Wound Management and Postoperative Care

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The ultimate goal of wound management in periodontal surgery is a tension-free primary wound closure which reduces postoperative problems, healing time, and the risk of bacterial contamination of the wound area to a minimum. Modern minimally invasive, microsurgical concepts using multilayered suturing approaches with thin monofilament suture materials facilitate primary wound closure and increase the predictability of an undisturbed primary wound healing. The major goal of postoperative care is – besides reduction of the postoperative patient-related problems – a stringent infection control of the operated area. This comprises the application of antiseptic mouthrinses by the patient as well as the monitoring and cleansing of the wound by the dentist at short intervals. For long-term protection of the healing result, supportive periodontal therapy is necessary, which is provided at regular intervals according to the individual treatment needs of each patient.

Key words: periodontal surgery/therapy, wound management, postoperative care, wound healing, suture technique

GENERAL ASPECTS OF WOUND HEALING

The wound is defined as a forced separation or circumscript damage of the skin or mucosa. Normally, the periodontal wound is – apart from injuries – a mechanical, surgically-placed incision, characterized by clean edges and strong bleeding with a generally good healing prognosis (Knapp, 1999). In the following, general wound healing aspects will be discussed only as far as they are relevant to the wound management of the periodontal mucosal wound. With regard to the wound healing processes in the periodontal defect itself, the reader is referred to the relevant literature (Bartold and Narayanan, 1998; Wikesjö and Selvig, 1999; Somerman et al., 1999; Christgau et al., 2000).

Wound healing is defined as the process by which an organism attempts to restore the structure and the function of a tissue which was damaged by an injury or inflammation. In this context, *regeneration* has to be distinguished from *repair*. In regeneration, the lost tissue is replaced by a new tissue identical to the original tissue in both structure and function. In repair, the damaged tissue is replaced by scar tissue. Both forms of wound healing require the coordination of a variety of physiologic processes at the cellular level. Blood components, soluble mediators, cells, and the extracellular matrix are involved in the wound healing process (Clark, 1996). In most tissues, the time sequence of wound healing is similar and characterized by three typical phases: inflammatory response, tissue formation, and tissue remodeling. The three phases are not mutually exclusive, but rather overlap in time (Bartold et al., 1981; Wikesjö et al., 1992; Clark, 1996; Wikesjö and Selvig, 1999):

First phase of wound healing: inflammatory response (exudative phase)
The inflammatory response immediately follows the injury and lasts about 2 to 3 days in the skin wound. The wound site is filled by a blood clot, which is rich in fibrin and fibronectin. The clot provides tensile strength and stability to the wound, serves as provisional matrix for ingrowing cells, and it is a source for growth factors. The special aspect of the periodontal wound is that the wound margins additionally adhere to the root surface by fibrin. The stability of this adhesion seems to be essential for the formation of a new connective tissue attachment along the root surface (Hiatt et al., 1968; Sigurdsson et al., 1995; Wikesjö and Selvig, 1999). In a typical dermal wound, polymorphonuclear granulocytes (PMNs) followed later by monocytes and lymphocytes migrate into the blood clot by chemotaxis. They remove necrotic tissue, bacteria, and foreign matter by phagocytosis. Within the first 24 to 48 hours, keratinocytes migrate from the wound edges into the wounded site to form a thin epithelial layer with a basement membrane underneath. At the same time, the clot is lysed by plasmin. Peptides derived from the lysis of the clot and extracellular matrix and inflammatory cell products serve as chemotactic agents attracting cells to the wound site.

Second phase of wound healing: formation of granulation tissue
After approximately 3 to 5 days, the fibrin clot begins to be organized and replaced by granulation tissue. This intermediate tissue prevents an excessive epithelial ingrowth and provides the stroma for the formation of new blood vessels (angiogenesis) and new connective tissue. New capillaries are formed by budding of endothelial cells from the surrounding pre-existing blood vessels. Angiogenesis is driven by growth factors such as FGF (*fibroblast growth factor*), TGF-β (*transforming growth factor-β*), VEGF (*vascular endothelial growth factor*), and angiogenin. Already after one day, fibroblasts begin to migrate into the wound, where they are transformed into myofibroblasts (Desmouliere and Gabbiani, 1996) actively synthesizing new extracellular matrix components. In the dermal wound during the initial stages of healing, mainly collagen type III is formed, while collagen type I becomes prominent later (Epstein, 1974; Clore et al., 1979; Prockop et al., 1979; Eckes et al., 1996). There are some findings showing that in the periodontal wound collagen type I is formed first, subsequently followed by collagen type III (Christgau et al., 2000; Christgau et al., 2001). These processes are regulated by a variety of growth factors (e.g., platelet derived growth factor PDGF, transforming growth factor-β TGF-β), cytokines, and lymphokines. At this stage in the dermal or mucosal wound, myofibroblasts cause wound contraction, reducing large wounds to approximately 5 to 10% of their original sizes (Bartold and Narayanan, 1998). This wound contraction is not found in tissues strongly attached to bone (Krüger, E., 1986).

Third phase of wound healing: tissue remodeling
During the remodeling phase, the newly formed granulation tissue matures, meaning that most of the capillaries and myofibroblasts disappear. Its connective tissue is remodeled and converted into a fibrous scar. This phase is accompanied by apoptosis of endothelial cells and myofibroblasts. Proteoglycans and collagens are formed in a coordinated manner. The collagen synthesis reaches its maximum after 7 to 14 days, although it continues for weeks and months until the normal tensile strength of the tissue is restored.

Healing by primary vs. secondary intention

Healing by *primary intention* occurs if the wound edges are adapted without tension and grow together with only minimal new tissue formation. Healing by primary intention is the regular case in surgical incision wounds, which should also be aimed for in most of the periodontal surgical approaches. After adaptation of the smooth-edged wound margins, the narrow gap is filled with exudation. The secreted fibrin glues the wound edges together. The narrow gap between the wound edges is filled by proliferating cells and budding capillaries forming a granulation tissue, which is replaced later by a network of collagen fibers. In the dermal and mucosal wound, the result of primary healing is a very thin, almost invisible scar (Knapp, 1999). In osseous wounds, the ingrown connective tissue is initially replaced by callus-like woven bone growing in from the surrounding bone margins. The following remodeling process converts the initial woven bone into lamellar bone (Krüger, E., 1986).

Healing by *secondary intention* occurs in large wounds with poorly adapted wound edges. Wound closure is achieved by new tissue formation and wound contraction. In periodontal surgery, the external gingivectomy is an example of open wound healing. Due to the size of the wound, healing by secondary intention requires more time. However, the underlying repair processes differ only quantitatively from the healing by primary intention. The widely gaping wound is filled by granulation tissue. This phase is significantly reduced by wound contraction (Knapp, 1999).

