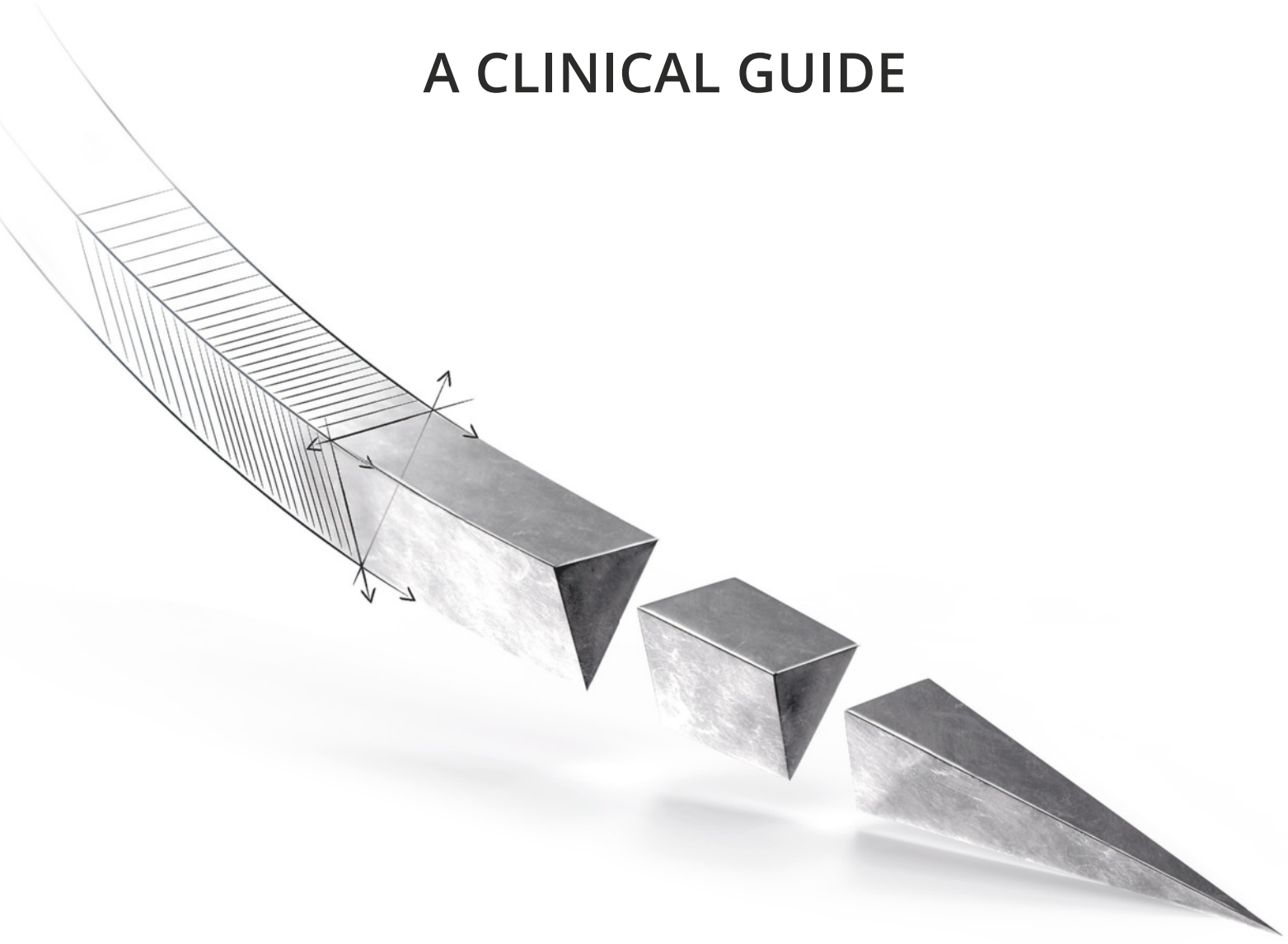
THE ART OF DENTAL SUTURING

A CLINICAL GUIDE



A. Burak Çankaya
Korkud Demirel

QUINTESSENCE PUBLISHING

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On the path that Atatürk has paved, toward the aims that he has set...

ACKNOWLEDGMENT

The start of this project dates back to October 2017. Although we started with much enthusiasm and energy, it did not take us long to understand that putting what we know on paper does not easily translate to performing the procedures in the clinic. Looking for new ways of telling the story took us to Ferhat Çevik, a self-improving, open-minded digital illustrator. We had never met him in person as he lives in another city, but our e-mail correspondence worked out perfectly, resulting in the magnificent illustrations in this book.

Undoubtedly, the illustrations alone were not sufficient; we also had to include the hand instruments for suturing. In this regard, Giana Spasic from Hu-Friedy provided generous support, as she always has, supplying us with all the necessary instruments in the shortest possible time.

So here we were, two authors from two different surgical disciplines, attempting to tackle instrument photography, again believing that whatever we know and do is right. We procured a photo light box, on top of all the photography materials we already had, and started to take photographs of our hand instruments. However, we realized soon enough that taking product photographs was nothing like taking family photos. It took us eight Saturdays and a pile of less-than-ideal-quality photographs to realize that this was not our forte either and that we needed help from professionals. Ahmet Koçak from Kandemir Photography came to the rescue and provided full support.

We would like to express our gratitude to Dr Ertuğrul Çetinkaya, the Managing Editor of Quintessence Türkiye, who mentored us through the process, and language editor, Avril du Plessis, for her exceptional cooperation.

We would therefore like to express our gratitude to all these esteemed and enlightened people whose support was essential in making this book a reality. We would also each like to express our special thanks to one another, as co-authors, not merely for completing the book, but also for having a pleasant time and becoming good friends during this process.

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TYPES OF WOUND HEALING

Diverse biologic events such as hemostasis, coagulation, inflammation, granulation, connective tissue formation, and reepithelization occur during wound healing and continue upon remodeling of the wound site, even after wound closure. The healing model where the wound edges are well approximated is known as primary healing or primary intention, and that where a gap is left between the wound edges is called secondary healing or secondary intention. However, in case of injuries with significant tissue loss and in which the wound is contaminated with bacteria through contact with a foreign body, the wound is often left open for a couple of days to avoid the risk of infection, and then closed once this risk is eliminated. This is known as tertiary healing. In such cases, the wound should be irrigated with saline while it is left open.

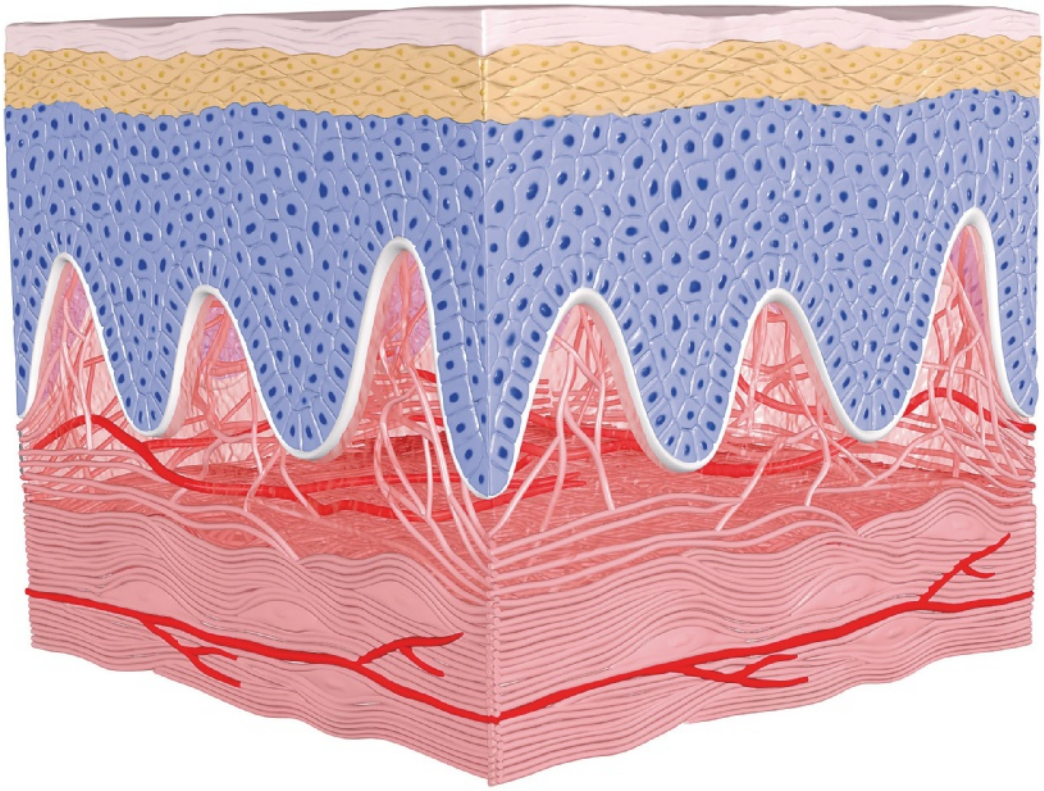
In primary healing, the wound remodels rapidly with a very small amount of granulation tissue formation, whereas in secondary healing, a void exists between the wound edges, resulting in more granulation tissue formation. In these types of injuries, the epithelium needs to extend further to cover the wound surface by filling the gap between the wound edges due to tissue loss. This indicates prolonged epithelization compared with primary healing. In addition, healing becomes more complicated in contaminated wounds with the additional process of eliminating the infection.

Wound healing takes place through either regeneration or repair of damaged tissue. Healing through regeneration involves the recovery of lost tissue with that which is structurally and functionally similar to the original. In healing through repair of damaged tissue, however, structure and function are not of primary importance; the main goal in such cases is the closure of the wound using available onsite cells and/or mechanisms. Whether the tissues heal through regeneration or repair depends on the availability of the required cells, the existence of signals to be transmitted to stimulate these cells, and the distance between the wound edges. The duration of healing varies depending on local and systemic factors.

Wound healing is managed by inflammation resulting from the complex interaction between cells, soluble substances, molecules, and perfusion. The outcome and duration of healing is estimated by the timing of these interactions and associations as well as the magnitude, severity or duration of their mutual activities. Over the past decade, significant progress has been made in exploring some of these processes. Important insights have been provided by various models used to inhibit healing processes that yield poor outcomes (i.e. non-healing wounds, chronic wounds or wounds leaving scars) and in identifying underlying mechanisms that ensure wound healing. Regeneration is preferred to reparative tissue when it comes to healing, as the former is associated with no scars and with improved function. Recent research studies have therefore focused on regenerative healing.

CHAPTER 1

WOUND HEALING



INTRODUCTION

All surgical residents, as rookies, are somehow first assigned suturing tasks. In fact, suturing is one of the most important phases of surgery, if not the most important, requiring utmost concentration and adaptation of the technique to prevailing circumstances. Therefore, considering its significant contribution to the success of surgical procedures in general, we feel that suturing ought to be approached as an art that deserves appreciation and advancement.

The use of sutures in surgical procedures dates back to the 16th century BC. Various materials have been used since then, including horse mane hair, bristle, gold or silver filigrees, silk, silkworm guts, linen, cotton, and the tendons or viscera of various animals. The common function of these materials and procedures is to hold wound edges in approximation until the time of completion of healing, to secure them at the desired position, to protect the wound from physical external factors or microorganisms, to stabilize clots for hemostatic purposes, and to keep the tissues together with the aim of shortening healing time and thus improving the patient's quality of life.

Biologic and technological advances in recent years have resulted in a variety of suture threads being introduced. Factors influencing the choice of suture to be used may vary depending on the patient, wound, tissue characteristics, anatomical position, and procedure to be performed. The preference of the surgeon also plays an important part; the surgeon's experience is relevant because a good knowledge of the properties of suture materials is essential in making the correct choice.

No single suture material currently available on the market can fulfill all surgical requirements. Consequently, the structural characteristics of sutures should be considered for a better understanding of where best to use them. These characteristics include, but are not limited to, suture thread materials, capillarity, tensile strength, knot holding security, elasticity, memory, tissue reactivity, ease of handling, and ready-to-use form. By the same token, no single suture is ideal in all circumstances or conditions. More importantly, suture type should be chosen based on the characteristics of the wound, considering the aforementioned aspects.

Wound characteristics play a key role in wound healing. Therefore, an accurate assessment of the wound healing phases would facilitate decision making compatible with the circumstances.

This book comprehensively covers the healing of surgical wounds, with a focus on scalpel-induced incision wounds. It should be borne in mind, however, that although wound healing phases and tissue response are identical in traumatic injuries, irregularity of wound edges and additional problems introduced by microorganism contamination may further complicate the healing process.

