Wound closure and wound healing. Suture techniques in contemporary periodontal and implant surgery: Interactions, requirements, and practical considerations

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In contemporary reconstructive periodontal and implant surgery, attaining uncomplicated wound healing in the early postoperative healing phase is the key to achieving a successful treatment outcome and is of central interest, from the clinical as well as the scientific perspective. The realization of primary wound healing is the central challenge in most cases. Two of the evidence-based factors that affect postoperative wound healing can be influenced by the surgeon: the blood supply to the surgical site and postoperative wound stability. The surgical suture is a key determinant of whether adequate wound stability is achieved in this context without complicating the course of wound healing by exerting unnecessary trauma or excessive tensile strain on the wound edges. Therefore, the inclusion of anchors in the suturing process that make it possible to achieve the best wound stability possible is often an important key to success. This article provides an overview of the principles of successful wound closure that are relevant to postoperative wound healing in order to equip dentists with the tools needed for the correct, indication-specific selection and performance of surgical suturing techniques in daily practice. (Quintessence Int 2017;48:647–660; originally published (in German) in Implantologie 2016;24:281–294; doi: 10.3290/j.qi.a38706)

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Reconstructive hard and soft tissue augmentation procedures in periodontal and dental implant surgery are increasingly shaping the treatment spectrum of dentistry. More and more emerging evidence shows that the key to success is to achieve fast and uncomplicated wound healing. The successful integration of graft and augmentation materials commonly used in this context depends on a range of factors, such as, and in particular, the good blood supply to the surgical site, the prevention of bacterial infections, and the achievement of maximal wound stability. The realization of primary wound healing is therefore the measure of all things in the majority of these cases.¹² From a biologic perspective, wound healing by primary and secondary intention leads to the same result: wound closure. However, the two processes differ significantly in terms of the chronology of the different phases of wound healing and the tissue quality at the end of the healing period.³

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From a surgical point of view, smooth, well-vascularized, tension-free, and precisely adapted wound edges are the most important prerequisites for primary intention healing. After primary wound closure in this manner, a thin but stable blood clot forms between the wound margins, and little to no local tissue ischemia occurs. Consequently, it is virtually impossible for bacteria to infiltrate the wound, particularly the deep tissue layers. The blood supply to the wound is rapidly restored, and a provisional matrix quickly forms to cover the wound. Under favorable conditions, a wound can close within a few days of primary wound closure in the absence of clinically detectable inflammation, wound secretion, and granulation tissue. There is very little to no scar tissue formation after wound healing by primary intention. The outcome of primary wound healing can thus be described as wound tissue regeneration in the sense of “restitutio ad integrum”, i.e. restoration of the tissue to more or less its original intact condition.

Secondary wound healing, on the other hand, is associated with the formation of repair tissue. To quickly close the wound and restore the integrity of the epithelial lining of the oral cavity, the body produces low-grade scar tissue to bridge over the gap resulting from tissue damage or removal. When suture closure results in excessive tension on flap edges, or when suture loosening occurs due to improper suture tying, or a restricted local blood supply leads to wound edge necrosis, healing by secondary intention often occurs in spite of primary wound closure. Especially in the intraoral cavity, such wounds are associated with a high risk of bacterial contamination. In many cases, this results in a compromised treatment outcome characterized by the development of volume defects, fibrotic tissue, and hypertrophic scars.

Against the background of this knowledge, it is evident that the successful performance of any reconstructive-surgical procedure requires a deep understanding of the importance of wound healing as well as the identification and control of factors influencing the wound healing process. From the clinical perspective, these are basic keys to success. prognostic factors associated with wound healing have been investigated in research on the treatment of gingival recession in the context of reconstructive periodontal and implant surgery. Risk factors for failure can be divided into three broad categories: patient-related, defect-related, and technique-related. It seems feasible to transfer the knowledge gained in the context of gingival recession treatment to other settings. While both patient-related factors (e.g., general health) and defect-related factors (e.g., the defect configuration) are primarily controlled by appropriate patient selection, it is mainly via technique-related factors that the clinician can have a positive influence on wound healing and, thus, a direct effect on the outcome of treatment. Surgical soft tissue management is therefore a key determinant of the success or failure of treatment. Careful preoperative planning of all parts of the procedure (from the first incision to flap elevation to wound closure) is needed to ensure optimal wound stability and an optimal blood supply to the surgical site. Surgical suturing techniques play an important role in this context.

