



Design and Ergonomics of Microsurgical Instruments

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Abstract

Instrument design in microsurgery has evolved mainly as an organic logistic response to the inherent progression in the operational demands by surgeons and their teams across different medical and dental disciplines. The understanding of the function of the human hand and the role played by its complex neuromotor framework, which fuels unparalleled motion and sensory capabilities, have been fundamental to translate the concept behind microsurgical instruments becoming natural extensions of the human body.

A well-designed microsurgical instrument ought to enable a stable grip, facilitate fine rotatory movements, provide feedback of the position of the instrument and how it is interacting with the elements of the surgical field, and minimize triggering tremors due to operational fatigue. Quality of materials utilized for crafting these instruments, along with the size, shape, and texture of the handle will ultimately determine the quality of that symbiotic relationship that exists between the hand and the instrument itself.

Understanding the intricacies of instrument design and how it interacts with the gloved hand of the microsurgeon ought to help make decisions relevant to acquisition and care of armamentarium that will ultimately facilitate the execution of tasks and enhance surgical performance when utilizing the operating microscope.

Keywords

Microsurgery · Touch Perception · Touch Ergonomics

1 Introduction

Despite the promising results of periodontal microsurgery and unlike in other specialties in dentistry, there is a slow acceptance of the surgical microscope in the periodontal community [1]. This might be explained by the fact that the novice has to overcome considerable psychomotor and perceptual problems before even learning to perform periodontal microsurgery safely. Human factors (HF), a discipline of study that deals with the human–instrument interface, is at the core of learning microsurgery and, therefore, has to be addressed when writing about microsurgical instrument design. HF is a multidisciplinary field incorporating contributions from psychology, engineering, industrial design, operations research, and others [2]. To understand the impact and the importance of instrument design on surgical performance, we have to focus on behavioral psychophysics and neurophysiology in order to explain how the use of instruments extends the internal representation of the surgeon's hand and how haptic feedback is task-specifically processed to the hand and fingertips of the surgeon. Once familiar with these aspects of HF, this knowledge helps us to improve the quality and efficiency of the microsurgical training and education.

The present chapter about design and ergonomics of microsurgical instruments is organized into four sections. The first one reviews the human hand function. It begins with describing the hand's anatomy, mechanics, and skin structure. It then examines human hand function from a neurophysiological perspective and finally, it considers manual behavioral tasks that require tactile and haptic feedback, respectively. The second section addresses ergonomics of microsurgical instruments related to instrument design and its impact on prehensile skilled movements of fingers and hands. The third section describes a basic set of innovative instruments for periodontal and periimplant microsurgery, including information about the correct use and adequate protection in the sterilization processing. Section 4 draws some conclusions about ergonomics of microsurgical instruments and offers a guideline for the proper selection of microsurgical instruments.

2 From Touch Perception to Prehensile Skilled Movements in Periodontal Microsurgery

2.1 Anatomy and Neurophysiology of the Human Hand

There is no doubt that the human hand, from a biomechanical point of view, is the most complex body part and one of the most remarkable adaptations in the history of evolution. Not surprisingly, the study of human hand function derives its historical roots from multiple sources such as anthropology, paleontology, psychology, psycholinguistics, philosophy, and neurosciences (for overview see [3]). Darwin was credited with the first formulation of the potential impact of an upright walking posture: a hand freed of the obligation to support body weight can take on other tasks. Evolutionary researchers confirm that the acquisition of new hand functions such as tool use and throwing motion required enormous changes in visual-motor and tactile-motor connections [4, 5]. Biogenetically, these are closely related to the development of primate brains and, as a consequence, to certain behavioral traits which are distinctively and exclusively human, namely: language, reason, and self-consciousness.

The human hand from an anatomical and biomechanical perspective consists of 27 single bones which are interconnected with a complicated network of ligaments and tendons. This mechanical masterpiece is operated by the muscles of the forearm and the 29 muscles of the hand itself [6]. In total, the human hand, including the wrist, has 27 degrees of freedom of movement. If we had to count the number of possible hand positions and just take the two end and one middle position of each degree of freedom, we would get the enormous number of 3^{27} positions (a 7 followed by twelve 0). Compared to the average duration of a human life of approximately 3 billions of seconds, it is obvious that we can just use a small fraction of all possible hand positions. Based on the principle of economics, it makes sense to unite degrees of freedom of movements to frequently applicable motion synergies.