PHASES OF WOUND HEALING

Wound healing is basically divided into three major phases. The first is hemostasis and inflammation, where there is an attempt by the body to restore the tissue integrity and

during which contaminated components are removed from the wound. The next is the proliferation phase, where the cells required for reorganization migrate from neighboring tissue and new tissue is formed. The last is the remodeling and maturation phase, where the newly formed tissue is organized to harmonize with the peripheral tissue.

Hemostasis and inflammation

Intraoral soft tissue healing is subject to the same principles as the healing of other bodily tissues. Wound healing starts with hemostasis to preserve the integrity of the organism; the organized form of this is known as coagulation. Traumatic and/or surgical damage results in capillary injury and hemorrhaging, which is the organism's self-protection mechanism. Wound healing is delayed if hemorrhaging starts and stops repeatedly, as this impairs granulation tissue formation. The development of alveolitis and the resultant pain in patients with recurrent hemorrhaging following surgery may be associated with this impairment. The consequences of low viscosity, including the problem of the instability of blood, are addressed by the coagulation process. Coagulum serves two main functions: to temporarily protect the exposed tissue, and to create a temporary matrix – known as the fibrin plug – for the cells to migrate from neighboring wound edges. Coagulation is followed by inflammation, constituting the basis for wound healing.

Wound healing is a well-managed interaction between the cells of key importance (i.e. neutrophils, monocytes, lymphocytes, endothelial cells, and fibroblasts) and soluble regulating and signaling molecules (mediators) moderating intercellular substance synthesis. Coagulum typically contains a high number of neutrophils and macrophages that are released immediately following injury. These cells start to remove the necrotic and/or damaged tissue and microorganisms by secreting phagocytosis, toxic oxygenation products, and enzymes, and by releasing signaling molecules rich in polypeptide mediators, addressing cells that are effective in the wound healing process. These growth factors and cytokines released by macrophages play a central role in the proliferation of primarily fibroblasts and endothelial cells as well as smooth muscle cells, indicating the transition to the proliferation phase of healing. Although inflammation is an indispensable healing phase, the over or under release of inflammatory mediators may adversely affect the wound healing process. Inflammation reaches its final stage on or around the third day.

Proliferation

This complex process incorporates angiogenesis, the formation of granulation tissue, collagen deposition, epithelialization, and wound retraction. These processes occur simultaneously at various levels in different parts of the wound. Angiogenesis is triggered from the moment the hemostatic plug has formed, once the platelets have released growth factors. As the process of angiogenesis progresses, a rich vascular network of capillaries is formed; thus, nutrients and new cells are transferred to the healing front. With the cellular level signaling, fibroblasts populate the wound space and excrete the extracellular matrix proteins.

This clot is gradually replaced by vulnerable hemorrhagic vascular tissue, which is called granulation tissue. This tissue lays the foundation for epithelial migration, where epithelial cells migrate from the edges of the wound to seal the surface and provide the basis for the formation of connective tissue. During this period, the color of the wound starts to return to normal, with typical characteristics, and it develops resistance to trauma.

Although healing takes place in a hierarchical manner, all the stages of healing are always present at all times in a healing wound because the healing potential is not the same throughout the wound. Wound contraction, which is facilitated by myofibroblasts, may not seem very prominent in extraction sockets, yet it very often happens in wounds that lack keratinization. What is important to note is that the greater the wound space, the more granulation tissue will be required by the wound in the secondary healing phase, which results in faster repair potential and more scar formation. However, the extraction socket is an exception to this rule.

Remodeling and maturation

This process is the longest-lasting phase of wound healing, taking up to a year after proliferation ends. The duration of proliferation is closely related to the volume and function of the tissues. Proliferation takes longer in tissues with a thick phenotype than in those with a thin one. Downregulated mechanosensory signals during remodeling reduce the cellular activity, terminating intercellular matrix formation and the extermination of myofibroblasts (a type of cell between a fibroblast and a smooth muscle cell, narrowing the wound area) through apoptosis.

The final phase of wound healing typically comprises the formation of a tensile, sensitive scar tissue with random collagen fibers. However, a scarless type of tissue mimicking the histologic properties of intact connective tissue is formed during the wound healing process in certain intraoral areas such as the hard palate. Nonetheless, molecular bases of this type of healing that occurs without leaving a scar still remain to be elucidated.

Wound healing is completed by the end of the maturation period, and no alteration in the size of the newly formed tissue should be anticipated. Factors prevailing in the individual phases of wound healing are the main determinants of how rapidly and uneventfully this final stage can be achieved.

TYPICAL CHARACTERISTICS OF ORAL MUCOSAL WOUND HEALING

It is well established that oral mucosa wounds heal rapidly without leaving any complications or scars. Both cellular and intercellular substance as well as collagen fibers are arranged irregularly when a scar is formed, resulting in low matching with the neighboring tissue properties. Studies on healing models of oral mucosa in pigs and rodents have demonstrated that healing is more rapid and clinical, and histologic scar formation is less, when compared with similar skin injuries. However, the reason for the difference in healing between the skin and the oral mucosa is still unclear. It has been

suggested that slow wound closure resulting in low-quality healing of the connective tissue and scar formation is inhibited by evolutionary selection to protect the tissue from microbial infections. In other words, since any delay in wound healing in the oral cavity may lead to difficulties in eating and the disablement of the organism, it can be speculated that oral mucosa has acquired faster and improved wound healing properties compared with the skin in the evolutionary development process.

Furthermore, studies have also suggested that improved wound healing properties of the oral mucosa do not solely originate from peripheral therapeutic opportunities offered by the oral environment, and that signals transmitted by the intercellular substance, which play an important role in regulating cellular functions, are different from those of the skin.

Other mechanisms enabling the tissues to heal without scar formation include continuous bathing of the oral mucosa with saliva and strong inflammatory response. Saliva contains cytokines (i.e. cell-to-cell communication molecules) supporting wound healing, and growth factors such as epidermal growth factor (EGF), transforming growth factor beta (TGF-ß), and insulin-like growth factor (IGF). Delayed intraoral wound healing where there is insufficient saliva supports this hypothesis. However, the influence of saliva on scar formation is not yet clearly understood.

On the other hand, it should be borne in mind that infection-free healing, atraumatic surgical techniques, and uncompromised systemic health are as effective as the basic biologic mechanisms in wound healing.

WOUND HEALING AND SYSTEMIC FACTORS

Systemic factors are as effective as local factors for uneventful and scar-free wound healing. The following discussion covers some systemic factors that have been selected due to their significance and prevalence, although this is not an exhaustive list.

Age

Aging is a natural life process associated with anatomical, biochemical, and physiologic alterations in all systems of the human body. Aging by itself does not affect the healing of intraoral wounds. However, chronic diseases acquired due to aging, medications, and drug-drug interactions may have an adverse effect on wound healing. In addition, dementia may occur at advanced ages, which together with malnutrition has an adverse effect on the healing process. Other factors that influence healing are lax adherence to prescribed drug regimens and poor oral hygiene.

Nutrition

Nutrition does not usually have an effect on wound healing in healthy individuals as it would, for example, in those with malnutrition induced by systemic disease. However, the availability of sufficient protein, zinc, and vitamins (A, B, and C) during the recovery of the body's immunity, which declines immediately following an injury, can support cellular activity and secure the required collagen synthesis at the wound site. However, malabsorption due to gastrointestinal diseases (e.g. Crohn's disease, ulcerative colitis, gastritis, or prolonged

use of proton pump inhibitors) may result in malnutrition, leading eventually to a deficiency of essential vitamins and minerals as well as soft and/or hard tissue healing problems.

Dehydration

Electrolyte imbalance resulting from fluid loss or reduced intake may cause cardiac and renal dysfunction as well as functional disorders of the cellular metabolism, the oxygenation of blood, and hormonal activities. It is therefore recommended to inform patients regarding possible risks of dehydration in wound healing.

Diabetes

Certain chronic systemic diseases adversely affect the magnitude and quality of post-injury tissue response by modulating the hematopoietic system, while others modulate the endocrine system. In this context, diabetes has a special clinical significance. In 2019, the International Diabetes Federation (IDF) announced that there were 463 million people with diabetes globally, ranging in age from 20 to 79 years (according to the IDF Diabetes Atlas). This figure is expected to rise to 700 million by 2045. It is estimated that almost half (49.7%) of diabetic patients have not yet been diagnosed.

In 2019, approximately 4.2 million adults aged 20 to 79 years were estimated to die as a result of diabetes and its complications. Also in this year, annual global health expenditure on diabetes was estimated have been USD 760 billion. It is projected that expenditure will reach USD 825 billion by 2030, and USD 845 billion by 2045. New estimates of the prevalence of diabetes show that health expenditure worldwide due to diabetes and diabetes-related deaths will continue to pose a huge social, financial, and health-system burden. In the light of this, the significance of diabetes for patients seeking dental treatment is clear. Detailed information on diabetes, its importance in dental surgery procedures, and related issues that need to be taken into consideration is available in other sources. However, it is worth mentioning that wound healing may be impaired if the blood glucose level is not controlled. Glycemic control is achieved by measuring the blood glucose level and glycosylated proteins. Even in non-diabetic individuals, the blood glucose level may vary during the day, and it may fluctuate 10 times more in uncontrolled diabetic patients. Also, the blood glucose level only indicates the glucose level at the time of analysis, but gives no information about how well it is being maintained. On the other hand, the glycated hemoglobin (HbA1c) assay, used for the follow-up of diabetic patients, can provide information about the patient's glucose level over a period of about 3 months. However, considering that the HbA1c assay covers a specific timeframe, and that wound healing is initiated simultaneously with surgery, it is advisable to recognize the patient's blood glucose level in addition to the HbA1c assay at the start of an extensive surgery.

Furthermore, complications in the other organ systems of diabetic patients may also provide information regarding the potential of wound healing. Since dental tissue can be deemed terminal tissue, particular attention to circulatory abnormalities seen in similar terminal tissue/organs would facilitate the planning

of appropriate treatment. For instance, micro- or macro-angiopathy in a diabetic patient may indicate the likelihood of impaired wound healing. It should be borne in mind that retinal examination is a common diagnostic method for angiopathies, and the treating physician should be contacted, if necessary.

Previous studies have suggested an increase in the incidence of osteoporosis in diabetic patients. Human and animal studies have also shown that the reduction in bone mass of type 1 diabetic patients is induced by elevated alkaline phosphatase levels and decreased vitamin D_3, parathyroid hormone, and osteocalcin levels as well as intestinal calcium absorption impairment and excessive urinary hydroxyproline excretion. Insulin increases the collagen synthesis and osseous ingestion of amino acids. A decreased release of IGF-1 may contribute to the development of diabetic osteoporosis. In addition, malnutrition and a sedentary lifestyle may lead to osteoporosis in diabetic patients.

Nicotine intake

This section is headed 'nicotine intake' rather than 'smoking' or 'tobacco use' because most smokeless or electronic cigarettes commonly used in the cessation of smoking also contain nicotine. Chronic nicotine intake has an adverse effect on wound healing. Several studies have demonstrated that the wound healing potential of smokers is impaired and that their immune response functions less effectively than in nonsmokers. Nicotine intake results in vasoconstriction of the peripheral vessels, adversely affecting blood supply to the tissues. Chronic nicotine intake affects the organism in a dose-dependent manner. Furthermore, when inhaled, all components of nicotine are in contact with the surface of the oral cavity and also with the wound. Therefore, when tailoring surgery, it is of the utmost importance to recognize the patient's daily dose of nicotine intake.

Although it is considered helpful for patients to cease nicotine intake prior to surgery and not to resume for a while afterwards, this temporary measure only mitigates but does not eliminate the associated problems because nicotine metabolites survive 2 to 24 hours in blood. In this context, the following practical tip may offer benefits from this effect, albeit to a limited extent: Patients should be advised to discontinue nicotine intake at least 24 hours (half-life of metabolites) before the surgical procedure, and resume nicotine intake no earlier than 24 hours after the completion of the procedure (phases of wound healing), but as late as possible, and attempt to keep the daily nicotine dose as low as possible during wound healing.

Diseases and/or therapies affecting the host defense mechanism

Since immune response protects the patient from infections, the outcome of the surgical procedure is severely jeopardized if the immune system is suppressed. Patients infected with human immunodeficiency virus, those receiving chemotherapy, radiotherapy, hemodialysis or a high dose of catabolic steroids, or patients with an organ transplant, may suffer immune response deficiency or disorders. Note that certain patients may be sensitive to certain suture materials, latex, or metal instruments.