GENERAL ASPECTS OF WOUND MANAGEMENT

Wound closure

The ultimate goal of most periodontal surgical approaches is primary wound closure. Following access flap surgery, the wound edges must be adapted to each other and to the root surfaces without tension in an appropriate manner. A prerequisite for primary healing is a complete coverage of the buccal, oral, and interproximal bone, limiting the postoperatively occurring superficial bone resorption to a minimum. For this reason, if necessary, the wound edges should be trimmed in such a way that the bone margins and the interproximal bone can be covered properly. If there is not enough soft tissue available for a dense and complete wound closure, the wound margins must be recontoured and the flaps coronally repositioned (Wennström et al., 1997).
The flap margins are secured by sutures in the correct positon. The surgical suture is intended to temporarily reunite the separated wound margins, and must withstand the forces affecting the wound. Depending on the tissue maturation, the function of the suture is temporally limited. The supreme principle with regard to the surgical suture is to create optimal conditions for undisturbed wound healing and to reduce the tissue damage to a minimum (Knapp, 1999).
Suture materials should fulfill the following requirements:

- sufficient tensile strength
- absence of a wick effect
- good biocompatibility
- minimal plaque accumulation
- minimal tissue damage
- absence of swelling of the material
- safe knot position
- absence of immune reactions caused by foreign proteins

Despite the great variety of suture materials available, so far there is no ideal material which fulfills all of these requirements. To reduce tissue reactions to a minimum, non-resorbable materials should be used for all sutures, which can be removed postoperatively. Resorbable materials should be limited to sutures which cannot be removed after wound closure.
In periodontal surgery, only atraumatic and synthetic suture materials – preferably 5-0 to 8-0 thick – are used (Fig. 1a). Suture materials made of polytetrafluoroethylene (PTFE) and polypropylene are preferred due to their excellent biocompatibility and the absence of a wick effect. Compared to PTFE sutures, polypropylene sutures are characterized by a very minimal plaque adhesion (Cortellini and Tonetti, 2001; Wachtel et al., 2003). A curved needle describing a 3/8 circle with a cutting point is preferred for most indications in periodontal surgery (Fig. 1a and 2a). To facilitate interproximal sutures, a combination of a thin suture material (6-0, 7-0) with a sufficiently long needle (15 mm) should be chosen (Fig. 1). The high elasticity and smooth surface of monofilament synthetic suture material require a careful knotting technique with a third knot.
In the rare case requiring resorbable suture materials, exclusively synthetic materials are used. Bioresorbable polyesters, which are made of polyglycolic acid or copolymers of polyglycolic and polylactic acids, are preferred, because they are completely degraded by hydrolysis to carbon dioxide and water, independent of any enzyme reactions (Hutmacher and Hürzeler, 1995). Suture materials made of collagen (e.g., catgut) are no longer allowed for clinical use. The problem of polyfil sutures is their rough surface, which results in strong plaque accumulation.

Suture techniques

The most important suture techniques in periodontal surgery are interrupted single sutures, vertical and horizontal mattress sutures, as well as crisscross sutures.

Figure 1 Monofilament polypropylene suture material

Fig. 1a comparison of sutures of different diameters, all equipped with a 3/8 curved needle (from left to right): 7-0 suture with a DSM11 needle, 6-0 suture with a DSM15 needle, and 5-0 suture with a DSM19 needle.

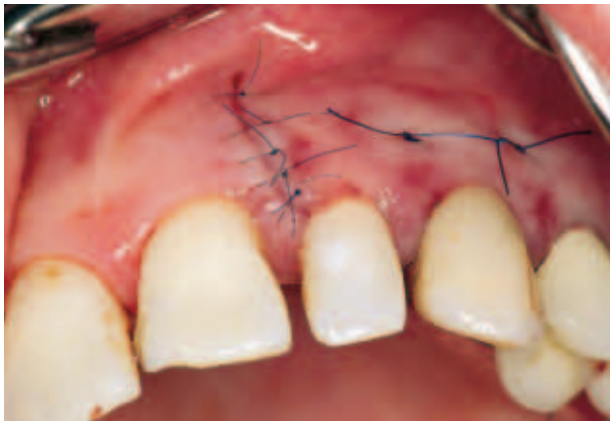


Fig. 1b comparison of different suture diameters in situ: deep horizontal mattress suture of 5-0 thickness; closure of the vertical releasing incision with 7-0 single sutures.

Interrupted single sutures

This suture technique facilitates a dense interproximal wound closure with evenly distributed tensile forces on both wound margins, and serves to immobilize the flaps in their original position (Fig. 2b and c). It is not suitable for fixation of the wound margins in a coronally advanced position. The knots should be placed on the buccal side to avoid any irritation of the tongue. For this purpose, the needle is passed through the buccal flap from the external surface, across the the interdental area and through the oral flap from the internal surface. It is essential that excessive tearing of the flap tissues is avoided.

Mattress sutures

Horizontal and vertical mattress sutures provide a wide adaptation of the internal flap surfaces without causing a direct tear on the wound margins (Fig. 2 d to g). In regenerative and augmentative procedures, the horizontal mattress suture is the suture technique of choice. It keeps the flaps in a coronally advanced position without tearing the wound margins. For this purpose, the needle is passed through the buccal flap from the external surface (paramedian to the tip of the papilla and below the bone crest level), across the interproximal area, and through oral flap from the internal surface (paramedian to the tip of the papilla and below bone level). Then the suture is brought back to the buccal side by passing the needle through horizontally staggered, again through the oral and buccal flaps. When tying the knot, the suture is stretched across the bone crest, repositioning the flap margins cornally. Afterwards, the papilla tips, which have been exverted by the mattress suture, can be adapted in a tension-free way by very thin interrupted sutures or further mattress sutures (Fig. 6b).

As an alternative to this suturing technique on two different levels, a modified mattress suture can be used (Fig. 2 h to i). In this case, after a vertical mattress suture, the suture is brought through the interproximal site coronally to the tissue, passed through the loop of the suture on the oral aspect, and then brought back to the starting point on the buccal side and tied. Thus, the wound margins are pressed onto the bone surface. However, the more time consuming combination of horizontal matress and additional interproximal single suture is preferred to the modified mattress suture, because the latter tends to cause an inversion of the wound margins.

Criss-cross sutures

In criss-cross sutures, the suture material is placed on the outer surface of the flaps. Consequently, they are used when the flap margins should be pressed against the bone surfaces (Fig. 7e). A further indication for this suture technique is given when the position of a free gingival graft or a connective tissue graft has to be secured without pass-

Figure 2 Demonstration of the most important sutures on an experimental animal:

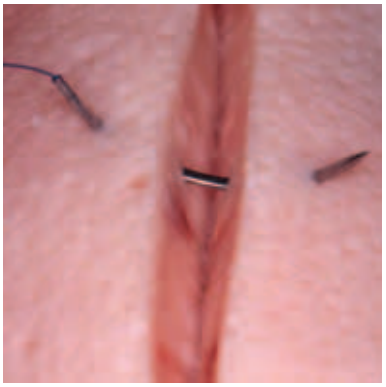


Fig. 2a 3/8 curved needle

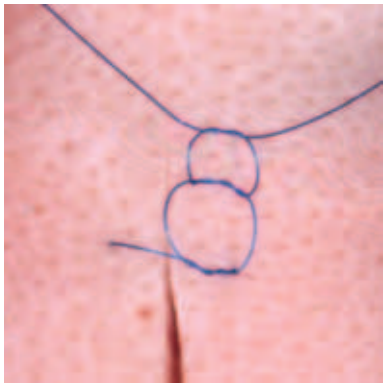


Fig. 2b surgical knot

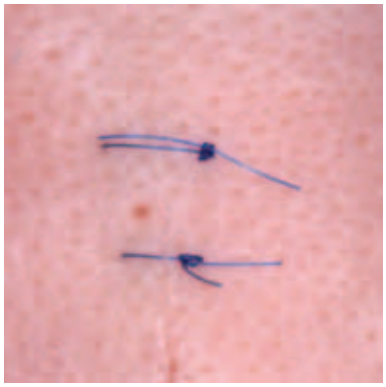
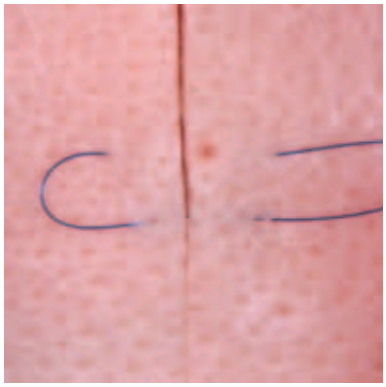
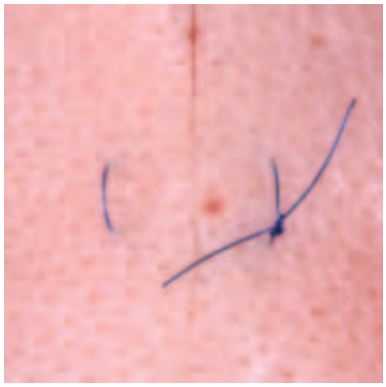
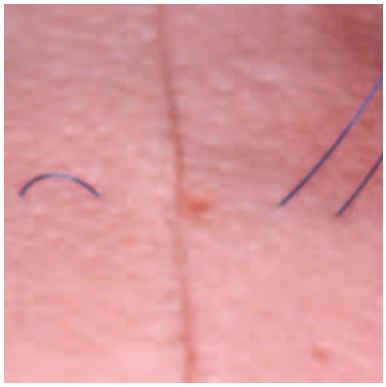


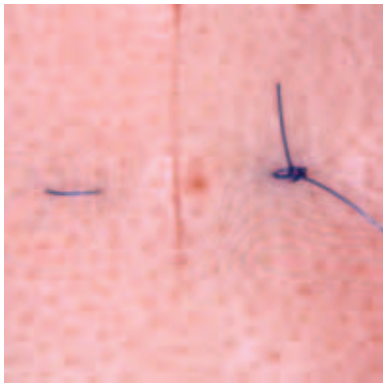
Fig. 2c two single sutures in situ



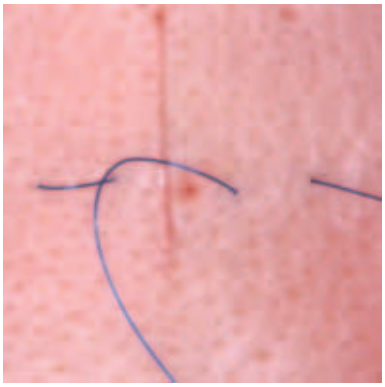
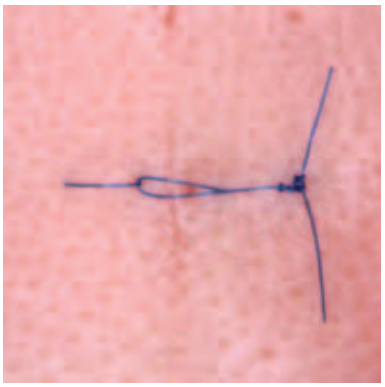


Figs. 2d–e horizontal mattress suture

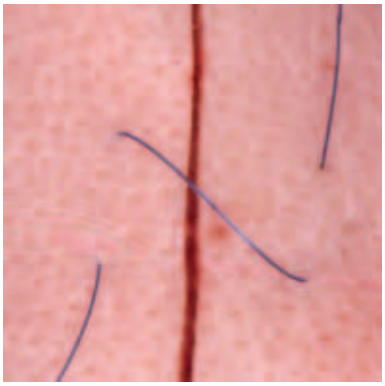
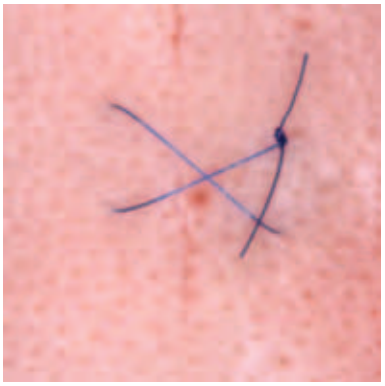




Figs. 2f–g vertical mattress suture

Figs. 2h–i modified mattress suture: before tying the knot, the needle is passed through the loop of the suture on the lingual aspect. In this way, when tying the mattress suture, the wound margins are adapted simultanously.

Figs. 2j–k Criss-cross suture

ing the suture through the grafts (Fig. 7b). For this purpose, the sutures have to be passed through the adjacent periosteum, facilitating a sure fixation.

In recent years, an increasing number of authors have suggested a minimally invasive, microsurgial approach and suturing technique in periodontal surgery as well (Shanelec and Tibbetts, 1996; Tibbetts and Shanelec, 1998; Cortellini and Tonetti, 2001; Wachtel et al., 2003) to improve the predictability of primary wound closure and to decrease to a minimum the risk of postoperatively occuring wound dehiscences. The combination of special microsurgical instruments (Fig. 3a), optical magnifying devices (magnifying eyeglasses, operating microscopes) (Fig. 3b), and very thin suture materials (Fig. 1a) facilitate a significantly more gentle handling of the tissues and a very precise, passive adaptation of the wound edges. An accelerated revascularization decreases the postoperative trauma for the patient and significantly improves the predictability of undisturbed primary wound healing. As a consequence of this, the predictability of the regenerative and esthetic healing outcome is significantly improved (Cortellini and Tonetti, 2001; Wachtel et al., 2003).