The aim of this article is therefore to equip practicing dentists with the tools needed to correctly select and perform the various suturing techniques used in oral surgery in an indication-specific manner. Clinical examples are provided to illustrate a range of aspects, from the indication-specific selection of appropriate suture materials and suturing techniques and practical tips on how to perform them. It is our hope that this will contribute to a better understanding of the importance of achieving wound closure based on biologically sound principles for successful wound healing in the oral cavity.

MACRO- OR MICRO-SURGERY?
Thanks to the availability of optical magnification and special microsurgical instrument kits, it is now possible to perform surgical procedures in the oral cavity with relatively little trauma and high precision. More and more scientific evidence is emerging to support the clinical observation that the consistent use of a
Microsurgical approach not only leads to superior early wound healing with significantly less morbidity, but also significantly improves the clinical results of oral surgery. Microsurgical approaches to reconstructive periodontal and implant surgery were originally introduced in the early 1990s, and the ensuing development of suitable microsurgical instruments and suture materials has been a decisive driver of advances in this field.

In contrast to the classic microsurgery disciplines such as neurosurgery or ophthalmic surgery, the microsurgical techniques used in periodontal and implant surgery must be adapted to meet the very special requirements of the oral cavity: they must be delicate enough to ensure the atraumatic and precise adaptation of sometimes very fragile oral mucosa under optical magnification yet sturdy enough to withstand high mechanical stresses, especially in the gingiva or palatal masticatory mucosa.

Regarding the suture materials, it has proven to be advantageous to use needles of sufficient length and stability. Ideally, the needle should be sturdy enough to penetrate the intraoral tissues smoothly and without bending, long enough to cross the interdental space in a single pass, and fine enough to be combined with fine sutures.

In light of these instrument requirements, it does not seem absolutely necessary to use an operating microscope. Loupes with 4.5- to 6-fold magnification have proved to be an adequate and easy-to-use alternative. In terms of the range of optical magnification and instruments used today, microsurgical interventions in the oral cavity fall somewhere between the realms of classic microscopic surgery and traditional macroscopic surgery. This development increasingly raises two reasonable questions:

- Will strict differentiation between macro- and microsurgery still be useful in the future?
- Should surgical interventions in the oral cavity generally be performed via a microsurgical approach with adequate magnification, using instruments and suture materials developed specifically for this purpose?

**BIOLOGIC AND PHYSICAL REQUIREMENTS OF SUTURE MATERIALS**

A wide range of different suture materials are available for oral surgery today. Sutures may be classified on the basis of their structural and physical properties. Structurally, sutures are defined in terms of their size (diameter), number of filaments (monofilament vs multifilament/braided), and surface texture (smooth vs rough). In terms of their physical properties, suture materials are classified based on their biodegradability (absorbable vs nonabsorbable), stiffness, tensile strength, and knot security.

The ability of a suture to withstand mechanical stress depends on its combination of physical and structural properties. Equipped with a wide base of knowledge about the specific properties of different suture materials, surgeons can not only correctly choose an appropriate suture for a specific case, but are also able to enhance the healing process to a certain extent. There are very high requirements that an “ideal” suture material must meet.