DRUGS AND WOUND HEALING

Antithrombotic therapy

There are two drug groups that are effective for the blood coagulation mechanism: anticoagulants and antiplatelets. Coagulation, which is the initial step of wound healing, is executed by coagulation factors. Oral anticoagulants inhibit the coagulation factor synthesis. Antiplatelet agents, also called antiaggregants, affect coagulation by modifying the aggregation properties of platelets. Antithrombotic therapy is used to reduce the risk of thromboembolism. Antithrombotic agents are mainly used for the prevention of coagulation or the enlargement of venous clots. Oral anticoagulants are often used to prevent venous thrombosis, and antiplatelets are mainly used in arterial occlusive diseases. Two widely used antiplatelet agents are acetylsalicylic acid, which is a cyclooxygenase inhibitor, and clopidogrel, which is an adenosine diphosphate receptor antagonist.

Anticoagulants comprise vitamin K inhibitors such as warfarin or factor Xa inhibitors such as heparin. Novel oral anticoagulants include dabigatran, rivaroxaban, apixaban, and edoxaban.

Since difficulties encountered in the formation and preservation of the fibrin plug in patients using these drugs may complicate wound healing, special measures may be required for closing and subsequently protecting the wound.

Antiangiogenic agents

Angiogenesis is the formation of new blood vessels in existing vascular structures. Antiangiogenic agents inhibit the development of existing blood vessels or the formation of new ones. Although these agents were originally developed to block the blood supply to tumors in the treatment of cancer, currently they have also been widely used in the treatment of other vascular diseases. A new vascular network starts to form on the third day of wound healing, supplying oxygen and nutrients to the wound site. Antiangiogenic agents downregulate this mechanism and adversely affect the wound healing process. However, these adverse effects are not the same for every patient population.

Antiresorptive agents

Antiresorptive treatment aims to decrease the rate of bone resorption. It mainly exerts its effect by blocking osteoclastic activity, thus bone mass is preserved. However, the biologic activity of osteoblasts is very limited without osteoclasts, which utterly affect the bone turnover. These agents are mainly used for the treatment of osteoporosis in postmenopausal women and to prevent metastasis among oncologic patients.

Drugs inhibiting bone resorption include estrogen, selective estrogen receptor modulators (tamoxifen, raloxifene, lasofoxifene), calcitonin, bisphosphonates (alendronate, risedronate, ibandronate, zoledronic acid), monoclonal antibodies such as denosumab, ipriflavone, tibolone, vitamin D and active metabolites, and calcium. These drugs also delay wound healing due to their antiangiogenic effects.

Corticosteroids

Corticosteroids have a wide spectrum of use, including treatment of rheumatic and

non-rheumatic diseases and conditions. They exert a strong anti-inflammatory and immunomodulator effect. The use of corticosteroids induces anti-inflammatory proteins; it also inhibits cytokine secretion and chemotaxis. Furthermore, it is associated with fibroblast dysfunction and reduced collagen generation, angiogenesis, and reepithelization, critical components of the wound healing process, which would be impeded by their absence. Commonly used corticosteroids include prednisolone, triamcinolone, betamethasone, dexamethasone, and hydrocortisone.

LOCAL FACTORS AFFECTING WOUND HEALING

Direction and length of incision

A properly planned incision should be long enough to provide adequate visualization. Short incisions may cause injuries and blood supply deficiencies that result from the rupture of wound edges due to overstretching and pressure on the flap to improve visibility. This, in turn, adversely affects wound healing.

Planning incisions in a way that allows for a larger mucoperiosteal flap base is crucial for the nutrition of the flap. Special care should be exercised when performing the incision to preserve the integrity of capillaries advancing from the base of the flap. Incisions should always be planned in a way that leaves a margin of intact tissue, both mesial and distal to the surgical site, and they should not pass through the papillae or areas where the tissues are thin (Fig 1-1).

The following principles should be followed when planning the direction of the incision:

- The natural direction of healing of a surgical wound is side to side, not end to end.
- Tissue fiber arrangement in the area to be incised and dissected varies according to the type of tissue. The optimal cosmetic result can only be achieved by making the incision parallel to the tissue fibers. However, the result may vary depending on the tissue layer incised.

Fig 1-1 The incisions should not be placed at sites with a low regeneration potential such as the papillae, or on thin tissue such as the zenith of the clinical crown. There should be a 90-degree angle where the incisions meet the gingival margin. The releasing incisions should be placed at a safe distance from the adjacent gingival margin and there should always be intact bone underneath. The base of the flaps should be wider so as not to cut the vessels and to prevent the blood supply to the elevated flap.

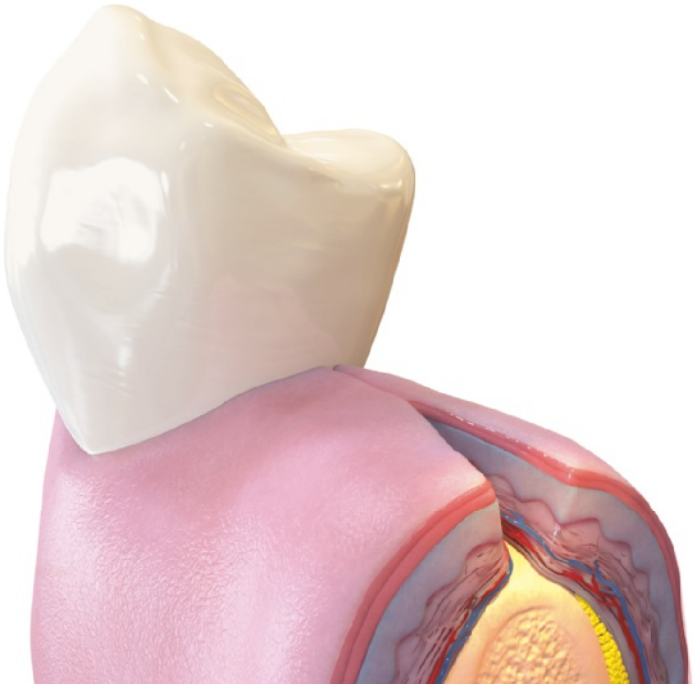


Fig 1-2 Blades should be held perpendicular to the mucosal surface in order to prepare clear-cut wound margins, facilitating uneventful healing.

Surface angle of incision

Care should be exercised to incise the tissues smoothly with a single stroke of the scalpel. Placing the scalpel perpendicular to the mucosal surface facilitates maximum adaptation of wound margins without tapering and creating dead spaces, thereby leading to maximum perfusion. This would result in the fibrin layer between the wound edges being as thin as possible, allowing fluid exchange between these edges (Fig 1-2).

Hemostasis

There are various mechanical, thermal, and chemical means to control blood and fluid flow at the wound site. Hemostasis enhances the visibility for the surgeon and minimizes the risk of human error. Failure to control bleeding from dissected or punctured blood vessels or from periosteal tissue that is not clearly elevated results in limited visualization of the surgical site. Complete bleeding control before wound closure prevents the formation of postoperative hematoma. Accumulation of blood or serum at the incision site further hinders the approximation of the wound edges and provides an ideal environment for the growth of microorganisms, leading to infections. Therefore, mild pressure with a wet gauze should be applied on the surgical site following wound closure to help control fluid accumulation. However, in cases such as guided bone regeneration (GBR), where it is imperative to preserve the space for hard tissue growth under the membrane, care should be taken not to press down and collapse the space under the membrane.

Tissue moisture control

Rinsing the wound with lukewarm sterile saline solution on a regular basis during prolonged surgical procedures or covering exposed surfaces with gauze patches soaked in sterile saline solution aids the healing by preventing tissue dehydration.

Removal of necrotic tissue and foreign bodies

The complete removal of all necrotic tissue and foreign bodies that are impossible for the body to resorb is crucial for uneventful wound healing. The presence of foreign bodies such as dust, metal, calculus or filler remnants increases the risk of infection. The removal of tooth and tissue residuals that cannot receive blood supply from the wound accelerates healing.

Prevention of dead space in wounds

The accumulation of fluid, blood, air, foreign bodies or dead tissue residuals between the tissue layers results in dead space in wounds, which in turn leads to the formation of a thicker fibrin layer, resulting in insufficient perfusion. It also enables the hosting of microorganisms. A drain can be placed to prevent this situation, which may occur upon completion of the surgical procedure. An alternative is to apply compression with a wet gauze patch at the wound site, when necessary. However, compression should be applied with caution when GBR is used, since this technique aims at preserving a space under the membrane.

Tissue tension

Over-tensioning of tissue to the extent of disrupting circulation endangers blood supply, which adversely affects wound healing. In addition, the tensioned suture may tear the tissue itself because of the buildup of swollen tissue due to postoperative edema. Special care should therefore be exercised to ensure that measures taken to release tension do not jeopardize blood supply. Consequently, the impact of releasing incisions or periosteal incisions made on the blood supply of the wound site should be considered. Furthermore, the closing of wounds covered by approximated or displaced tissue merely through the use of simple sutures leads to circulatory impairment caused by suture tension on the wound edge. It is therefore recommended to place the sutures (see mattress sutures, page 56) approximating wound edges away from the margin where the healing process would take place, and to place additional sutures at the wound edges.

Infection

Preventing invasion of the area by microorganisms during wound healing allows the tissues to concentrate their entire biologic potential on closing the wound. The presence of an infection impairs wound healing and reduces healing quality due to chronic irritation caused by the infection. It should be borne in mind that an infection involving other parts of the oral cavity also increases the microbial load and affects the closure and healing of the wound. Therefore, an attempt should be made to reduce the microbial load of the mouth prior to the surgical procedure and to keep it under control by resuming oral hygiene as soon as possible after the intervention.

Wound and clot stabilization

Given the fact that mobile tissue cannot heal, measures should be taken to stabilize and fix the wound margins and/or areas in order to ensure proper healing. Such measures should start with clot stabilization. The thicker the clot that forms immediately after the

intervention, the thicker the temporary intercellular substance will be. Hence, the distance between the wound margins would increase, leading to insufficient intercellular fluid transport. As a precautionary measure against this, it is reasonable to apply pressure with a wet gauze dressing immediately after the process. The applied pressure would control the thickness of the clot layer while allowing the clot to form by stabilizing the tissues, albeit briefly. However, if bone augmentation has been performed, the applied pressure should not adversely affect the circulation or cause tissue contusion, nor should it crush the augmented volume.

Blood supply to the wound site

Oxygen is essential for tissue vitality and thus for wound healing. The tissue heals faster on or around the neck and the face, which receives a good supply of blood, and heals more slowly on the limbs (i.e. distant organs and tissues). To facilitate blood supply and nutrition of the tissues, an evaluation of blood supply possibilities should be made when planning surgical incisions. It is also important to ensure that the technique to be used is compatible with atraumatic surgical principles.

Enhanced visualization

The aim of the atraumatic surgical technique is to achieve rapid wound healing while minimizing tissue damage. Although this technique is commonly interpreted as a minimally invasive one that minimizes the number of incisions made, having a better visualization of the operation site reduces the risk of damage to peripheral tissue. Additional pressure exerted or tissue tension created during the process of tissue retraction with a retractor may endanger blood and lymph circulation and damage the tissues. The resulting hematoma may increase the risk of proliferation of microorganisms. Furthermore, it is always possible to enhance the visualization of the site by using additional sutures (see view-enhancing sutures, page 67). In addition, well-planned and properly executed incisions can be made as they would not adversely affect healing.

In conclusion, sutures used during and after the surgical procedures should facilitate event-free healing of the wound. The phases of healing and factors that play a role in such phases should be utilized to ensure rapid and successful wound healing. Therefore, the surgeon should always be completely familiar with the materials and instruments to be used during the surgery.

Recommended reading

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CHAPTER 2
SUTURE MATERIALS AND SUTURING INSTRUMENTS

Having a good understanding of the properties of suture materials and suturing instruments facilitates decision making regarding specific operations and increases the success of the surgeon and the procedure. What follows in this chapter is an overview of the requirements for successful surgical suturing.

SUTURE THREADS AND NEEDLES

Sutures comprise two main components, namely the thread and the needle.

It is impossible to suggest suture materials that fit all purposes as the choice should take into consideration the characteristics of the tissues and of the materials as well as the requirements of the technique to be applied.

The following tissue characteristics and conditions should be taken into consideration:

- Physical characteristics or consistency of the tissues to be sutured.
- Biologic properties of the tissues.
- Health status of the tissues.
- Proximity of the tissues.