Periodontal dressings

Since almost all periodontal surgical approaches today aim for primary wound closure, periodontal dressings are applied only very rarely. Currently, periodontal dressings are indicated only in the following cases:

Figure 3 Devices for microsurgical/microinvasive approaches

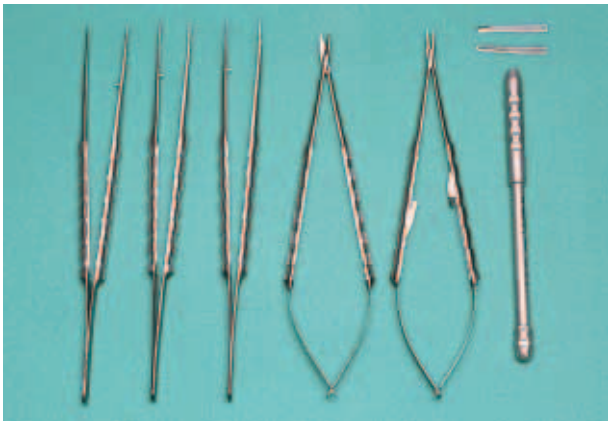


Fig. 3a microsurgical instruments

Fig. 3b magnifying devices: e.g., magnifying eyeglasses with a 4.5x magnification

- external gingivectomy, when a wide open wound area has to heal by secondary intention
- securing an apically repositioned flap
- cases when postoperative bleeding problems have to be expected

Periodontal dressings should perform the following functions (Wennström et al., 1997; Müller, 2001):

- mechanical, chemical, and thermal protection of the wound area
- close adaption of the soft tissue to the underlying osseous surface (especially to secure apical flap position)
- increasing the comfort of the patient
- prevention of postoperative bleeding

For this purpose, a periodontal dressing should fulfill the following requirements:

- soft application form with a reasonable setting time
- sufficient rigidity after setting
- smooth surface
- no adverse effect on the wound healing process
- antimicrobial properties to prevent excessive plaque formation (e.g., addition of chlorhexidine powder)

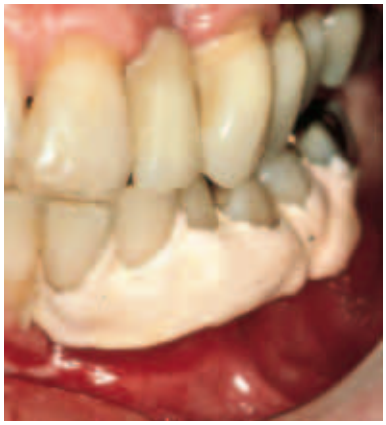
The following eugenol-free dressings are commercially available:

- PeriPac: dressing on a calcium sulfate basis, which completely hardens after contact with saliva
- CoePak: synthetic dressing material which remains elastic (Fig. 4a, b)
- Barricaid: light-curing synthetic dressing material (Fig. 4c, d)

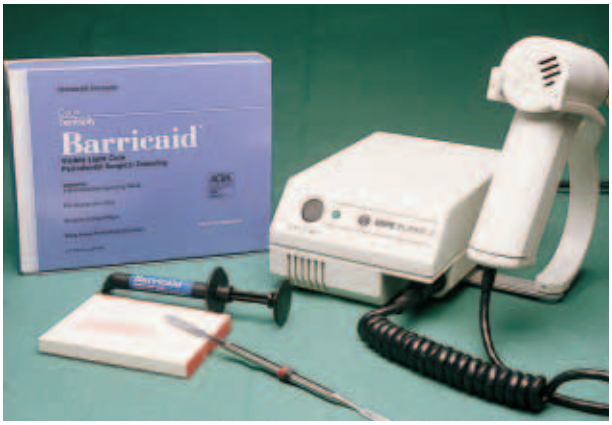
A thin roll of the mixed material is pressed from the gingiva against the dried tooth crowns and into interproximal areas. Care has to be taken that the material is neither pressed between the flaps and the underlying bone or root surfaces nor is placed in the area of the alveolar mucosa and frenula to avoid ulcera and displacement of the dressing. Periodontal dressings are normally removed after 4 to 7 days of healing (Plagmann, 1998).

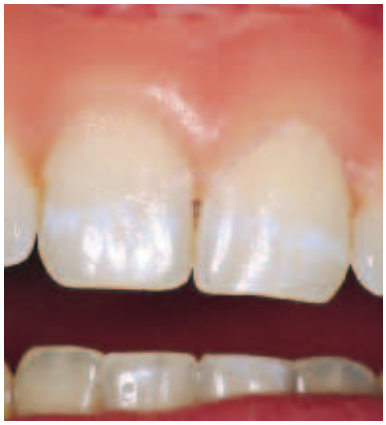
The main problem inherent in all periodontal dressings is infection prophylaxis under the dressing material. Although antimicrobial substances (e.g., chlorhexidine powder) can be added, in vitro studies have demonstrated that the antimicrobial properties have only a short-term effect. Mouth rinsing solutions containing antimicrobial agents cannot prevent plaque accumulation under the dressing material. Clinical studies have shown that periodontal dressings are usually not necessary and should be avoided in access flap procedures, especially when primary wound closure is achieved (O'Neil, 1975; Haugen et al., 1977; Wennström et al., 1997).

Figure 4 Periodontal dressings



Figs. 4a and b CoePak (two-component synthetic dressing material)





Figs. 4c and d Barricaid (light-curing synthetic dressing material on acrylic basis)

GENERAL ASPECTS OF POSTOPERATIVE CARE

Postoperative care for the patients

Following wound closure, the mucoperiosteal flaps are pressed against the bone with moist gauze swabs for 1 to 2 minutes to avoid blood clot formation between the soft and hard tissues. Finally, the wound area and the face of the patient are cleaned. Cream (e.g., vaseline) should be put on the lips to avoid sore and painful corners of the mouth.

To a certain degree, every surgical intervention causes physical and especially emotional stress for the patient, who requires special care during the first minutes following surgery. Patients with a circulatory lability should be slowly and stepwise brought back up to an upright position. The surgeon or the nurse should instruct the patient on how to behave postoperatively:

Cooling

To reduce postoperative edema to a minimum, the surgical area should be extensively cooled by applying a cold pack to the cheek. If the cold packs are stored ready to use in the dental office, they can be given to the patient immediately after the surgical intervention. The patient is supposed to cool continuously for several hours. It is important that only mild coolness is applied to avoid

reactive hyperemia and with that the opposite effect. For this purpose, the cold pack should be wrapped in one or two layers of paper towels or thin cotton towels. The patient must be informed that postoperative edema will increase until the second day after surgery and then decrease again.

Ability to operate a motor vehicle
The influence of the dental local anesthesia on the ability to operate a motor vehicle is a contentious issue in the literature (Hahn, 1981; Riepert et al., 1993; Riepert et al., 1995; Haffner and Graw, 2003). Although most investigations were carried out in healthy subjects, they could not show a significant influence of local anesthesia applied lege artis on the fine coordination, reaction speed, and concentration power (Riepert et al., 1995). However, it should be taken into consideration that following dental treatment, the patient's ability to drive is significantly influenced by emotional components (e.g., decrease of the vegetative stress at the end of treatment) and by the kind and extent of surgical intervention (Frenkel, 1989; Riepert et al., 1993; Riepert et al., 1995). Furthermore, the clinical manifestation of the disease as well as the medication (e.g., premedication) may influence the ability to drive. Following surgical interventions, the ability to drive may be negatively influenced by wound pain after the anesthesia has worn off, and by the occurrence of edema. In addition, vasovagal mechanisms following horizontal positioning of the patient during surgery and hypoglycemia could increase the risk of a traffic accident (Riepert et al., 1995).
Finally, the dentist has to decide when the patient will be fit to drive again. For forensic reasons, the patient should always be warned not to drive himself during the first hour following dental treatment with local anesthesia (Riepert et al., 1995; Haffner and Graw, 2003). When a stressful surgical intervention is planned, the patient should be forbidden to drive a motor vehicle before and after the treatment. Instead of this, the patient should be accompanied by another person or should use a taxi (Frenkel, 1989; Riepert et al., 1993; Riepert et al., 1995). The patient is not allowed to go out on the street alone during the first 24 postoperative hours if the surgical intervention was performed under analgo-sedation or general anesthesia.