Regarding factors related to the manufacturing process, the ideal suture material should be easily sterilizable and precision-fabricated so as to ensure a uniform and consistent thread size. High tear and tensile strength, good handling properties, and high knot security are other requirements it should meet. Moreover, the ideal suture material should cause minimal trauma during tissue passage and minimal immunologic tissue reactivity with no capillarity tendencies associated with the so-called “wick effect.” Capillarity is a process by which fluids and microorganisms are drawn into the wound via the filaments of sutures, multifilament materials in particular, which act like the wick of a candle due to their rough and braided surface. The tendency for biofilm formation and the risk of patients injuring themselves on stiff suture edges during the healing phase should be as low as possible, and the duration of function of absorbable sutures must be clearly defined. Last but not least, manufacturing costs should be low enough to ensure a reasonable sales price appropriate for the large volume of sutures used in daily practice.
Absorbable and nonabsorbable sutures are classified on the basis of their in-vivo biodegradability. Absorbable sutures may be either natural or synthetic in origin.15 Natural absorbable sutures are broken down by proteolytic enzymes, while synthetic absorbable sutures are degraded by hydrolysis. The degradation process by which sutures are absorbed triggers an inflammatory reaction in the surrounding tissues.21,22 Therefore, it seems advisable to limit the use of absorbable sutures to deep tissue layers that are no longer accessible after wound closure and healing. Because natural sutures generally elicit a greater degree of tissue reaction than synthetic sutures,23,24 they are no longer recommended for use in oral surgery. The inflammatory response associated with the absorption of polyglycolic acid (PGA)-based synthetic sutures is relatively small.25 PGA sutures are absorbed over a period of 60 to 90 days.26 However, they appear to have a maximum of 50% of their original tensile strength after an implantation period of 60 days.26

Synthetic nonabsorbable sutures made of polyamide polymer, polyolefin, polypropylene, or polyvinylidene fluoride feature outstanding tissue compatibility.2,27 These monofilament sutures have a much lower degree of capillarity than multifilament sutures.28 In line with this, there is evidence suggesting that monofilament sutures are associated with a lower risk of wound infection.29-31 This advantage, however, is offset by certain disadvantages: monofilament sutures are somewhat stiff and inflexible, which results in poorer handling properties and knot security.23

For the surgeon, the challenge is to choose a suture material that provides an optimum balance between the advantages of monofilament and multifilament sutures. Smooth polyvinylidene fluoride-based synthetic monofilament sutures appear to be the suture materials that offer the best compromise at present.32 Evidence suggests that the aforementioned disadvantages with respect to handling properties and knot security no longer apply from a suture size of 6-0 and 7-0.33 However, precise knot-tying technique is still needed to achieve secure wound closure with monofilament sutures.

Expanded polytetrafluoroethylene (ePTFE) is a special type of nonabsorbable synthetic suture material. Expanded PTFE fibers form monofilament sutures with “pockets of air” incorporated in the material. They have excellent tissue compatibility, but their porosity (air content of 50% to 60%) and porosity-related swelling capacity result in increased bacterial biofilm colonization of the thread surface. These are major drawbacks, but ePTFE also offers some great advantages, such as excellent glide characteristics. Therefore, ePTFE suture material can now be recommended as a standard material for macrosurgical sutures in oral surgery. However, because of their porous surface, ePTFE sutures should not be used in cases where the suture material must be left in place for long periods of time.2

Proper surgical needle selection is not only important for successful wound closure, but also for preventing additional tissue trauma. Surgical needles must have high flexural strength: they must be rigid enough to resist bending when passed through tough tissues, yet ductile enough to keep from breaking as soon as they encounter resistance. Furthermore, a good surgical needle must be sterilizable and corrosion-resistant. The material that best meets these requirements is high-quality stainless steel, which is usually nickel- or chrome-plated to make it easier to polish.