The decision regarding the requirements of the technique should be based on the question of which of the following procedures needs to be applied:

- Repositioning of the tissues or approximation of wound edges.
- Wound closure.
- Hemostasis.
- Enhanced visualization.

PHYSICAL PROPERTIES OF SUTURE THREADS

Currently, a wide range of suture threads of various physical and/or biologic properties are available on the market, most of which were originally manufactured for the textile market and then used for surgical purposes. Since the physical and structural properties of surgical suture threads are decisive for the purpose and area of their use, the considerations in the following paragraphs should be taken into account.

Gauge

Gauge refers to the diameter of the suture thread. Common surgical practice is to use a suture thread with the smallest diameter that is capable of keeping the healing tissues in place. Thus, the trauma the suture thread will cause when passing through the tissues is minimized.

Moreover, the chosen suture thread should be thinner than the tissues, i.e. the tensile strength of the suture should be lower than that of the tissues to ensure that the thread is broken before the tissues are ruptured (Fig 2-1).

The diameter of suture thread is stated numerically in accordance with the United States Pharmacopeia (USP) and European Pharmacopeia (EP) (Table 2-1). The USP system is more commonly used.

As the number of the suture thread increases, its diameter decreases, i.e. 5-0 thread is thinner than 4-0 thread. A reduction in the thickness of the suture thread also refers to a reduction in its tensile strength. As the suture thread becomes thinner, auxiliary instru-

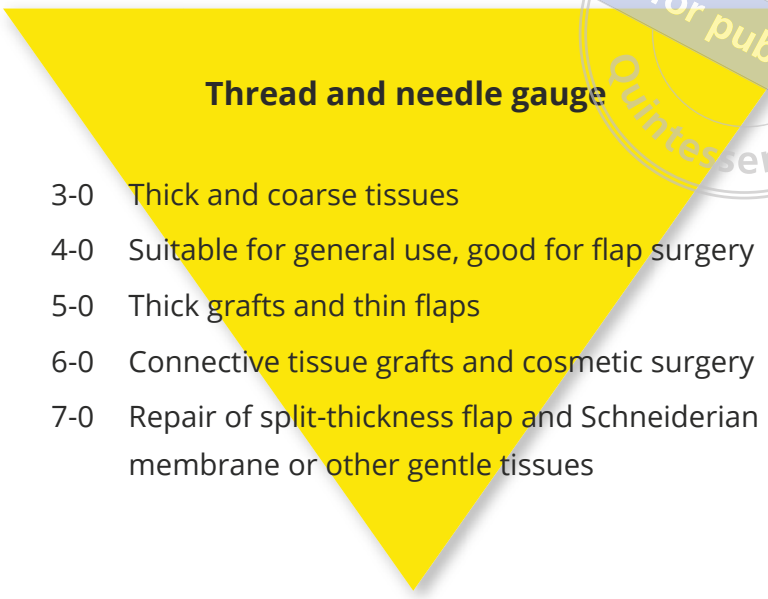

Fig 2-1 Diagram summarizing the correct thread and needle gauge for specific tissues. The principles to bear in mind are: 1) If something is going to break, it should be the thread rather than the tissues; and 2) Thin thread should be selected for thinner tissues, and thicker thread for thicker tissues.

Table 2-1 The diameter of suture thread is stated numerically in accordance with the United States Pharmacopeia (USP) and European Pharmacopeia (EP)

USP	EP	Suture thickness [mm]
12–0	0.01	0.001–0.009
11–0	0.1	0.010–0.019
10–0	0.2	0.020–0.029
9–0	0.3	0.030–0.039
8–0	0.4	0.040–0.049
7–0	0.5	0.050–0.069
6–0	0.7	0.070–0.099
5–0	1	0.10–0.149
4–0	1.5	0.15–0.199
3–0	2	0.20–0.249
2–0	2.5	0.25–0.299
	3	0.30–0.349
0	3.5	0.35–0.399
1	4	0.40–0.499
2	5	0.50–0.599
3+4	6	0.60–0.699
5	7	0.70–0.799
6	8	0.80–0.899
7	9	0.90–0.999
8	10	1.00–1.099
9	11	1.10–1.199
10	12	1.2–1.299

ments such as suture holders and scissors should be chosen accordingly.

Physical structure

The structure of suture thread depends on the number of strands used in its production. Suture threads may be of a monofilament or multifilament structure. Monofilament threads comprise a single strand and feature a hostile environment for microorganisms, since they have a smooth surface with no retention areas. Their drawbacks are low knot-holding security and shape memory. Multifilament threads are made by twisting or braiding multiple strands (Fig 2-2a and b), which makes them easier to use during suturing and knot tying. Their disadvantage is that they facilitate the accumulation and proliferation of microorganisms. They are therefore not suitable for use in areas subject to microbial contamination or where there is a risk of infection. Furthermore, the tissue passage properties of multifilament threads may degrade due to blood clotting on the surface

a b

Fig 2-2 (a and b) Single-strand monofilament sutures (a) have several advantages such as smooth tissue passage. On the other hand, braided sutures provide improved knot stability (b).

during prolonged suturing. This blood should be wiped off with a wet gauze patch. Suture threads may swell due to the absorption of ambient fluid, in which case their knots may become loose.

Capillarity

This property refers to the absorption and transmission of fluid by the suture thread along its entire length. Suture threads that have capillarity allow for the transmission of microorganisms between the interior and exterior of the wound, leading to contamination. Capillarity is a more evident feature in braided compared with monofilament threads. The surface of some monofilament threads is coated with wax, silicone, polytetrafluoroethylene (PTFE) or polyester to minimize the effects of this feature.

Tensile strength

This is a measurement calculated by dividing the force that stretches and breaks a suture thread by the cross-sectional area of that thread, which is directly proportional to the diameter of the thread. This coefficient gradually decreases in absorbable sutures, once the suture contacts the tissues. This decline in the tensile strength of absorbable sutures is not directly proportional to the rate of absorption and may vary depending on the suture thread material. However, tensile strength is directly proportional to the diameter of the suture thread. The weakest point of a suture is its knot. A tied suture thread is weaker than an untied one.

Tissue passage

The glide of a suture thread is directly proportional to its coefficient of friction. The coefficient of friction indicates the level of lubricity of the suture thread. It is more difficult for multifilament sutures, which have a high coefficient of friction, to pass through tissues. Multifilament sutures therefore tend to cause more tissue damage, both during suture placement and removal. A larger surface area of multifilament sutures results in blood clotting on the surface during prolonged suturing, further increasing the already high coefficient of friction. In such cases, wiping the suture with a wet gauze patch facilitates the operation.

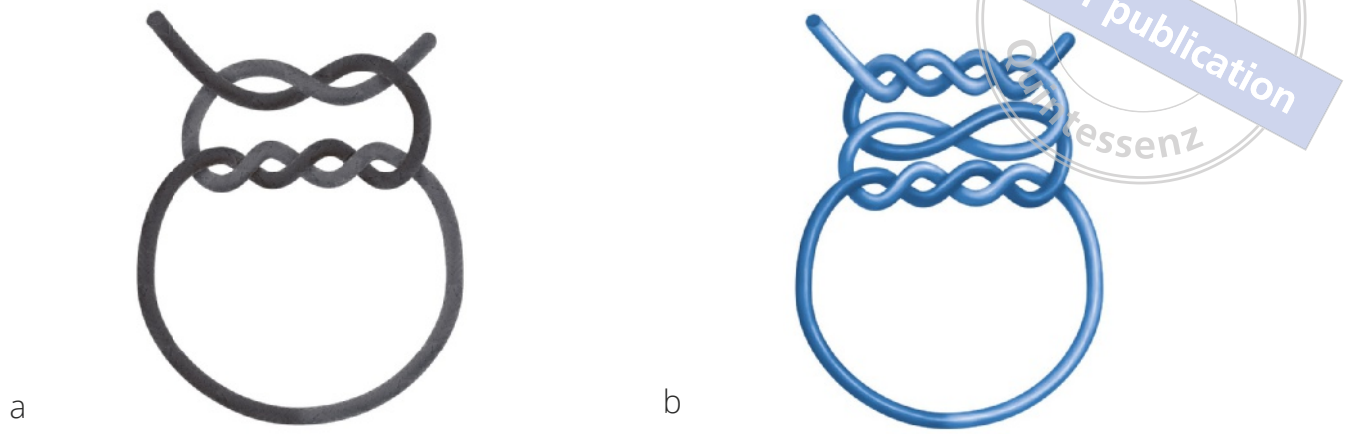

Fig 2-3 (a and b) A surgical knot using a multifilament suture thread with low shape memory should be fastened by a single twist spiral knot tied in the opposite direction on a double twist spiral knot fastened in a particular direction (a). To tighten the first knot fastened with a monofilament thread with high shape memory that tends to loosen, a single twist spiral knot tied in the same direction with the first knot should be made with a view to recovering the loosened part of the double spiral twist knot prior to locking. A final reverse knot should be made to lock the knot (b).

Knot-holding security

This depends on the pliability and shape memory of suture threads. It is easier to fasten a knot with threads that are easily pliable and have a low shape memory. Knot-holding security is the resistance of the knot against forces leading it to slip, either in part or entirely. The knot-holding security of monofilament sutures is low, resulting in the knot loosening more easily after it is locked. There are two ways to avoid this loosening in a monofilament thread: 1) Ensure that the knots rest on the soft tissue instead of being suspended between the wound margins; and 2) Tighten the first knot with an additional knot tied in the same direction as the first knot (Fig 2-3a and b). Typically, this additional tightening is highly restricted and can only recover a part of the loosening. Making the knot overtight does not improve knot security; instead, it endangers blood circulation.

Elasticity

This property refers to the ability of suture thread to regain its original form and length following the pulling force applied during the operation. Sutures with high elasticity can resume their original size following deflation of postoperative edema, keeping wound edges intact without being separated. Most non-absorbable sutures exhibit this property.

Shape memory

This refers to the tendency of suture thread to resume its original form following the deformation occurring after a knot is tied. High-memory sutures are more durable in maintaining their shape; they preserve their original packaged form and offer less knot-holding security. In particular, monofilament sutures have high shape memory. Another characteristic of these sutures is that their ears irritate adjacent tissues when cut short. To avoid this problem, it is recommended to retain longer

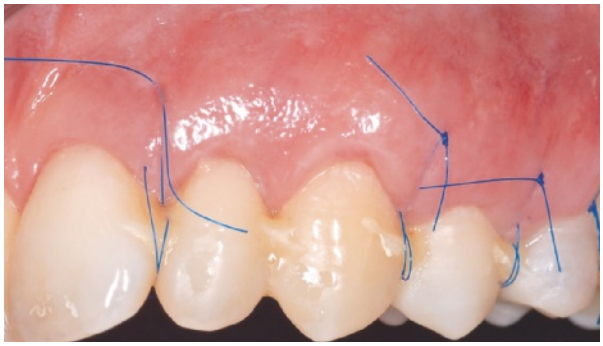

Fig 2-4 Since they preserve their plasticity, high-memory sutures tend to irritate the surrounding tissues. Damage to these tissues can be avoided by leaving the ears long, as shown in the photograph.

ears in suture threads with high shape memory (Fig 2-4).

In conclusion, no individual suture thread is ideal for all circumstances. For instance, a suture thread to be used after hard tissue augmentation should have a smooth tissue passage and low capillarity with minimal tissue reactivity. In such as case, a monofilament thread would be indicated. However, such properties would be entirely useless for a suture to be placed for bleeding control, where the main property required is knot-holding security.

ABSORPTION CHARACTERISTICS OF SUTURE THREADS

Suture threads are typically classified into two main groups depending on their material of manufacture, namely absorbable suture threads that can be totally dissolved by the tissues and non-absorbable suture threads that cannot be absorbed at all.

Absorbable sutures usually lose their tensile strength within 60 days, whereas non-absorbable sutures endure for a longer period of time. Both groups have monofilament, multifilament, natural, and synthetic types.

All threads may cause inflammation and a wide range of other tissue reactions of varying degrees. Inflammation reduces the resistance of the body against infections, delaying the healing process. Non-absorbable sutures may lead to negligible tissue reactivity. Tissue reactivity caused by absorbable sutures is associated with the absorption mechanism of the material. Natural materials dissolved by enzymes in which proteins are absorbed through proteolysis are more often associated with inflammatory reactions, whereas synthetic products absorbed through hydrolysis result in less tissue reactivity.

Although tissue response to suture threads is an important issue, it is not long lasting. Ultimately, the method of wound closure is the key factor, i.e. whether the wound is healed with primary intention or not is of the utmost importance (Fig 2-5a to c).