Eating
The patient must avoid eating before the anesthesia has completely worn off to avoid bite wounds. On the day of surgery, the patient should either fast or only eat soft foods to avoid mechanical disruption of the fresh wound and consequently the risk of wound dehiscences. Furthermore, the patient must abstain from consuming nicotine, alcohol, coffee, black tea, fruit juices, and dishes made of flour, milk, eggs and sugar on the first day. During the following days until suture removal, the food should be chopped, and not be chewed in the wound area. The patient must avoid manipulating the sutures with the tongue to prevent wound dehiscences.

Oral hygiene
Until suture removal (or even longer following regenerative procedures or soft tissue grafting), mechanical oral hygiene measures must be avoided. In place of tooth brushing and flossing at the surgical site, the patient should use an antiseptic rinsing solution (e.g., chlorhexidine).

Postoperative bleeding
For stabilization of the blood clot and prevention of postoperative bleeding, the patient should reduce mouth rinsing to a minimum and not suck at the wound on the day of surgery. The patients should rest in a more or less upright position during the first hours. Sports and other demanding physical activities must be avoided during the first four postoperative days.
In the case of postoperative bleeding, the patients should carefully bite on sterile gauze sponges or a clean, ironed cotton handkerchief for 30 minutes. If the bleeding cannot be stopped by these measures, the patient must consult his/her dentist or any other emergency service.
Since patients are often not able to remember all instructions immediately after treatment, it is recommended that written instructions for postoperative behavior be additionally provided.

Pain control

Although the threshold of pain is subjective and and may be very different between individuals, the pain following periodontal surgery tends to be rather low and limited to the first postoperative days. This is especially true if surgery is performed

in a microinvasive manner. Postoperative pain can easliy be avoided by commercially available ibuprofen or acetaminophen preparations. It is important that the analgesics be started before the anesthesia wears off. In this way, greater pain – which would require the intake of more analgesics – can be avoided.
It should be explained to the patients that pain which occurs after the first two to three days can be indicative of a postoperative infection, requiring immediate medical attention.

Infection prophylaxis

Postoperative plaque control is one of the most important parameters for the long-term success of periodonal surgery (Cortellini et al., 1994; Wennström et al., 1997).

Antiseptics
As long as mechanical oral hygiene cannot be performed in the surgical area during the first healing period, plaque accumulation and infection risk have to be prevented by antibacterial mouth rinses. For this purpose, a 0.1 to 0.2% chlorhexidine solution has proven to be the most effective (Fig. 5a): the patients must rinse with either 10 ml of a 0.2% solution or 15 ml of a 0.1 to 0.12% solution twice a day for 1 minute (Loe and Schiott, 1970). Bisbiguanide chlorhexidine digluconate, which is a synthetic, cationic detergent, has a broad antimicrobial spectrum against gram-positive and gram-negative microorganisms. It is one of the best investigated and most effective antiseptics for intraoral plaque inhibition (Addy and Moran, 1997). Numerous studies have shown the importance of chlorhexidine for secondary infection prophylaxis after periodontal surgery (Addy, 1986; Addy and Moran, 1997). The special effectiveness of chlorhexidine is caused by its high substantivity. The cationic chlorhexidine molecule binds to anionic sulfate, phosphate, and carboxylate groups. Thus, it interacts with anionic glycoproteins and phosphoproteins of the oral mucosa and the pellicle. From there, it is released again in active form during the next 8 to 12 hours (Jones, 1997). For this reason, the patients should not rinse with water or similar substances afterwards. Chlorhexidine affects the metabolism of all bacteria in the mouth by changing their cell membrane. Most of the commercially available chlorhexidine solutions are alcohol solutions. Aqueous preparations should be prescribed for alcoholics.
The patients should know about the local side effects of long-term usage of chlorhexidine. These are the reversible dark stainings of teeth (Fig. 5c), fillings and the tongue (Fig. 5d), increased calculus formation, a significantly impaired sense of taste, as well as painful erosions of the mucosa. The latter occur rarely and are dependent on the concentration. Normally, relief can be achieved by reducing the concentration (e.g., from 0.2% to 0.1%) and the rinsing frequency.
For postoperative plaque inhibition, chlorhexidine is used in 0.1 to 0.2% ready-to-use solutions. It is also available in 1% gels for local application (Fig. 5b). Conversely, beside the plaque inhibitory effect, chlorhexidine itself may delay early wound healing by chemical action on the host tissues, depending on the concentration (Bassetti and Kallenberger, 1980; Shahan et al., 1993; Addy and Renton-Harper, 1997).
Chlorhexidine is the most effective mouthrinse for postoperative care to inhibit plaque formation. The plaque inhibitory effect of other commercially available antiseptic mouthrinses, such as phenol derivatives (e.g., triclosan), quaternary ammonium compounds (e.g., dequalinium chloride, benzalconium chloride), metal ions (e.g., amine and stannous fluoride), polyvidone iodine and hexitidine, is insufficient due to their inferior antimicrobial effect and inferior substantivity compared to chlorhexidine (Plagmann, 1998).
However, one of these other antiseptic agents must be used if the impaired sense of taste caused by chlorhexidine is not acceptable to the patient for professional reasons (e.g., for cooks).

Antibiotics
Apart from regenerative and augmentative interventions (see chapter 4.2), routine postoperative antibiotic prophylaxis is not necessary in systemically healthy patients following periodontal surgery. This is especially true if the periodontal infection was already treated preoperatively. If there are general systemic risk factors (e.g., risk of endocarditis, immune suppression), adequate preoperative antibiotic prophylaxis must of course be performed with a broad spectrum antibiotic (e.g., amoxicillin or clindamycin), according to the recommendations of the *American Heart Association*.
Antibiotic therapy in addition to the surgical inter-

Figure 5 Chlorhexidine and its unwanted side effects:

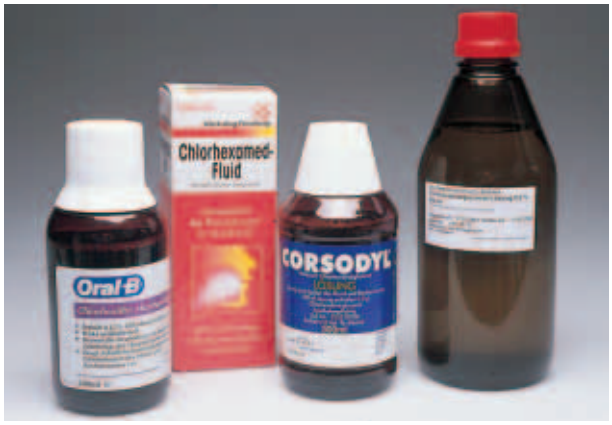


Fig. 5a commercially available 0.1 to 0.2% chlorhexidine solutions for postoperative mouth rinsing at home

