process in terms of blood supply and flap survival (45). If both factors are not guaranteed, esthetic as well as functional success become unpredictable (28).

Among other principles (incision and flap design, atraumatic and gentle tissue management), a passive and tension-free wound closure is fundamental for proper wound healing and for a successful functional and esthetic outcome. In earlier days, the suturing process was solely regarded as bringing the wound edges together and keeping them in this position until body has healed the defect. It was customary to leave the sutures in place for 7 – 10 days and the clinical findings seemed to confirm this protocol. In an animal experiment the papilla suture was simulated with a needle corresponding to a 4/0 suture (Fig. 12a). The same area was photographed with a magnification of 4x (Fig. 14b). It is obvious that already the needle tract penetrating through the tissue almost dissects the papilla in half. This generates a large defect, which might compromise tissue survival. Changing the size of the suture material and accordingly the size of the needle as in microsuturing, it is evident in Figure 9 that this is much less traumatic. In the same animal experiment excessive suture pulling forces on the two tissue parts resulted in crushing and further trauma to the wound. The scanning electron microphotograph (SEM, Fig. 14a) illustrates the amount of tissue damage inflicted. Note the highly wrinkled and squeezed tissue beneath the suture. If a suture is applied in such a traumatic way, the healing process will have to repair additional and considerable damage induced by both the size and excessive tightness of the suture. It is of no surprise that healing will take longer and will result

in esthetically unpleasant healing patterns. Figure 14b (SEM) displays how even minute tissue misalignment of the wound edges may delay wound healing. In the center of the picture, there is a small vertical discrepancy in alignment of the tissues. This translates to a larger distance for the cells to cover, as compared to the area on the left, where both wound edges touch each other closely. In addition, note small wrinkles in the upper tissue portion, which led to tearing of the tissues at the point of the needle penetration. Perfect adaptation and atraumatic tissue handling will allow improved healing results (Fig. 15).

Papilla preservation / protection

The interdental papilla, the portion of the gingiva between two adjacent teeth, is critical for functional, phonetic and aesthetic reasons. Complete and predictable restoration of lost interdental papillae is one of the biggest challenges in periodontal reconstructive surgery (22). It is therefore imperative to maintain the integrity of the papilla during surgical procedures. Most frequently, a sulcular full thickness flap is used in periradicular surgery. In this flap technique the buccal papilla is mobilized and becomes part of the flap (89). Ideally, the sulcular incision should dissect the buccal from the lingual papilla. In narrow interproximal spaces, complete mobilization of the papilla is often difficult and may cause tissue loss. Shrinkage of the papilla during the healing phase can occur, and may initiate the ultimate loss of papilla height. Zimmermann and coworkers (90), in a preliminary study, investigated the shrinkage of papillae after sulcular flaps in patients with healthy periodontal tissues. The reduction of papillary height increased gradually during healing. Immediately post-operatively papilla height loss due to surgical manipulation resulted in a recession ranging from 1 quarter (n=14) to 1 quarter to one half (n=3) of the original height. At suture removal, six sites had a loss of height of up to one half the original position. None of the 17 sites remained at pre-operative levels at any time.

A quantitative study analyzed recession of the interdental papilla in periodontally healthy situations following apical surgery using sulcular flap incisions (91). All experimental sites exhibited a significant loss of papilla height at 1 month ($p<0.003$) and 3 months ($p<0.004$). Main loss of papilla height occurred between baseline and the 1-month recall situation (-1.1 ± 0.8mm), while a small but significant further loss occurred between the one and 3-month recall appointment ($p<0.05$, 0.2 ± 0.3mm). At 3 months retractions increased in 10 sites, while in 3 sites the loss had diminished

compared to the value after 1 month. These results suggest that the conventional sulcular flap results in considerable retraction of papilla height after 1 month and 3 months postsurgically.

The issue of papilla preservation has been largely addressed in periodontal therapy. In anterior periodontal surgery, a papillary retention procedure is advocated in order to maintain papillary height to maximize postoperative esthetics (67,92). Cortellini and coworkers (93,94) suggested a modification of the papilla preservation technique, which allows primary closure of the interdental space over a bioabsorbable membrane. A horizontal incision is performed at the base of the papilla. The papilla is subsequently elevated to the buccal side. After coronal repositioning of the buccal flap over the membrane, the interproximal area is covered with the papilla, which is attached to the buccal flap. Primary closure over the membrane was obtained in all treated sites using the modified preservation technique. Probing attachment level gains and pocket depth reduction were observed after one year when using this technique.