ABSORBABLE SUTURE THREADS

Suture materials are absorbed by tissues through two different mechanisms: The first is enzymatic degradation or enzymolysis, which is the metabolization of suture material through the inflammatory response of the tissues. The second is hydrolyzation, which is the dissolution and cleavage of the polymer chains of the suture by the addition of water. Naturally, hydrolyzation does not lead to tissue inflammation. Catgut sutures manufactured from the intestines of ruminants are dissolved through enzymatic absorption, whereas all synthetic sutures are dissolved through hydrolysis. Al-

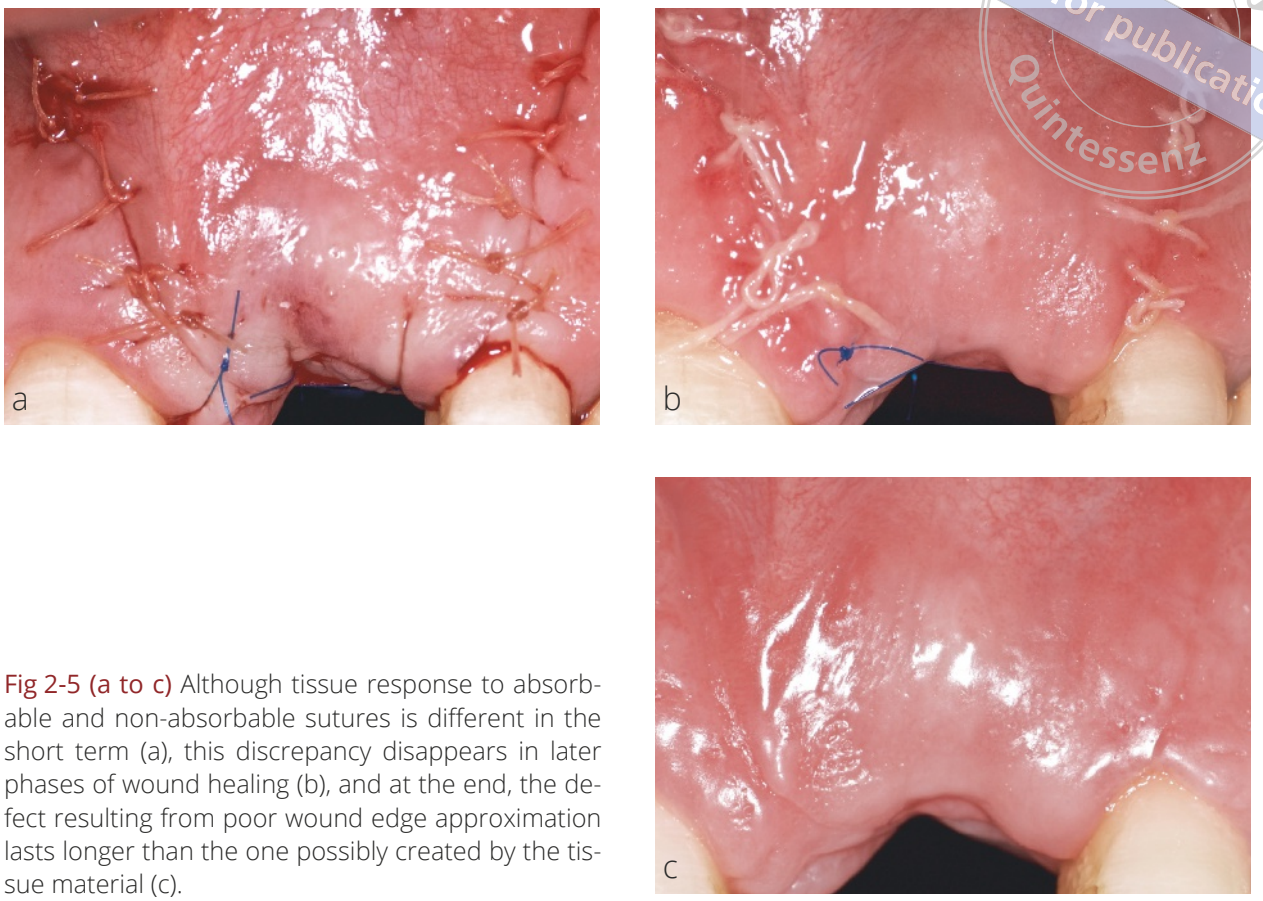

Fig 2-5 (a to c) Although tissue response to absorbable and non-absorbable sutures is different in the short term (a), this discrepancy disappears in later phases of wound healing (b), and at the end, the defect resulting from poor wound edge approximation lasts longer than the one possibly created by the tissue material (c).

though some tissue reactivity results from the hydrolyzation of suture threads, it is negligible compared with enzymolysis.

Although the use of absorbable threads was initially limited to sutures that are impossible or difficult to remove, they are currently used in a wider range of procedures and applications. In recent years, they have been used for patients traveling long distances in order to eliminate the need for a second visit, to minimize the risk of contagious diseases, and to avoid undue patient stress in cases requiring anesthesia for suture removal or in pediatric cases. However, in general, non-absorbable suture threads should be the first choice when suture removal does not constitute a problem technically, medically or socially, since the prolonged absorption process may cause the suture to stay in its place, leading to excessive microorganism accumulation.

Absorption of suture threads results in a reduction of their tensile strength. Half-life is the term for the period of time in which a thread loses half of its tensile strength. It is one of the main criteria for the evaluation of absorption. Dissolution, on the other hand, is the period required for complete destruction of the thread. There are numerous variable factors affecting the duration of these periods, including but not limited to thickness of the suture thread, tissue type (i.e. catabolic processes work slower in some tissues), pH of the conditions (i.e. absorbable sutures are hydrolyzed faster in an alkaline environment), the circumstances of the environment in which the thread is used (i.e. temperature,

infection, etc), and the overall health of the patient (i.e. the presence of diseases complicating wound healing). Although the rate of absorption is important for many complications resulting from suture threads, the rate of loss of tensile strength is also critical as a guarantee for keeping the wound closed during healing. Consequently, absorbable suture threads should be chosen based on the rate or time of absorption and the rate or time of loss of tensile strength. Therefore, in addition to their physical properties, the half-life of absorbable suture threads should also be considered.

Absorbable natural suture threads

Catgut was the first suture material to be used that could be absorbed by tissues. Catgut threads are obtained from the intestinal collagen of sheep or cattle. Some manufacturers package these products in an alcohol solution to retain their flexibility and prevent desiccation and breakage. Three different types of catgut are currently available on the market, namely plain, chromic, and fast-absorbing, all of which are monofilament. Plain catgut causes a certain level of reaction in tissues and can maintain its full tensile strength for 7 to 10 days following surgery. It is completely absorbed by the end of 70 to 90 days. Chromic catgut is treated with a chromium salt solution to reduce the rate of absorption and tissue reactivity and to improve tissue passage properties. This type of catgut maintains its tensile strength for 10 to 21 days and is completely absorbed by the end of 90 days. Fast-absorbing catgut is heat treated for faster absorption and can maintain its tensile strength for only 5 to 7 days. It is completely absorbed within 2 to 4 weeks. However, in accordance with EU regulations, this type of catgut is no longer manufactured or used in Europe.

Absorbable synthetic suture threads

Polyglycolic acid

This was the first synthetic, absorbable suture thread to be manufactured. Monofilament and uncoated variations of this thread have a high tensile strength of up to 60% on day 7, 35% on day 14, and 15% on day 28. This thread is completely hydrolyzed within 90 to 120 days. It is easy to use, with a high knot-holding security. However, its multifilament structure with insufficient tissue passage properties may cause tissue damage. Although it is not associated much with tissue reactivity, its multifilament structure promotes microorganism accumulation. There is also a version of this thread that is coated with polyacrylate to improve tissue passage and reduce microorganism retention. However, an additional knot is required to improve knot-holding security.

Polyglactin

Polyglactin was the second synthetic absorbable suture to become available. It is a coated, braided, multifilament suture like polyglycolic acid. This thread is manufactured from glycolic acid (90%) and lactic acid (10%), both natural materials that can be metabolized easily. A combination of lactide and glycolide forms a molecular structure, maintaining the tensile strength to approximate tissues safely in the critical phases of wound healing. The thread can be dissolved through hydrolysis in a similar way to all other absorbable syn-

thetic threads. The hydrophobic properties of lactide prevent fluid from infiltrating into the fibers of the thread. This reduces loss of tensile strength in the biologic environment compared with natural absorbable threads subjected to enzymatic absorption. The thread is able to maintain 65% of its tensile strength by the end of 2 weeks and 40% by the end of 3 weeks. It is completely absorbed by the end of 60 days.

Poliglecaprone

Poliglecaprone is a monofilament absorbable suture material made of glycolide and epsilon caprolactone copolymer. This thread features superior pliability for easy handling and tying. It is one of the durable absorbable suture materials currently available, allowing for the selection of suture sizes that are one to two times smaller than would ordinarily be chosen. It is usually preferred for procedures requiring high initial tensile strength, since its tensile strength tends to decrease 2 weeks after surgery. Dyed versions retain 55% and undyed versions retain 45% of their tensile strength by the end of the first week postsurgery. Both versions are completely absorbed within 90 to 120 days.

Polydioxanone

Polydioxanone is a synthetic, absorbable, monofilament suture thread that is preferred in procedures where sutures need to remain in place for a prolonged period. It is absorbed very slowly through hydrolysis. On the one hand, the thread facilitates tissue passage with its smooth structure, but on the other hand it has the poorest knot security of all the synthetic absorbable sutures. It retains 70% of its tensile strength by the end of 2 weeks, 50% by the end of 4 weeks, and 14% by the end of 8 weeks. This retention of strength after implantation is an advantage compared with other synthetic absorbable sutures and is useful wherever extended approximation of tissues under tension is required. Absorption and hydrolysis processes would be halfway complete by the end of 90 days following the day of application and would be complete within 6 months.

NON-ABSORBABLE SUTURE THREADS

These threads do not undergo structural changes and mostly retain their original properties. Therefore, they are used only in situations where it is possible to remove them. Natural materials include stainless steel wire, silk, cotton, and linen. Non-absorbable synthetic threads, on the other hand, are made of polyamide, polypropylene, and polyester. They are used in cases where prolonged support is required for wound edges.

Non-absorbable natural suture threads

Silk

This is a multifilament thread made of protein fibers from silkworm larvae. Although it is typically considered to be a non-absorbable thread, it is metabolized in just over 2 years. It is recognized as the gold standard thanks to its superior handling qualities and high knot-holding security. It also has high capillarity. In addition, silicone or wax-coated versions are available to suppress its capillarity property. It was originally manufactured in white

but has subsequently been made available in vivid colors to increase its visibility. The suture ears do not irritate the tissues because their shape memory is almost nonexistent. They have a high coefficient of friction due to their multifilament structure and thus may cause tissue damage when passing through the surrounding tissues.

Non-absorbable synthetic suture threads

Polyamide

Polyamide fiber, usually referred to as nylon, was the first synthetic fiber ever manufactured. There are two types available on the market, namely monofilament and multifilament. The monofilament type is the most commonly used non-absorbable nylon surgical suture thread due to its widely recognized high tensile strength and excellent elasticity. It also causes minimum tissue reactivity. The main disadvantage of this type of thread is its high memory, which requires a knot with an additional three or four loops to avoid the suture untangling. Some versions are soaked in an alcohol solution prior to packaging to reduce their memory and facilitate handling. Regarding multifilament types, there is a risk of them hosting more microorganisms due to their retentive surface structure, although they also feature good pliability for easy handling. Another disadvantage is that their capillarity is higher than monofilament types, and for this reason they are often coated in silicone.

Polypropylene

This is a monofilament suture thread that is difficult to handle, with a shape memory that is even higher than that of polyamide. In addition, the knot-holding security of this type of thread is very low, and the first knot often tends to loosen. Although it is possible to tighten the first knot with a second one in the same direction, it should be borne in mind that the benefit of this measure is very limited (see Fig 2-3). This thread is capable of maintaining its durability for years in a biologic environment without being degraded by tissue enzymes. It features a very slippery surface that does not adhere to tissues. It is a user-friendly thread with good tissue passage and does not invoke tissue reaction thanks to its chemical structure. As there is a very high possibility for suture ears to injure surrounding tissues if they are cut short, they should be cut long enough so that they rest freely on the tissues.

Polyester

This is a braided, multifilament, synthetic, non-absorbable suture thread. It has a high tensile strength and it is easy to handle. It has a low knot-holding security and tissue reactivity. Coated versions are available for improved tissue passage. The soft, pliable nature of polyester suture thread makes it suitable for suturing mucosal tissue or for use in intertrigginous areas.