Fig. 5b 0.2% chlorhexidine solution and 1% clorhexidine gel for postoperative wound care at the follow-ups

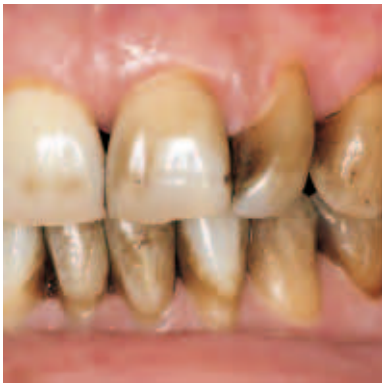


Fig. 5c dark tooth staining

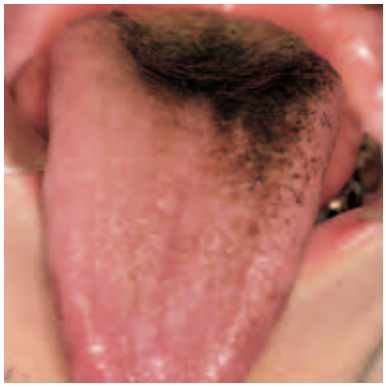


Fig. 5d dark staining of the tongue

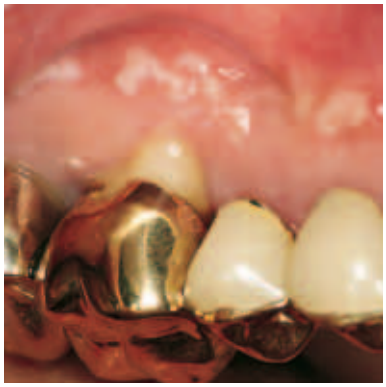


Fig. 5e painful mucosal erosions

vention is only indicated in the acute treatment of infection processes (e.g., abscesses) with general symptoms (e.g., fever, swollen lymph nodes) as well as in the treatment of aggressive periodontitis and progressive chronic periodontitis (Müller, 2001; Beikler et al., 2003). Since the spectrum of periopathogens differs very widely between indivduals, the selection of adequate antibiotics should be based on a preoperative microbiological analysis of subgingival plaque samples (Slots and Jorgensen, 2002; Beikler et al., 2003). If the individual bacterial spectrum is unknown, those antibiotics should be preferred which – systemically given – reach an effective concentration in the gingival sulcus that is higher than the minimal inhibitory concentration (MIC_{90}) in vitro (Beikler et al., 2003).

Dentinal hypersensitivity

Most patients suffer from dentin hypersensitivity during the first weeks and months following periodontal surgery or even after repeated non-surgical scaling and root planing. Although the removal of root cementum should be kept to a minimum, root instrumentation exposes dentinal tubules to the oral environment, exposing dentin to a variety of bacterial, chemical, and mechanical

stimuli. The hydrodynamic theory of Brännström is widely accepted as an explanation and basis for the treatment of root hypersensitivity (Brännström, 1966; Pashley, 1996; Plagmann, 1998).
Root dentin hypersensitivity often disappears even without treatment within a few weeks or months by formation of secondary dentin and natural occlusion of the exposed dentinal tubules by intertubular dentin (Pashley, 1996; Plagmann, 1998). This process can be supported by special toothpastes or mouthrinses containing desensitizing agents, for instance, calcium hydroxide, potassium nitrate, silver nitrate, strontium chloride, fluorides, and hydroxyapatite. Furthermore, root dentin hypersensitivity can be significantly reduced by modern dentin bonding agents (Plagmann, 1998).

WOUND MANAGEMENT AND POSTOPERATIVE CARE FOLLOWING DIFFERENT TREATMENT MODALITIES IN PERIODONTAL SURGERY

Access flap surgery

The goal of the different techniques of open flap debridement is to gain access to the diseased root and bone surfaces, allowing the removal of the causes of inflammation under direct view (Wennström et al., 1997; Plagmann, 1998).

Wound management
Independent of the surgical technique, primary wound closure should be achieved with complete coverage of the buccal, lingual, and interproximal bone with the soft tissue flaps. For an adequate approximation of the wound margins, sometimes a coronal repositioning of the buccal flaps has to be achieved by a basal periosteal releasing incision or formation of a basal split flap (Wennström et al., 1997), (Müller, 2001). Usually, the wound closure is carried out with interproximal single sutures using synthetic, non-resorbable 5-0 to 7-0 suture material as already described. Horizontal mattress sutures are necessary to stabilize a coronally advanced flap. Vertical releasing incisions are sutured by thin interrupted single sutures (7-0 or 6-0). In most cases, a periodontal dressing should not be applied.

Postoperative infection prophylaxis
Mechanical oral hygiene is limited to the nonoperated teeth during the first two weeks following surgery. The surgical sites are kept clean with chemical plaque inhibition by rinsing the mouth with a 0.1 to 0.2% chlorhexidine solution for 1 to 2 minutes twice a day. An additional antibiotic therapy is only indicated in the presence of systemic risk factors or for the treatment of aggressive periodontitis or progressive chronic periodontitis (Müller, 2001; Beikler et al., 2003).

Suture removal
Usually, sutures are removed after 7 days. The patient can carefully resume mechanical oral hygiene at the surgical sites about a week after suture removal.

Follow-ups in the dental office
Postoperative check-ups should be carried out at least once a week during the first two weeks. These are necessary to monitor the healing process and to clean the surgical site using cotton pellets soaked with chlorhexidine (Fig. 5b). Then the gingival sulcus is rinsed with a 0.2% chlorhexidine solution, and finally a 1% chlorhexidine gel is applied to the surgical site. Until the re-evaluation after 2 to 3 months, the patients should attend monthly check-ups. Afterwards, supportive periodontal therapy (recall) is carried out at time intervals according to the individual treatment needs to maintain the healing outcome (Lang et al., 1997; Plagmann, 1998).

Regenerative periodontal surgery

The goal of periodontal regeneration is the re-establishment of all periodontal tissues lost due to the inflammation process, i.e., formation of new root cementum, new alveolar bone, and new periodontal ligament (Christgau, 2001). Important prerequisites for the occurrence of periodontal regeneration are:
- presence of undifferentiated progenitor cells within the residual periodontal ligament that facilitate regeneration
- re-establishment of a biocompatible root surface
- selective exclusion of the gingival epithelium from the root surface during the healing process
- stabilization of the blood clot

Figure 6 Wound management in GTR therapy:

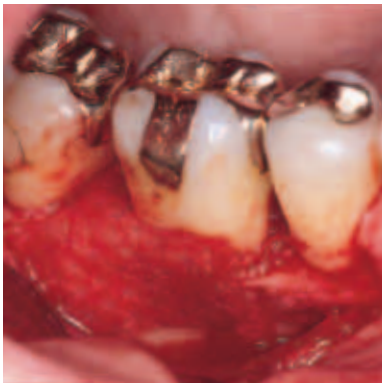


Fig. 6a resorbable GTR membrane in situ

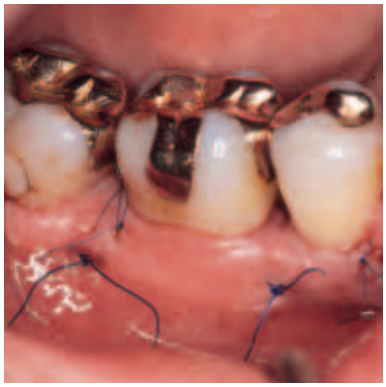


Fig. 6b coronally repositioned flap with a deep horizontal mattress suture (5-0) and tension-free adaptation of the wound margins using an interproximal modified mattress suture (7-0)