In endodontic surgical access, Lubow et al. (51) suggested an alternative to classical full thickness flaps with the mobilization of the papilla. In the technique described, the flap involved full thickness dissection with easily recognizable landmarks and straight-line incisions. A beveled horizontal incision was designed to incorporate the maximum amount of facial keratinized tissue into the body of the flap, while leaving the interproximal tissue untouched. Healing was described as rapid and with excellent esthetic results.

Preservation of the papilla in periodontal therapy is an accepted procedure as described by several authors in the literature (29,92,95). Straight-line incisions during endodontic surgery, without mobilization or inclusion of the papilla into the buccal flap, lead to a clear indentation line where the incision was placed. Figure 16 represents a clinical example of such an incision. The same type of result is also visible in the publication by Lubow et al. (51). This result was described as esthetically excellent, while in today's critical and microscope-enhanced judgment it is no longer considered as such. A further, nevertheless important factor is the location and microconfiguration of the flapped and unreflected tissue in vertical incisions. In the cross-sectional diagram (Fig. 17), the red line represents a paramarginal, single straight incision directed to the crestal bone. The pointed tissue ending will necrotize at its very end, creating a small, but visible defect and a

recession. This type of incision is simple to perform, but will result in a poor healing result. It is evident in the drawing that the mobilized tissue has a sharp edge at the coronal end of the flap. The tissue margin comprises unsupported epithelial cells without the epithelial base cells, which are responsible for formation of a multilayered seal of epithelial cells. The connective tissue at the proximal end of the flap forms a sharp and thin edge, which is not sufficiently vascularized for survival. The healing process will result in localized necrosis with a small tissue defect, visible as a clearly detectable indentation (Fig. 16).

Consequently, the incision line should begin in a 90-degree angle to the outer contour of the marginal gingiva as shown and marked with a green line in Figure 17. This rule applies to any type of incision, to avoid thinning out of tissues and allowing sufficient blood supply to reach the area, promoting better healing.

The importance of proper incision and surgical technique in obtaining recession-free and esthetically improved healing was pointed out by a recent clinical study on the papilla base flap (96). A papilla base flap consists of two vertical releasing incisions, connected by a papilla base incision and an intrasulcular incision. The marginal incision commences by the preparation of the papilla base using a microsurgical blade. The size of the blade should not exceed 2,5 mm in width. Suitable shapes are blades with rounded end (BB 369 , Aesculap, Tuttlingen, Germany) or standard 15C blades (Fig. 18). The crucial point is controlled movement of the scalpel blade within the small dimensions of the interproximal space.

The papilla base incision requires two different incisions at the base of the papilla.The first shallow incision separates epithelium on the surface of the gingiva and connective tissue up to a depth of 1.5 mm. The incision is placed at the level of the lower third of the papilla in a slightly curved line, connecting one side of the papilla to the other (Fig. 19). The incision begins and ends in a 90-degree angle to the tooth and gingiva (see lines in Fig 17). This shallow incision prevents thinning of the coronal aspect of the flap.

In the second step, the scalpel is placed to the base of the previously created incision and subsequently inclined apically, almost parallel to the long axis of the tooth, directed towards the crestal bone margin. With this second incision, a split thickness flap is prepared in the apical third of the base of the papilla. The incision terminates at crestal bone level, and separates the periosteum from the bone (Fig. 17). From

this level on the preparation continues as a full thickness mucoperiosteal flap (Fig. 20).

While the papilla base incision (PBI) is challenging to perform, its use can lead to predictable results. Firstly, atraumatic handling of the soft tissues is mandatory to obtain good results. Secondly, two different incisions are needed for good healing and to avoid excessive scar formation or an indentation at the site of the incision. The key point of the PBI is to avoid thinning of the split flap. The epithelium of the partial thickness portion of the flap needs support by underlying connective tissue, which has to be thick enough to maintain vitality through sufficient blood supply. If this goal cannot be obtained, the tissue will necrotize, resulting in a tissue defect, followed by scar formation. On the other hand, excessive thickness of the connective tissue layer of the split flap portion could compromise the survival of the unreflected buccal papilla. The ideal thickness of a partial thickness flap is unknown. Epithelium thickness varies between 111 to 619 µm with a mean of 364µm (97). The recommended thickness of free gingival grafts was reported to be 1mm to 2mm (98,99). Based on gingival graft studies a thickness of 1 to 1.5mm was chosen for the split flap in PBI. The selected thickness resulted in excellent healing patterns.