Polybutester

This non-absorbable, monofilament, synthetic suture thread is relatively new on the market. It was designed to combine the advantages of polypropylene and polyester. It also offers better handling than polypropylene, including lower memory, increased flexibility, and better knot security. Due to its unique elasticity, it re-

sponds well to edematous tissue and has very good tissue passage. Polybutester appears to be stronger than other monofilaments and does not have significant memory. Unlike nylon and polypropylene, polybutester does not maintain its packaging shape.

Polytetrafluoroethylene (PTFE)

PTFEs are synthetic, monofilament, non-absorbable sutures that are soft, biocompatible, and chemically inactive. PTFE is obviously more practical for intraoral applications than other monofilament sutures. Its prominent characteristics include durability, excellent tissue passage, high biocompatibility, low bacterial retention, and low memory (despite its monofilament structure). However, as it has low knot-holding security, it is advisable to make additional knots to lock it on both sides, since the possibility of knots loosening is very high if they are fastened under tension. Due to its porous structure, bacterial attachment would increase in cases where the sutures need to remain in the mouth for a long period of time.

Polyvinylidene fluoride

Polyvinylidene fluoride is a synthetic, non-absorbable, monofilament thread material. In recent years, polypropylene sutures have been associated in some clinical reports with suture failure. Polyvinylidene fluoride threads, in comparison, feature a smaller suture diameter, a greater knot pull strength, and less delayed extension when under creep testing. They are also more resistant to needle holder trauma than polypropylene threads.

Antibiotic-coated sutures are also available on the market although their use is controversial. Absorbable and non-absorbable suture materials have their advantages and disadvantages. When choosing suture materials, surgeons need to consider all these characteristic features and make a decision according to the needs of each individual case, based on their experience and knowledge.

SUTURE NEEDLES

Surgical suture needles are designed to carry suture threads through tissues with minimal damage to the tissues. They are therefore manufactured from high-grade stainless steel in various thicknesses compatible with the available suture threads. Surgical suture needles need to be durable and offer excellent physical strength and flexibility so that they do not break. The eye of the needle should not damage the tissues and, most importantly, the point should pierce the tissues flawlessly.

Needle anatomy

The area where the surgical suture needle is attached to the thread is called the swage end or the eye, the curved section between the eye and the point is called the body, and the section piercing the tissues is called the point in all surgical suture needles, regardless of their purpose of use (Fig 2-6).

Eye

This is the part of the needle formed into a loop for pulling the thread. It is categorized into three groups, namely closed eye, French eye, and swage end, with the last being the

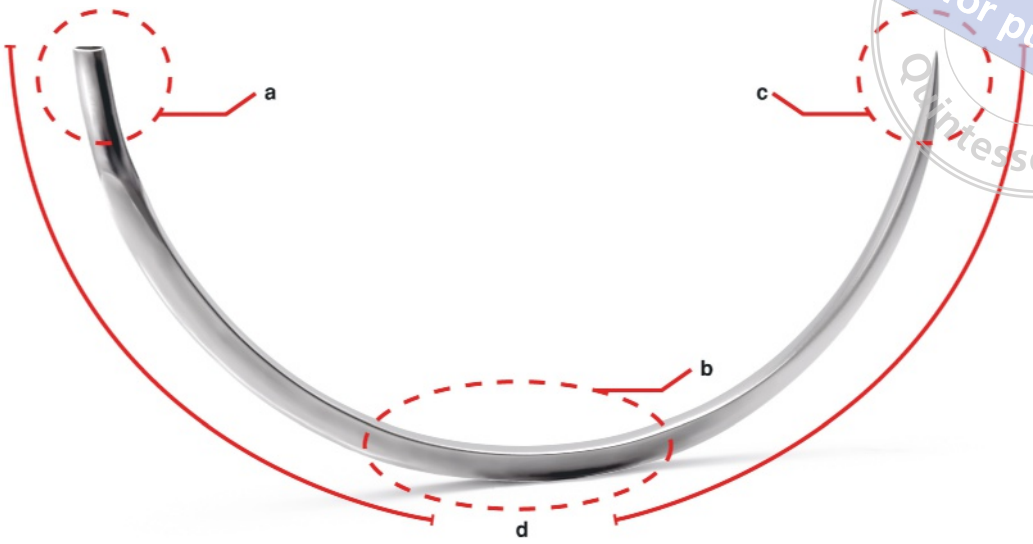

Fig 2-6 A suture needle comprises three main components: the eye [a], body [b], and point [c]. Needle length [d] is the distance between the eye and point.

a b

Fig 2-7 (a and b) Examples of swage end needles, currently the most common type used in dentistry. The eye is the part of the needle formed into a loop for pulling the thread. The eye is the weakest point of the needle and should never be grasped with a needle holder.

most commonly used today (Fig 2-7a and b). The eye is the weakest point of the needle and should never be grasped with a needle holder.

Closed eye needles resemble domestic sewing needles. The shape of the eye may be round, oval or square. Threading closed or French eye needles is a meticulous and time-consuming task. French eye needles have a slit at their rear end to facilitate this task. Another problem with closed eye and French eye needles is that a larger hole is forced in the tissues when inserting a double suture thread through it, leading to more severe tissue trauma (Fig 2-8a to c). In addition, the thread may slip out of the eye, further prolonging the operation time. These needles become blunt after repeated usage, making it difficult to pass them through the tissues. Currently, almost all surgical needles are of the swage end type.

In swage end needles, the thread is inserted in the slot at the rear end of the needle. Tissue passage is less traumatic with this type of needle, since the diameter of the needle and the swage end is compatible with that of the thread. Closed eye or French needles, on the other hand, cause a wound surface larger than the diameter of the needle each time they pass through the tissues with the suture thread (Fig 2-9).

Body

The body is the section of the needle between the end and the point. The body is the part

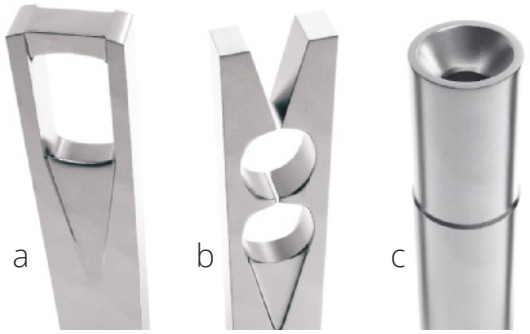

Fig 2-8 (a to c) Threading through a closed eye (a) or French eye (b) needle is a time-consuming task because the diameter of these needles is not compatible with the thread, since the thread thickness eventually doubles as it goes through the eye. Swage end needles (c) have become widely used because this problem is eliminated.

Fig 2-9 Since the diameter of the needle and that of the attached thread are not compatible, the surface of the wound caused on the tissues by each passage of this type of needle is larger than that caused by a swage end needle.

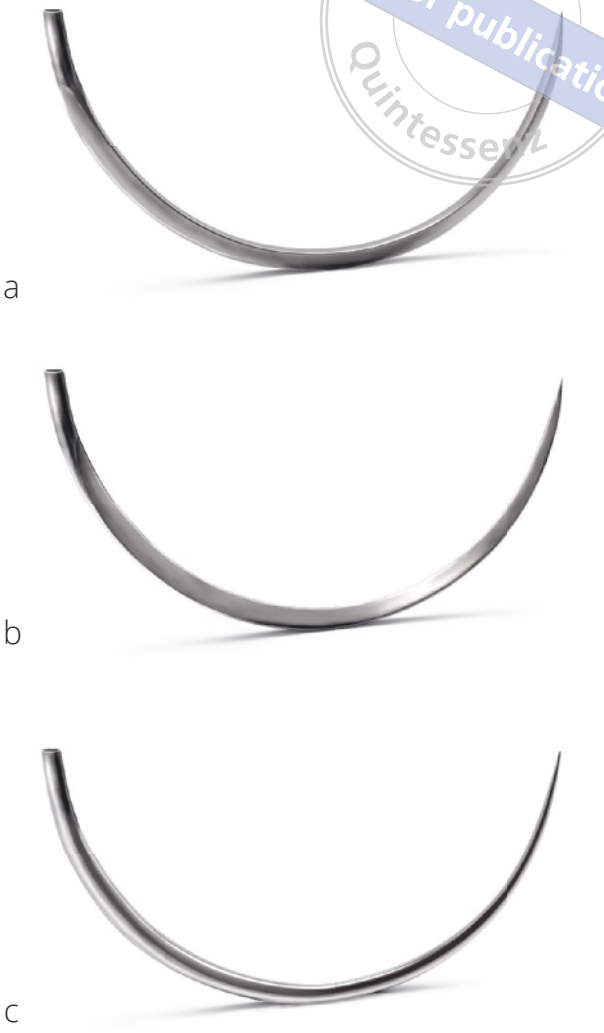

Fig 2-10 (a to c) Needles are classified based on the cross-section of their bodies, namely cutting, round or spatula. A cutting needle, the cross-section of which is triangular, is referred to as a reverse cutting needle (a) when the apex of the triangle faces the exterior of the curvature of the body. The possibility of rupture of the tissues by the thread is lower in sutures placed using this type of needle. If the apex of the triangle faces the interior of the curvature of the body, the needle is referred to as a cutting needle (b). These types of needles may damage the tissues through which they pass during suturing. Needles with a round cross-section (c) are difficult to grasp with a suture holder and can twist inside the tissues.

that is grasped by the needle holder during the operation. There are various shapes of needle bodies (e.g. triangular or round), each one serving a particular purpose. The needle body should be able to maintain its shape throughout the procedure and not deform when grasped by the needle holder.

Needles are classified based on the cross-sections of their bodies: conventional cutting, round, or spatula (any form with more than three corners). Cutting needles have a triangular cross-section and are the most common type used in dentistry. They are referred to as reverse cutting needles when the base of the triangle faces the interior of the curvature of the body (Fig 2-10). Although surgical suture

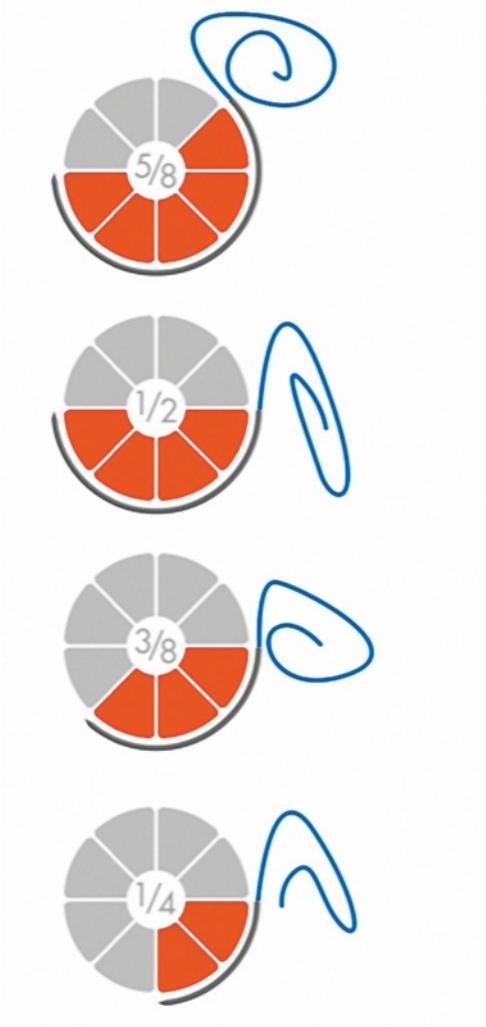

Fig 2-11 Needle curvatures are identified by the ratio of their arc to a full circle. Needles with a 1/2 and 3/8 circle are most commonly used in dentistry.

needles are available with both straight and curved bodies, needles with curved bodies are most commonly used in dentistry. The curvatures of needles with curved bodies are identified by the ratio of their arc to a full circle, i.e. the arc of a 1/2 circle needle is exactly half of a full circle. This type of needle is mostly used when the distance between the insertion and exit points is expected to be short. On the other hand, 3/8 circle needles are mostly preferred for interproximal sutures due to their relatively open curvatures. In addition to 1/2 and 3/8 circle needles that are most commonly used in dentistry, 1/8 and 5/8 circle needles are also available for use on the skin (Fig 2-11).

The entire needle structure comprising the eye, body, and point constitutes the needle length. The choice of needle length depends on the distance between the tissue layers through which the needle is going to pass, where in the oral cavity the needle will need to reach for the particular procedure, and the experience of the surgeon. Usually, needles with a length of 10 to 22 mm are used in dentistry (Fig 2-12).