Curved needles are easier to control in confined spaces. They guide the path of the thread through the tissue such that pulling on the free ends of the suture brings the edges of the wound into apposition with slight eversion. Straight needles, on the other hand, result in inversion of the wound edges, which generally should be avoided in periodontal surgery. When making interdental sutures, it should be possible to insert the needle through the interdental space in a single pass. This requires the use of longer needles, especially in the molar region. Needles with a ⅜ or ½ curve and an arc length of 8 to 15 mm are preferentially used in periodontal and dental implant surgery for this reason. Needles with a triangular cutting blade have proved effective in periodontal microsurgery. Only the front third (tip) of the needle should be sharp, and the middle third (shaft) should be flattened.
for better retention in the needle holder. A polished surface enhances the ability of the needle to glide through tissues. Round-bodied needles are not recommended because they bend more easily and are more difficult to pass through periodontal tissues. The junction between the needle and the thread is another important factor. Eyed needles are reusable. The eye of the needle and the doubled strand of thread in that region produce in a relatively broad suture footprint, which causes substantial tissue trauma. Atraumatic suture needles were developed for this reason. Unlike eyed needles, the suture thread is glued or welded to the blunt end of the eyeless atraumatic suture needle, creating a smooth junction (swage) between the needle and the thread. Because these are disposable needles designed for single use only, they are always new and sharp. Consequently, atraumatic suture needles result in a tremendous reduction of tissue trauma. All of these are good reasons why atraumatic suture needles should be used in oral surgery in general and oral microsurgery in particular.

PRINCIPLES OF SUTURE CLOSURE

Because complete immobilization of wounds in the oral cavity during the postsurgical period is rarely possible, precise and stable suture closure is crucial to successful wound healing following oral surgery. The surgeon should always keep the goal of suturing in mind: Surgical sutures must passively secure the flap in the position established during surgery, keep the edges of the wound in intimate contact (this is especially important for grafts depending on initial nutrition by diffusion), and stabilize the wound during the early healing phase. The selected suture materials, suturing techniques, and soft tissue management must ensure that suture knots do not come undone and that both the suture materials and the soft tissues are able to resist the mechanical stresses exerted upon them during the early healing phase. All of these conditions must be met in order to achieve healing by primary intention and, most importantly, good cosmetic results without scarring, especially in the esthetic zone.

Incisions should be placed in keratinized tissue whenever possible because this makes it easier to achieve precise suture closure. The selected incision technique and flap design should ensure that the edges of the flap are held in the desired position without tension and that they can be coapted with sutures without excessive pulling force. This is essential for achieving the required stability of wound closure without the sutures tearing out of the skin during healing. If mobile and immobile flap components are to be connected, then suturing should always be performed from movable to non-movable tissue to prevent the sutures from tearing through the edges of the immobile flap. Gently mobilizing the edges of the immobile flap can make it easier to achieve precise suturing.

As a general rule, the needle should be inserted at a 90-degree angle to the tissue to minimize trauma. The force used to guide the needle should always be applied in the direction of the needle curvature. The use of needle holders with a round handle cross-section facilitates controlled and precise rotational movement of the fingers. As a rule, the needle is held perpendicular to the incision line. The general rule is: the fewer sutures needed to achieve precise and stable approximation of the flap margins, the better.

The needle holder should be sturdy enough to grasp fine needles of different sizes securely, yet small enough to allow easy access into interdental spaces. Needle holder jaws with a round cross-section prevent damage to the sutures as well as trauma to the surrounding tissues during suture placement. Needle holders with a ratchet lock normally are not used in conventional microsurgery, but have proven very helpful in periodontal and implant surgery. They are designed to hold the needle securely and enable controlled passage of the needle through the often coarse periodontal soft tissues without excessive pressure on the instrument handle.

To ensure sufficient knot security, each suture knot consists of multiple loops. The first loop determines the position and tension of the suture and, thus, the exact position of the wound edges. The second loop (and
A simple reverse-direction knot can be tied using microsurgical suture materials of size 7-0 and smaller. First, a double loop is formed, followed by a second single loop in the opposite direction. The short end travels in the opposite direction. It should be noted that once the second loop has been made, it is not possible to tighten the first loop by pulling on the second. Therefore, it is important to ensure that the first loop is securely placed in precise position before making the second. After making the first loop, it can be helpful to turn the suture ends 180-degrees before making the second loop. If it is not possible to check loop position during suturing, a third single loop should be made in the opposite direction. The same rule applies when using size 6-0 microsurgical suture material. Macrosurgical sutures made of ePTFE should be tied using a square knot with an additional third throw to ensure adequate knot security. This knot is constructed with three consecutive single loops, each in the opposite direction of the preceding throw. Due to the excellent gliding capacity of ePTFE, the first loop can still be tightened after the second loops have been made. The third loop is needed to ensure knot security.