As mentioned previously, flap closure using atraumatic and tension free sutures is a key factor to improved healing. The correct size of the needle and appropriate suture thickness are equally critical. Depending on the incision site following materials have been used: vertical incisions should be sutured with 6/0 sutures, due to close proximity to inserting muscles in the mucosa, which might exert some tension to the wound during mastication and speech. As nylon monofilament materials are somewhat stiff in size 6/0, softer material, such as polyamide (Supramid®) was preferred. This material is a multifilament suture, with a coating providing monofilamentous appearance with a smooth surface.

For closure of the horizontal incision and the delicate area of the papillae, we recommend polypropylene interrupted sutures with a size of 7/0 or smaller (Fig. 21). As the wound edges should be perfectly adapted to each other, depending on the dimensions of the papilla two or three interrupted sutures are needed.

Suture removal performed after 3-5 days promoted rapid healing. The critical area for suture removal after 2-3 days is the apical portion of the vertical releasing incision - the mucosal wound, in particular in the region with muscle tension, which might require 24 to 48 hours longer to initiate healing (59,76,78).

The evaluation of healing patterns of the papilla base incisions after three months revealed mainly completely undetectable or only partially detectable incision lines and generally demonstrated excellent healing. None of the operated sites displayed any measurable loss of papilla height, or other complications (96).

Another study analyzed degrees of papilla shrinkage, when papilla base flaps and sulcular full-thickness flaps were raised (100). The comparison revealed significant loss of papilla height, when the papilla was mobilized during the surgical procedure. In contrary, the papilla base incision resulted in rapid and predictable recession-free healing. In order to avoid opening of the interproximal space in esthetically relevant areas, the use of the PBI was recommended for periradicular surgical procedures. A further study (101) investigated surgical outcomes concerning main vertical loss of height during 12 months. After three months, only minor vertical changes took place; in nine out of twelve sites, increases in recession depth were observed, while in three sites a small gain of papilla height occurred, compared to the one-month situation. At 12 months two sites exhibited further recession, the remaining sites showed a certain degree of tissue “creeping”. However, the observed gain of the papilla height was not significant, when compared to short-term observation periods and the pre operative situation. In cases of full thickness flap elevation, mean papilla loss of height after 1 year was 0.98mm (Fig. 22).

In contrast to full mobilization of the papilla, the PBI resulted in significantly lower ($p<0.001$) recession depths of only 0.07 ± 0.09mm at one month, 0.10 ± 0.15mm at three months and $–0.062 \pm 0.21$mm after one year.

Conclusions

The introduction of microsurgery to surgical endodontics attempted to minimize trauma and enhance surgical results. In combination with magnification and illumination, resected roots reveal intricate anatomical details. In conjunction with ultrasonic root-end preparation and tight sealing of the root end cavity, the requirements for mechanical and biological success are more adequately fulfilled. Although application of basic rules leads to fair soft tissue healing following endodontic surgery, there is a great potential for improvements in postsurgical esthetic outcome. As in other dental fields, “pink esthetics” of oral soft tissues become increasingly important and efforts are made to minimize scar formation and

recessions after surgical procedures. This is even more the case when larger restorations are present and healthy periodontal tissues are reflected as access flaps for periradicular surgeries. Microsurgery alone will not accelerate epithelial healing rates, but through perfect tissue adaptation of wound edges, it can create smaller distances for epithelial migration during the healing process. More rapid soft tissue healing is a result of reduced tissue trauma and enhanced wound closure during microsurgical procedures.

In order to achieve these goals several measures are necessary, including accurate preoperative treatment planning in reference to the condition and quality of the tissue to be manipulated. Minimal trauma should be inflicted during incision and raising of the flap. Both the flap and unreflected tissue remaining on the tooth surface should be kept moist during the entire procedure, especially in situations where excellent hemostasis can be achieved. Finally, sensitive handling of the soft tissues during suturing is mandatory, with wound edges being reapproximated without tension and held in place with nonabsorbable atraumatic sutures. The flap design plays an important role as to how much recession will occur postoperatively. Papilla base flaps have allowed virtually recession free healing following endodontic surgery.