Point

Sharp needle points that can easily penetrate through tissues are most often used in dentistry. The cross-section of triangular needles becomes thinner toward the point (Fig 2-13a and b). Sharp-pointed needles

Fig 2-12 The choice of needle length depends on the purpose of the surgery, tissue thickness, and access to the surgical site.

Fig 2-13 (a to c) Both needles have sharp points so that they cause minimal tissue damage. The passage created by a conventional cutting needle (a) is more prone to rupture by thread tension than that of a reverse cutting needle (b), which is more resistant to damage caused by threads. The cross-sections of round needles (c) also narrow down toward the point. Although the passage these needles create through the tissues is not prone to rupture, they can easily twist inside the tissues, hindering the operation.

pierce and penetrate through the tissues. Needles with round or tapered cross-sections become thinner and sharper toward the point. These types of needles are mostly used for nonfibrotic tissue to avoid neurovascular damage (Fig 2-13c). Blunt needles, on the other hand, are used to advance between the layers without penetrating into the tissues, although their use is limited in dentistry.

The choice of needles in dentistry is based on their curvature and cross-section. Sharp-pointed needles are suitable for all oral surgery operations. It is advisable to use a 3/8 circle needle for suturing interdentally and a 1/2 circle needle when fixing the opposing

mucosal margins. All needles should preferably be of the reverse cutting type.

HAND INSTRUMENTS

Needle holders

Needle holders are used to grasp surgical suture needles in order to guide them through the tissues. Their main purpose is to immobilize the needle they grasp and to ensure that it does not slip. Currently, needle holders are commercially available with short, straight, concave, convex, serrated or non-serrated jaws. The teeth added to the non-serrated jaws for an increased grip often damage or break suture threads. Needle holders with serrated jaws are therefore more convenient for use (Fig 2-14a to c).

Although many types of needle holders are currently available on the market, they are classified into three main groups depending on how they are handled. There are a variety of needle holders with finger-ring handles (sometimes incorrectly referred to as hemostatic clamps) such as Mayo-Hegar, Crile-Wood, Webster, and Collier (Fig 2-15a to d). As with most other surgical hand instruments, needle holders are named after the surgeon who designed them. Since hemostatic clamps are specially designed to grasp the

Fig 2-14 (a to c) It is advisable to use needle holders with non-serrated jaws when using thin suture threads to avoid damage to the thread structure (a). Serrated jaws may damage the structure of 3-0 or thicker threads, but would not cause them to break (b). Tungsten-carbide coating of the jaws and joint prevents corrosion on the beak of the needle holder caused by prolonged usage (c).

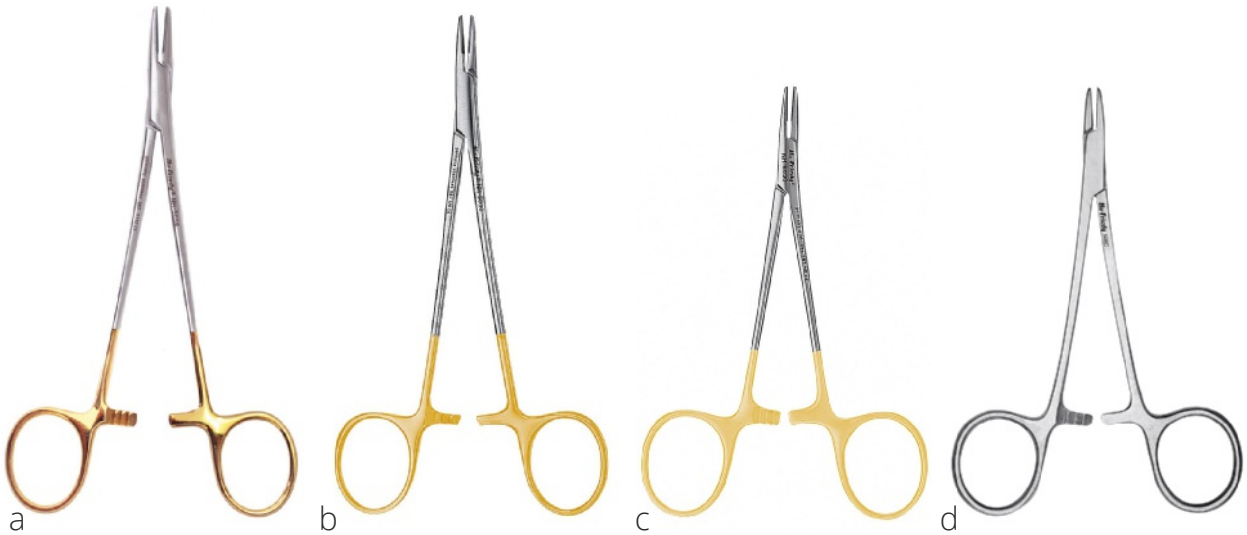

Fig 2-15 (a to d) Needle holders with finger-ring handles are available in varieties such as Mayo-Hegar (a), Crile-Wood (b), Webster (c), and Collier (d). Although their handles are all the same, their jaws differ depending on the suture thread and needle to be used.

Fig 2-16 The tooth structure of hemostatic clamps is more aggressive than that of needle holders. This allows hemostatic clamps to stop the bleeding completely through the pressure applied until the relevant blood vessel has been tied off. However, it should always be borne in mind that this surface specification may damage the suture threads.

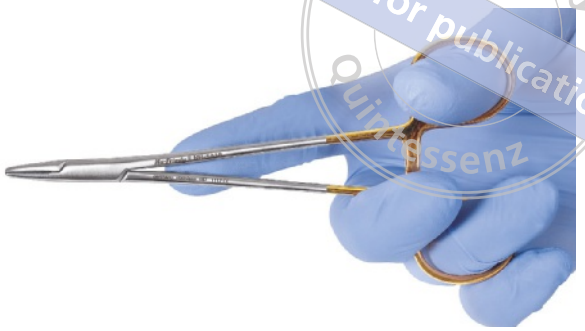

Fig 2-17 The needle holder is held in balance between the thumb and ring finger and guided with precision by the index finger. In this way, minimal pressure is applied on the needle to avoid the twisting of the needle due to the resistance it encounters when passing through the tissues.

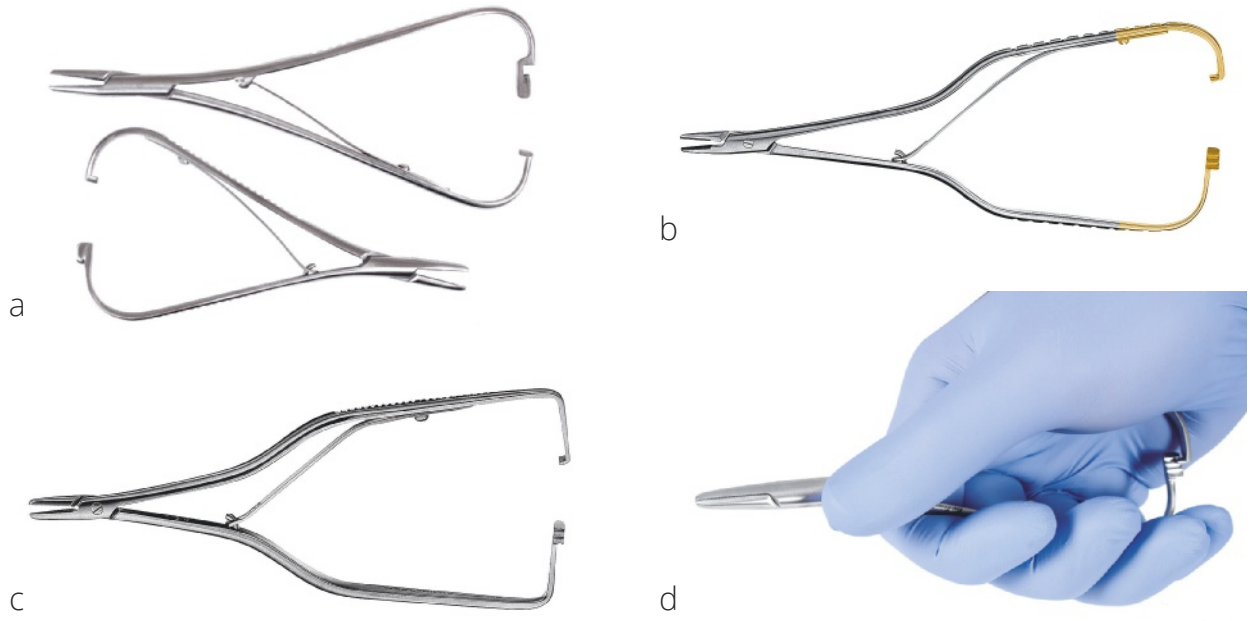

Fig 2-18 (a to d) Mathieu (a), Arruga (b), and Boynton (c) are the most commonly used palm grip needle holders, with Mathieu being the most popular among them. Mathieu needle holders require the exertion of force when used in high-precision operations, causing the hand to lose its balance (d).

tip of blood vessels to stop bleeding, particularly at hemorrhagic sites, their grasping jaws are considerably different to those of needle holders (Fig 2-16). Needle holders are held with the thumb and the ring finger and are supported by the index finger (Fig 2-17).

Another type of needle holder, called the Mathieu, Arruga or Boynton, is designed to be held in a palm grip (Fig 2-18a to d). Castroviejo needle holders are held in a pen grip as opposed to a palm grip (Fig 2-19a and b). In principle, needle holders with finger-ring handles and those held in a palm grip are more convenient for thick suture needles and for relatively low-precision operations, whereas those held in a pen grip are more practical when working with 5-0 or thinner threads or when performing high-precision operations.

a

b

Fig 2-19 (a and b) Castroviejo needle holders are more suitable for high-precision procedures when working with smaller/thinner needles as they can be held in a pen grip (a), allowing the surgeon to gain support from the stationary tissues (b).

The size of the needle holder to be used should be appropriate for the size and diameter of the needle. A very small surgical suture needle should be handled with a needle holder supporting a thin, small, and delicate working site. Larger surgical suture needles should be grasped using heavier needle holders supporting relatively less-delicate sites. The size of the hand tool to be used should be compatible with the position of the surgical site.

How to use needle holders

1. The needle should be held 1/3 or 1/2 of the way down the body shaft from the end. The needle should not be held on or around the swaged end (the point where the thread is attached to the needle), since this is the weakest point of a surgical suture needle (Fig 2-20).
2. Excessive pressure applied by the jaws of the needle holder may cause permanent deformation of the needle. When using a locking needle holder, it is sufficient only to lock it. If the needle is not grasped well after the hand tool is locked, it means that the needle holder is either worn out or is not suitable for the needle size being grasped.

Ensure prior to use that the jaw of the needle holder operates freely and locks properly. Always use a needle holder to remove a needle from tissue. Using a hemostatic clamp or any other forceps will damage the needle.

Scissors

Scissors are mostly used for trimming tissues, dissecting tissue layers, and removing sutures. Any type of scissors can be used to remove sutures (Fig 2-21a to e).

Scissors are usually held between the thumb and ring finger. The index finger should rest on the joint of the scissors (Fig 2-22).

Fig 2-20 Ideally, the needle should be grasped by the needle holder exactly in the middle. If it is necessary during the procedure to go back, the surgeon should travel up the body shaft of the needle only a third of the way. If one goes beyond this point, however, there is the risk of squeezing the swage end and dislodging the thread. Therefore, the needle should never be held on or around the swage end, nor should it be held at the front end near the point because this commonly causes bending, breakage or blunting of the needle tip.