To guarantee that the blood supply to the wound is not impaired during healing, it is important to ensure that the sutures are not pulled too tightly. The surgical knot should be as small as possible, and the cut ends of the knot should never be longer than 3 mm. To avoid irritation of the wound edges and to minimize plaque accumulation in the wound, knots should not be placed on the incision line, but lateral to the wound edges.

To prevent impairment of healing, the sutures should be removed with sharp instruments, with as little trauma as possible, 5 to 7 days after the procedure.

In oral surgery, sutures are tied either completely with instruments (needle holder and forceps) or partly with instruments (needle holder and fingers). Instrument tying enables better control of loop position, especially in poorly accessible sites.34,35

SUTURING TECHNIQUES AND THEIR CLINICAL APPLICATION

The main objective of the commonly used suturing techniques described below is the constant clinical challenge of achieving the most stable wound closure possible without significantly affecting the blood supply to the surgical site. Clearly, sufficient wound stability cannot be achieved if the suture only passes through mobile tissue flaps alone. Therefore, the availability of suitable anchors for the sutures is a decisive factor in the successful selection and execution of a suturing technique that meets the requirements of the specific clinical situation. Natural structures (such as the teeth, gingiva, masticatory mucosa of the hard palate, and periosteum) as well as artificial structures (such as composite resin anchors) can provide sufficient anchorage.

Single interrupted sutures

Optimal adaptation of two surgical flap edges is the central focus of suturing. Compared with continuous sutures, the advantage of interrupted sutures is that the loss of an individual suture does not mean the complete loss of suture closure. Although it can be assumed that the use of as few sutures as possible has a beneficial effect on wound healing in the oral cavity, interrupted sutures are relatively time-consuming. This is a major disadvantage, even if they are used sparingly. If wound closure is performed using single interrupted sutures, the distance between the incision line and the needle entry and exit points (bite size) should be kept as equal as possible. The closer to the surface the suture passes through the tissue, the smaller the bite size should be. However, the bite size should never be less than 1 to 2 mm (minimum bite size). Ideally, the suture should cross the incision line at right angles and should only deviate from this course in selected cases (Figs 1 to 3).

Tension-relieving sutures

Tension-relieving sutures are always used in combination with closing sutures to achieve tension-free adaptation of the flap edges before the actual suture closure.
The use of closing sutures alone leads to punctiform flap adaptation, whereas the combination of closing and tension-relieving sutures results in broader and intimate adaptation between the flap edges. This enhances the precision and mechanical stability of wound closure, which is particularly important in cases where increased wound tension or mechanical stress during the postoperative healing phase is likely to occur due to postoperative edema or to talking and chewing movements. Tension-relieving sutures are placed before closing sutures. They may have a crossed or parallel suture pattern and can be positioned horizontal or vertical to the incision line. Tension-relieving sutures may be placed externally or internally, above or below the incision line. The internal horizontal mattress suture is the most commonly used tension-relieving suture in periodontal and implant surgery. It may run parallel to or cross over the incision line (Figs 4 to 6).
Regenerative periodontal therapy for deep infra-alveolar bone defects often requires the simplified papilla preservation technique in interdental spaces, which runs obliquely through the papilla, from buccal to lingual. As the interdental space generally does not provide enough access for correct single interrupted suture placement, the single sling suture is a useful tool for achieving precise flap adaptation in these cases (Figs 7 to 9).

Fig 4  Clinical example: An internal horizontal mattress suture was used for wound closure after a subepithelial connective tissue graft was harvested from the lateral palate for soft tissue ridge augmentation (suture material: Seralene Blue 6/0 DS-15).