The muscles and skin of the hand are innervated by the radial, median, and ulnar nerves but the pattern of sensory and motor innervation does vary considerably

across individuals. From the perspective of the functional use of the hand, the median nerve is the most important in that it conveys information from a large area of skin on the palmar surface of the hand and innervates the intrinsic muscles controlling the thumb (for overview see [7]). From all the five fingers of each hand, the thumb of the dominant hand plays the most critical role in the “grasping repertoire of the hand” or as John Napier [6] had put it: “Without the thumb, the hand is put back 60 million years in evolutionary terms to a stage when the thumb had no independent movement and was just another digit.” If following amputation a thumb is missing, one estimates that there is a 40% loss in the functional capacity of the hand, which might be a reason for musicians or surgeons to take out an insurance, at least for the loss of a thumb [8]. There are different features that distinguish the human hand from nonhuman primates species, noting that these morphological features allow different kinds of precision grips and precise handling of tools [9].

To unravel the complexity of precise hand movements we have to shed light on the soft tissue covering of the hand, and especially, on the anatomical features of its volar aspect and the skin of fingers and fingertips [10]. The skin on the volar surface of the hand is described as “glabrous” in contrast to hairy skin, which is found on the dorsal surface of the hand. The skin on the volar aspect is relatively thick and is capable of bending along the flexure lines of the hand when objects are grasped (Fig. 1). These folds enhance the security of the grasp and demarcate the areas of the hand where the skin is mobile as compared to the adjacent areas that are tightly bound to the underlying tissue and bones. Like all skin, the soft tissue covering of the palmar surface of finger and fingertips consists of two histological subdivisions, namely the epidermis and the dermis. The former provides a protective barrier to prevent loss of moisture and intrusion of bacteria and appears as unique fingerprint patterns (epidermal raised ridges and recessed furrows) on fingers and thumb (Fig. 2) (for overview see [11]). These characteristic patterns are mirrored in the papillary layer of the underlying dermis [12, 13]. The functional tasks of the dermis, consisting of a papillary (upper) and an elastin rich reticular (lower) layer [14], comprise the nourishment of the epidermis through its extensive network of blood vessels and capillaries (Fig. 1) and the formation of a strong and supportive structure. The fibrillar network of the dermis is housing the key anatomical elements for touch perception, the mechanoreceptors, as well as the sweat glands ($>300\text{ cm}^{-2}$) (Fig. 3). The numerous eccrine sweat glands of the skin of the hand assist in controlling body temperature and regulate the moisture secreted by the sweat pores. This phenomenon is of utmost importance when gripping an instrument with ungloved hands. As the keratin of the skin outer layer is relatively stiff and rough at a small scale, the actual contact area between the fingerpad ridges and the impermeable metal surface is initially small as is friction. Because the keratin softens when it is hydrated by the sweat moisture, it requires many seconds for the contact area to increase to the value reached almost instantaneously with a soft material. That is why gripping a handle coated with a rubbery material is instantaneously more stable than grasping a metal instrument [15].

A good deal of what is known about hand function originally derived from two separate but related scientific disciplines, namely psychophysics and single-unit