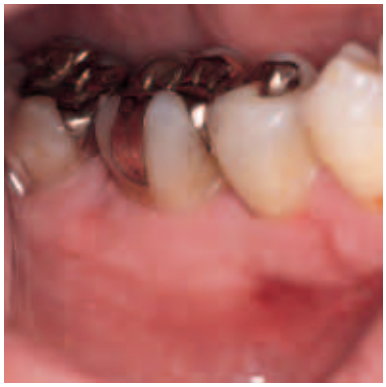


Fig. 6c wound healing 1 week p.o., immediately after suture removal: notice the only slight redness at the suture channels due to the significantly reduced plaque accumulation at the polypropylene sutures

At this time, scientifically accepted and clinically available procedures to achieve periodontal regeneration are:

- guided tissue regeneration (GTR) using cell-occlusive membranes
- application of enamel matrix proteins

Both procedures can be additionally combined with defect filler materials, i.e., bone or bone substitutes (Christgau, 2001).

Wound management

In all regenerative procedures, the maximum preservation of all soft tissues is essential for facilitating primary and complete coverage of the membranes and/or additionally used bone or bone substitutes. For this purpose, a strict intrasulcular incision is necessary. With regard to the width of the interproximal space, a papilla-preservation technique (Takei et al., 1985; Cortellini et al., 1995; Cortellini and Tonetti, 2000; Cortellini and Tonetti, 2001; Wachtel et al., 2003) should be applied whenever possible to reduce the risk of postoperative papilla dehiscences. A coronally advanced buccal flap facilitates primary wound closure covering the membranes. This can be accomplished by a basal periosteal releasing incision or formation of a basal split flap. A tension-free adaptation of buccal and lingual flaps is necessary to prevent postoperative wound dehiscences. A deep horizontal mattress suture (5-0) stabilizes the coronal flap position by bearing the total tension far away from the wound margins. The flaps must be coronally repositioned to the extent that a tension-free adaptation of the interproximal wound edges is possible with one to two additional single sutures (6-0 or 7-0) (Fig. 6 a to c). For this purpose, a monofilament and highly biocompatible polypropylene or polytetrafluoroethylene suture material should be used, due to the increased infection risk and the possibly necessary longer retention time. Because of the absolutely imperative primary wound closure, there is no indication for periodontal dressings.

The success of regenerative periodontal surgery is significantly influenced by the protection against mechanical stress and an effective infection prophylaxis.

Protection against mechanical stress

The patients should know about the sensitive healing processes following regenerative surgery. During the first 6 postoperative weeks, they have to avoid mechanical disturbance of the wound site. For this reason, they are not allowed to chew on the operated side or clean the surgical sites mechanically. Furthermore, to avoid tearing out the sutures, they should not pull on the lips and cheeks or manipulate the sutures with the tongue.

Postoperative infection prophylaxis
Since mechanical oral hygiene is limited to the nonoperated teeth during the first six weeks following surgery, the patients must rinse their mouths with a 0.1 to 0.2% chlorhexidine solution for 1 to 2 minutes twice a day. This should be explained to the patients before planning the surgery.
During the first six weeks, follow-up examinations are necessary at least once a week to facilitate early detection of wound healing problems (e.g., infections, membrane exposures) and professional cleaning of the wound area. The cleaning procedure comprises

- gentle removal of plaque and fibrin layers using cotton pellets soaked with chlorhexidine solution (Fig. 5b)
- rinising of the gingival sulcus with a 0.2% chlorhexidine solution using a blunt canula (Fig. 5b)
- final application of a 1% chlorhexidine gel (Fig. 5b). The patient should avoid eating and drinking for the next 1 to 2 hours to maintain a certain depot effect of the gel.

Six weeks after surgery, the tissues are mature enough again to make professional tooth cleaning possible. Afterwards, the patients can resume gentle mechanical toothbrushing. Until the re-evaluation after 12 months, follow-ups should be performed every 2 to 4 weeks within the first 3 months and then every 3 months subsequently. Supportive periodontal therapy, which is performed regularly and at short intervals, is a *conditio sine qua non* for the long-term maintenance of the new attachment gain (Cortellini et al., 1994). The regeneration outcome should be evaluated by clinical probing at the earliest after 3 to 6 months and by radiographs at the earliest after 6 to 12 months.
Contradictory opinions exist on the necessity of the administration of antibiotics in GTR therapy (Ciancio, et al., 1990; Demolon et al., 1993; Machtei et al., 1994; Nowzari et al., 1995; Kleinfelder and Lange, 1996; Slots et al., 1999). Patients who were given amoxicillin for 8 days following GTR therapy with e-PTFE membranes showed significantly better attachment gains after 6 months compared to a control group who had not taken antibiotics (Nowzari et al., 1995). The antibiotic group revealed sigificantly fewer bacteria on the membranes after 6 weeks. Another study (Mombelli et al., 1996) also found better regeneration results following additional systemic antibiotic administration, although the bacterial contamination of the membranes could not completely be prevented. The additional local application of a 25% metronidazol gel seemed to sigificantly reduce the bacterial load of the e-PTFE membranes during the initial healing phase and to improve the regeneration results (Sander et al., 1994; Frandsen et al., 1994). On the other hand, a study (Kleinfelder and Lange, 1996) on intrabony defects treated with a polylactic acid membrane could not demonstrate a significantly superior effect after systemic administration of antibiotics.
A routine administration of antibiotics does not seem to be necessary following the application of enamel matrix proteins, due to the good soft tissue healing observed clinically and histologically.

Suture removal
Similar to other techniques in periodontal surgery, sutures are usually removed 7 days after regenerative procedures. However, the sutures can also be left in situ for up to 6 weeks following GTR therapy, if there is a risk of wound dehiscences. In this case, it is essential that monofilament and highly biocompatible suture material be used (e.g., polypropylene, polytetrafluorethylene) to avoid plaque accumulation and suppuration from the suture channel.

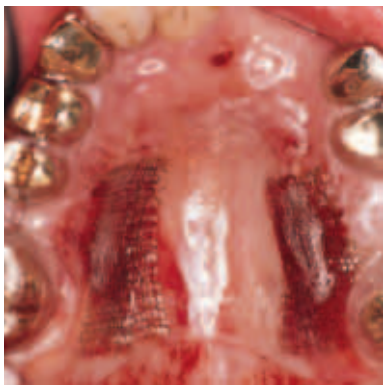
Smoking
There is extensive scientific evidence that smoking has a negative effect on the regeneration outcome (Tonetti et al., 1995; Cortellini et al., 1996; Falk et al., 1997; Trombelli et al., 1997; Mayfield et al., 1998; AAP Position Paper, 1999). Retrospective analysis of heavy smokers revealed significantly less attachment gains in intrabony defects following GTR therapy compared to nonsmokers (Tonetti et al., 1995, Trombelli et al., 1997).