Fig 5  Schematic representation of an internal horizontal mattress suture (occlusal view).

Fig 6  Schematic diagram demonstrating the use of an internal horizontal mattress suture for flap stabilization (arrow): the palatal masticatory mucosa is used for anchorage (A, anchor; MBF, mobile buccal flap; MPF, mobile palatal flap).

**Single sling sutures**
The double sling suture, a combination of single interrupted suture and tension-relieving suture, makes it possible to achieve very good and stable flap adaptation with relatively little time and effort. The first part of the suture achieves tension-free closure of deeper tissues while providing wound edge eversion. This facilitates the second part of the suture to ensure precise wound closure. The double sling suture is passed through the palatal masticatory mucosa (Fig 9).
tory mucosa or the gingiva of the lingual mucosa to stabilize the wound (Figs 10 to 13).

**Suspension sutures**

Suspension sutures are used with repositioned flaps to secure the surgically established flap position if in cases where the periosteum or attached gingiva does not allow for sufficient wound stabilization. The teeth or artificially created retention areas serve as anchors, eg for horizontal or vertical double-crossed sutures, respectively.

The double-crossed suture is a commonly used suspension suture. As its name implies, it crosses the interdental space twice. Horizontal double-crossed sutures use the circumference of the tooth as an anchor.
It is used, for example, for donor site closure after harvesting a free connective tissue graft from the lateral palate. Additional anchorage of the suture to the palatal masticatory mucosa apical to the harvest site results in simultaneous wound compression (Figs 14 to 16).

Vertical double-crossed sutures are anchored by composite resin bonded to the interdental space, coronal to the wound. They are used, for example, after plastic reconstructive surgery performed by tunneling technique and entirely without superficial buccal incisions. Vertical double-crossed suture placement allows for ideal coronal stabilization of augmented tissue as well as for compression and stabilization of the wound (Figs 17 to 20).
Various developments and trends toward improving the currently used wound closure techniques can be found in the literature. Antimicrobial/antibiotic-coated sutures as well as suture materials that deliver drugs to the surrounding tissue have been developed to reduce the risk of postoperative infection. They offer certain advantages over conventional suture materials but are still relatively expensive.39,40

“Smart” sutures made of shape-memory polymers (SMP) are already being used in minimally invasive cardiovascular surgery.15,41 They facilitate deep wound
closure because they shrink up to form self-tightening knots when external energy is applied.

“Barbed sutures” with sharp projections (barbs) on the material surface are currently used in plastic surgery for closure of deeper tissue layers. They allow for knotless wound closure after minimally invasive surgery; the omission of knots eliminates friction and thus helps to prevent wound irritation. Because these sutures have a relatively strong tendency to develop large biofilms when left in place for long periods of time, they seem to be unsuitable for surgical procedures in the oral cavity.

In cases where immediate hemostasis is not needed, wound closure with surgical staples is a time-saving alternative to suture closure. Surgical staples are still mainly used to close macrosurgical wounds outside the facial region, and the quality of wound closure is strongly dependent on the nature of the tissue involved.

The use of thrombin, fibrin, and cyanoacrylate glues that cure on contact with weakly basic fluids, such as water or blood, is an extremely atraumatic and time-saving method of wound closure. Fibrin glues are now mainly used in general medicine for endoscopic procedures; one of their main advantages is elimination of the need for postoperative suture removal. As evidence suggests that glues do not result in any significant increase in the tensile strength of closure, their hemostatic effect is clearly the main emphasis. However, tissue adhesives are rarely used in periodontal and implant surgery today.

The described developmental approaches show that current and future surgical suture materials development tends to be aimed at making simple and time-saving wound closure possible, even under difficult conditions, and at accelerating the pace of healing more actively than in the past. It remains to be seen which of these new developments will play a role in reconstructive periodontal and implant surgery in the future and will translate into clinical applications that benefit patients.

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