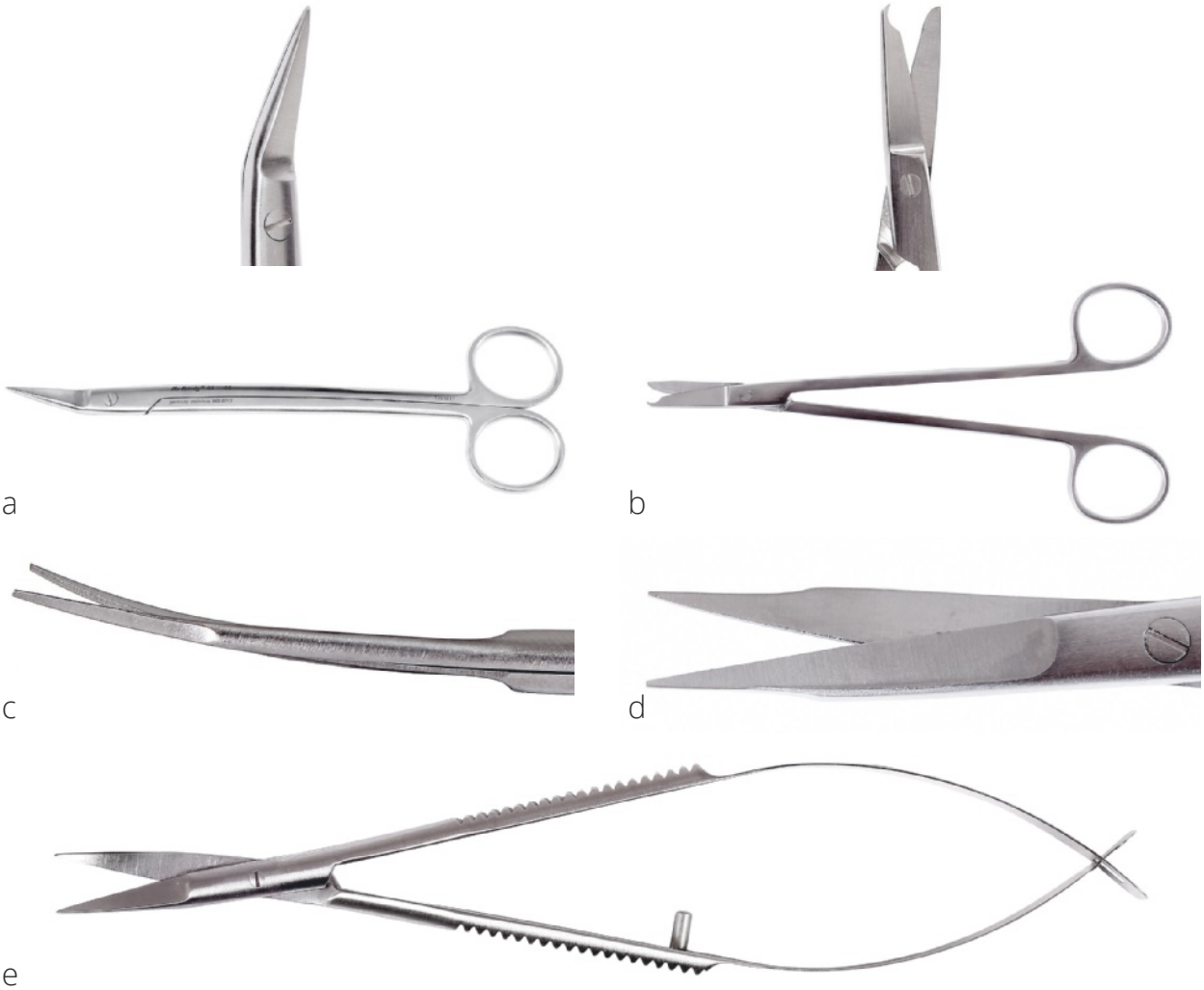

Fig 2-21 (a to e) The jaws of scissors designed for suture removal join their body at an angle (Dean scissors) (a). This angle facilitates the removal of knots from the mesial or distal area of the teeth. The tips may be blunt to prevent tissue damage or custom-designed to separate an impacted thread from the surrounding tissues when healing (b). Curved tissue scissors prevent damage to neighboring tissues during suture removal (c). However, scissors designed for trimming tissues and dissecting layers are extremely sharp and pointed (d). Scissors suitable for removing smaller-diameter suture threads are also available (e).

Fig 2-22 It is possible to prevent tremor while using scissors to cut the suture thread at the desired point by using the index finger to lightly support the joint of the instrument.

Tissue forceps

Tissue forceps are mostly used in surgical procedures for grasping tissues. They may also be used to retract and stabilize tissues for observation purposes or to secure tissues during suturing. Surgical tissue forceps are available with or without teeth in a variety of shapes and sizes for use in a wide range of surgical sites. Although tissue forceps without teeth cause less damage to the tissues they grasp, the tissues may easily slip due to their insufficient grasp. These hand instruments are available with a variety of tips at different angles, depending on the purpose and area of use (Fig 2-23).

The advantage of tissue forceps with teeth is that they can grasp the tissues firmly with less pressure being exerted. However, the teeth of these forceps may damage the tissues being grasped if too much pressure is exerted (Fig 2-24).

High-precision tissue forceps are also available. These forceps are specially designed to engage a suture needle through the tissues exactly at the targeted point (Fig 2-25a and b).

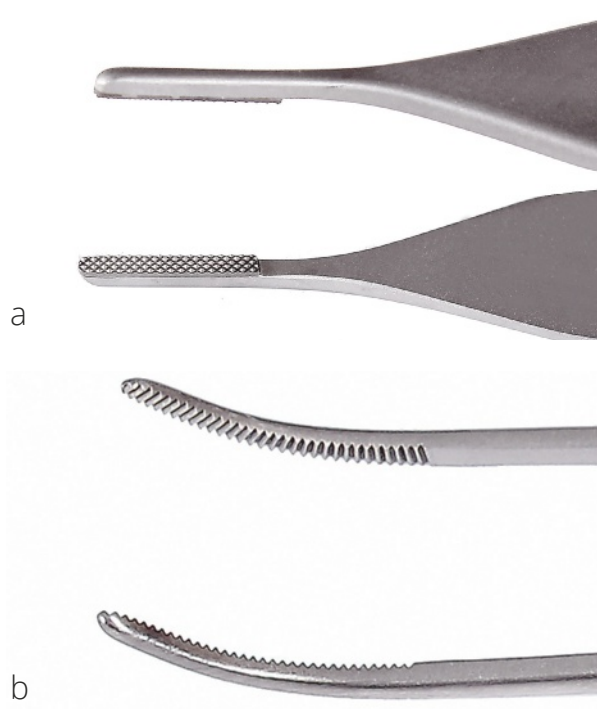

Fig 2-23 (a and b) Tissue forceps are used to support the tissues when passing a suture through them. They are available in straight (a) and curved (b) types. The tips of these forceps are serrated to grasp the tissues easily without allowing them to slip.

Fig 2-24 Tissue forceps with teeth incorporate a variety of grip configurations to easily grasp the tissues. Although they are capable of doing this without allowing the tissues to slip, they may cause damage to tissues with a thin phenotype.

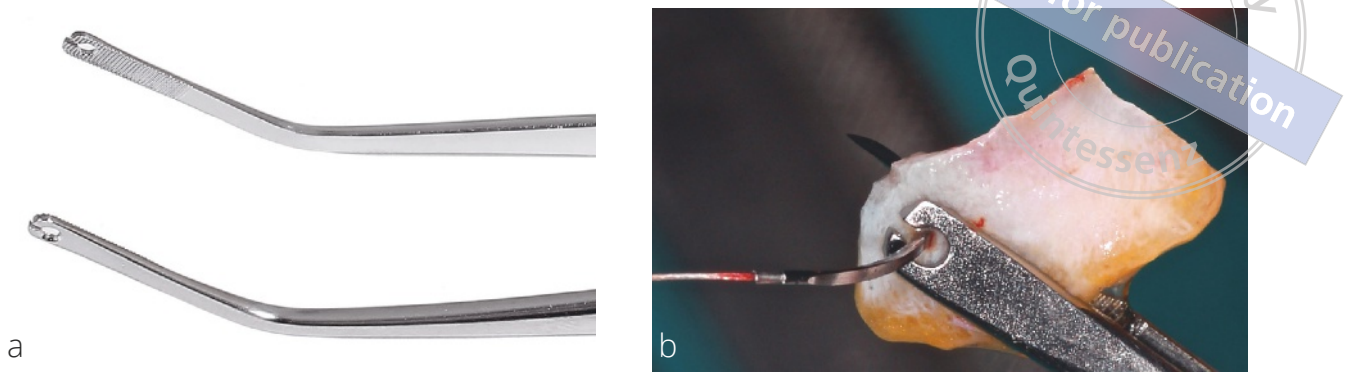

Fig 2-25 (a and b) Using tissue forceps with a guiding hole at the very end would facilitate placing sutures exactly at the desired position (a). Inserting the needle through the holes on both shafts of these forceps, which are aligned to each other, would facilitate suturing, particularly when handling soft tissue (b).

TISSUE ADHESIVES

With mechanical measures such as sutures and staples readily available on the market, tissue adhesives have been very much overlooked in the past. However, with technological advancement and improvements in adhesive materials, this situation has changed rapidly in recent years. The use of adhesives in wound closure has increased due to their ability to shorten wound closure time in cosmetic and reconstructive procedures, to widen the point of pull and thus reduce tension at the wound margins, to displace and stabilize large flaps, to cover tissues that are left exposed, and to stabilize wounds.

Tissue adhesives should:

- be biocompatible and biodegradable, without adversely affecting wound healing;
- have high tissue adhesion and cohesion;
- be quickly and easily prepared with convenient curing time;
- be hydrophilic, allowing operation on wet surfaces at body temperature;
- have an elasticity similar to that of the tissues to be adhered;
- not release heat during curing; and
- cause minimal inflammatory response during dissolution.

Currently, no single adhesive meets all these requirements.

Fibrin adhesives

An adhesive made from a combination of thrombin and fibrinogen was first used in the early 1940s. Fibrin adhesives are primarily used for hemostasis of large areas in head and neck surgeries. Although they are very effective in hemostasis, they are relatively weak adhesives. It takes a long time to prepare fibrin tissue adhesives due to the high number of ingredients they contain. They are fully biocompatible and resoluble materials.

Collagen and protein-based adhesives

These materials are developed as two-phase adhesives, taking advantage of the cross-linkage property of connective tissue constituents. An air- and liquid-tight, protein-based adhesive is formed when colla-

gen is cross- linked to glutaraldehyde. It also forms a bond, albeit weak, with the tissues, and is thus considered to be an adhesive as well as a membrane. Nonetheless, these tissue membranes have many disadvantages, as follows:

- They may cause interspecies transmission of diseases as they are obtained from bovine serum albumins.
- They can possibly lead to hypersensitivity since they contain foreign proteins.
- Glutaraldehyde, which is used as a cross-linking agent, is a neurotoxin.
- They take a long time to be absorbed/dissolved and cause a high inflammatory response.

Cyanoacrylates

These adhesives have been used for general wound closure for many years and are increasingly being used today in the oral cavity. All cyanoacrylates operate according to the same principle, i.e. they are initially applied as monomers and quickly transform into polymers with a high molecular weight.

Although cyanoacrylates are strong, antimicrobial adhesives, they are associated with severe inflammatory response because they are hydrophobic. In addition, they cannot be biologically absorbed. Their use is limited to superficial coverage of tissues. Nonetheless, they ensure strong adhesion at the wound margin, allowing the subcutaneous tissue to heal normally. Cyanoacrylates are used to save time and to obtain flexible and waterproof wound closure. Although they are mostly used in smaller wounds, they can also effectively close larger wounds where subcutaneous sutures are required. A minor exothermic reaction occurs during hardening, although this heat is not often noticed by the patient.

Polyurethane adhesives

These adhesives incorporate many positive features, making them the preferred adhesives for biomedical use. They react with the hydroxyl and amine content of the tissues, which results in a strong superficial synthesis. They also cure quickly in aquatic environments. Recent clinical studies on tissue adhesives derived from lysine have suggested that these products may be useful in deep tissue coverage. They are biocompatible, absorbable, nontoxic materials. They increase surgical success by closing the wound very effectively in the operation site. Polyurethane adhesives yield the best result when used on smooth areas. They are highly successful in large traumatic wounds and large soft tissue flaps and are also good at reducing dead space and preventing hematoma and seroma (buildup of fluid between the tissue layers).

Recommended reading

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Although the field of dental surgery has witnessed significant changes over the past decade, perfect wound closure remains a key aspect for uneventful wound healing. *The Art of Dental Suturing* is a unique overview of the different aspects of wound closure. Written by two experts in the field, this fully illustrated clinical guide on the management of suturing is intended to impart all the information necessary to achieve successful wound closure.

In line with the current dental literature, and carefully constructed in a concise and simple way, the book is divided into three chapters. The first chapter deals with general characteristics of wound healing and provides information to dental clinicians and surgeons on the basic principles involved. The second chapter presents the instruments and materials required for all the categories of wound closure in every clinical situation. The third chapter is a complete guide to the various wound closure methods and techniques required in dental surgery. It is constructed in a step-by-step manner for clear understanding and is accompanied by carefully designed, large-format illustrations and photographs to impart the essential knowledge needed to facilitate perfect suturing.

We hope that this book will serve as a reference guide to for all those in the profession who are tasked with the crucial role of successful wound closure.

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