Plastic periodontal surgery using either free gingival grafts or subepithelial connective tissue grafts

Wound management
The palatal donor site of a subepithelial connective tissue graft is closed by criss-cross suspensory sutures. They press the wound margins against the bone without pulling them (Fig. 7 e to f). Ideally,

Figure 7 Wound management in periodontal plastic surgery

Fig. 7a coverage of the palatal donor sites of two free gingival grafts with a plastic stent



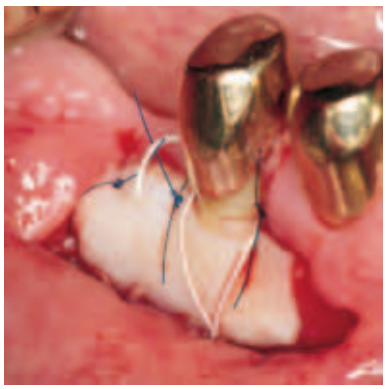
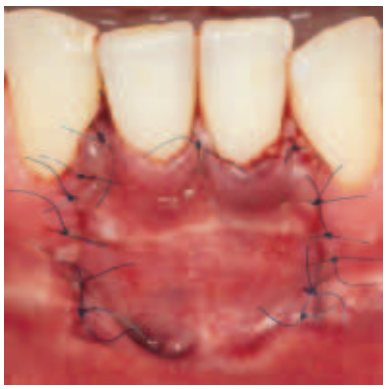


Fig. 7b immobilization of a free gingival graft in the recipient bed using 7-0 poly-propylene single sutures and 5-0 polytetrafluoroethylene criss-cross suture

Fig. 7c wound closure with 7-0 polypropylene single sutures following treatment of the gingival recessions on teeth #31 and #41 using a subepithelial connective tissue graft and a coronally advanced flap



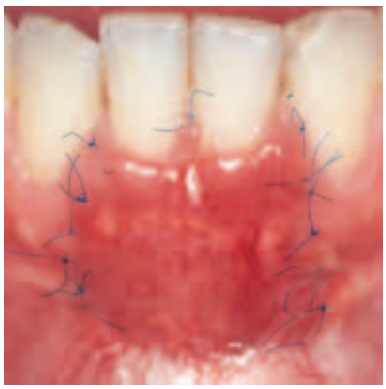
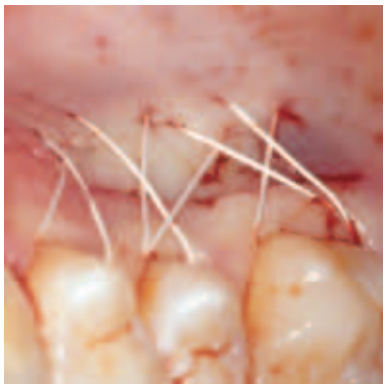


Fig. 7d wound healung of c) after 1 week

Fig. 7e palatal donor site of a subepithelial connective tissue graft: wound closure with criss-cross suspensory sutures



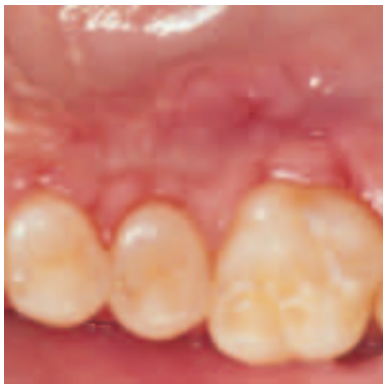


Fig. 7f wound healung of e) after one week.

during the first 1 to 2 days, the palatal wound at the donor sites of subepithelial connective tissue grafts or free gingival grafts is covered by a preoperatively fabricated stent (Fig. 7a). The stent facilitates hemostasis and diminishes postoperative discomfort by preventing wound irritations by the tongue and during food intake.

When augmenting the keratinized gingiva using a free gingival graft, the graft must be trimmed so that it fits into the recipient, apically leaving about 1 mm of the recipient bed uncovered. The graft is immobilized with single sutures to the adjacent gingiva at the coronal margin. Additional criss-cross sutures placed in the adjacent periosteum press the graft against the recipient bed. After suturing, pressure is exerted against the graft for about 2 minutes to eliminate the blood and exudate between the graft and the recipient bed.

Periodontal dressings should be avoided to prevent displacements and loss of the graft.
When treating gingival recessions with a subepithelial connective tissue graft, the graft should be covered by keratinized tissue of a coronally or laterally repositioned pedicle split-flap, facilitating fast revascularization (Wennström and Pini-Prato, 1997). The immobilization of the graft and the covering split-flap is achieved with single sutures and mattress sutures using monofilament 6-0 to 8-0 polypropylene suture material (Fig. 7 c to d). Periodontal dressings should be avoided.

Protection against mechanical stress
The patients are not allowed to chew in the operated areas to avoid dislocations of the grafts. Furthermore, the adjacent lips and cheeks should not be pulled.

Infection prophylaxis
In place of mechanical tooth cleaning, the patients must rinse with a 0.1 to 0.2% chlorhexidine solution for 1 to 2 minutes twice a day for 4 weeks.

Palatal donor site
The open wound caused by removing a free gingival graft can cause a burning pain/discomfort during the first weeks. During this time, patients should avoid spicy food. Mouth rinsing with a dexpanthenol solution (e.g., Bepanthen) can bring relief and accelerate the wound healing process.

Suture removal
Sutures are removed after 7 days.

CONCLUSIONS

Besides a perfect surgical technique, careful primary wound closure as well as stringent postoperative infection prophylaxis are important prerequisites for a successful healing outcome. A dense and tension-free adaptation of the wound margins accelerates the revascularization and decreases the healing time as well as the postoperative discomfort. Furthermore, it reduces the risk of bacterial contamination of the operated site to a great extent. Modern microsurgical/microinvasive techniques using monofilament sutures in different layers facilitate a long-lasting tension-free primary wound closure. Thus, especially in regenerative procedures, the risk of postoperative papilla deshiscences with membrane exposures can significantly be reduced (Cortellini and Tonetti, 2001; Wachtel et al., 2003).
It is crucial that postoperative care reduces postoperative discomfort for the patient to an absolute minimum. This is especially important for maintaining the compliance of the patient if more than one surgical intervention is planned. Since mechanical tooth cleaning must be avoided during the first weeks, the chemical plaque control with a 0.1 to 0.2% chlorhexidine solution is an essential part of the infection prophylaxis. Beside this, follow-ups should be carried out in the dental office at least once a week to thoroughly clean the surgical sites and to detect wound healing complications early. Following periodontal surgery, supportive periodontal therapy is a *conditio sine qua non* to facilitate long-term success of the healing outcome. Supportive periodontal therapy must be provided at regular intervals according to the individual treatment needs of each patient.

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