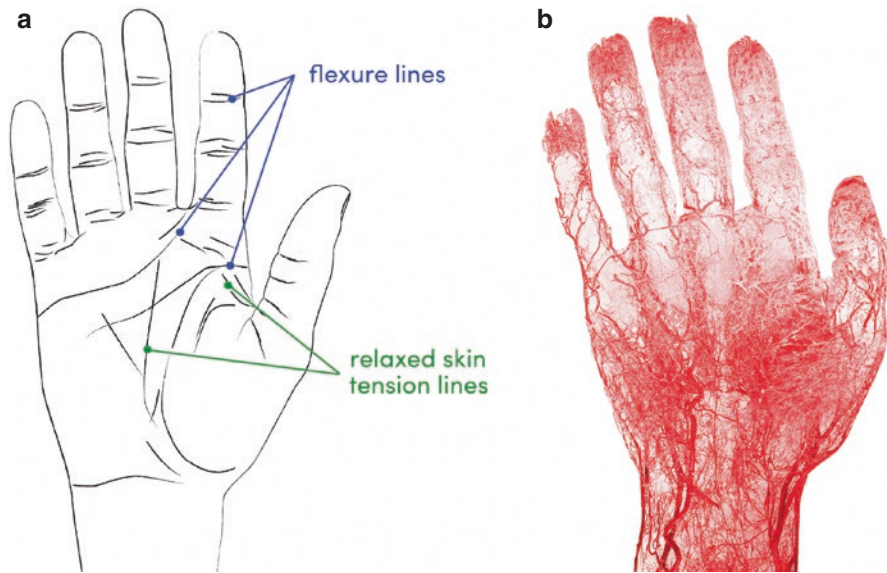


Fig. 1 Volar aspect of the human hand with the hairless skin described as “glabrous,” in contrast to hairy skin on the dorsal face of the hand. **(a)** Three types of lines can be distinguished in the hand: *flexure lines* are permanent skin creases that open and close during grasping and gripping following the movements of the underlying joints. They are lines of skin stasis produced by an anchoring of the skin to the deep packing tissues. Flexure lines define the principal axis of movements of the hand. *Relaxed skin tension lines* (RSTL; Langer’s lines) are topological lines drawn on a map of the human hand indicating the direction of the least flexibility of the palmar skin. They are parallel to the natural orientation of collagen fibers in the dermis and perpendicular to the underlying muscle fibers. *Papillary ridges* are explained in Fig. 2. **(b)** Corrosion specimen (epoxy resin) of the vessels of the human hand (palmar aspect). The vascular supply of the hand is a complex network of vessels derived from the radial and ulnar arteries. Two longitudinal lateral arteries on either side of each digit split up into a dense network of capillaries and anastomoses which characterize the good blood supply of the pulp of the distal phalanges of the digits

neurophysiology. Most of the research findings in the latter have been based on anesthetized animals, whereas the psychophysical work has been based on the responses of alert humans. This gap was bridged with the introduction of microneurography (recording from a single afferent unit) and microstimulation (stimulation of the same afferent), within an attentive human observer (for overview see [16–18]).

The four basic kinds of cutaneous sensations are pressure (touch/tactile sensing), warmth, cold, and pain, while other more complex sensory experiences such as itching, wetness, or tickling are based on combinations of all of these four sensations [19]. Tactile sensing activates a variety of tactile units, each consisting of an afferent fiber and its (presumed) ending. The four different types of endings in the glabrous skin of the human hand are (1) Merkel cells, (2) Meissner’s corpuscles, (3) Ruffini endings, and (4) Pacinian corpuscles. The location in the glabrous skin and structural form of the four mechanoreceptors can be seen in Fig. 3. Although all populations of these endings respond to mechanical stimulation, they may be characterized

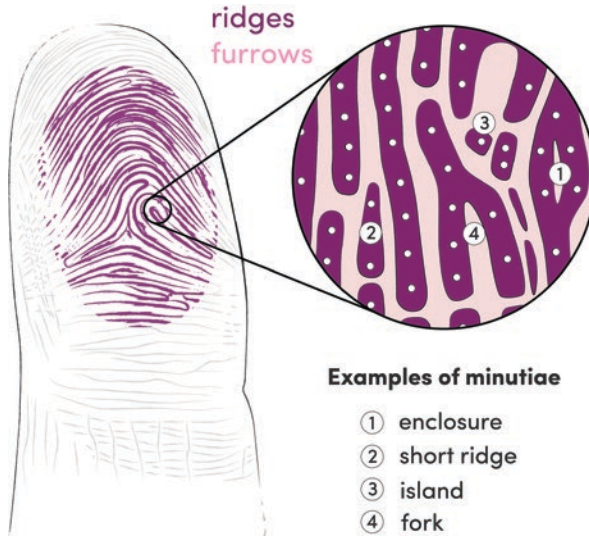


Fig. 2 Fingerprint structure, formed by the interconnection of epidermis and dermis via a series of papillary folds, characterizes the palmar skin areas which are involved in grasping. Fingerprint pattern exhibits many defects, called *minutiae* in fingerprint literature. Such defects include dislocations, island ridges, and incipient ridges. Sweat pores (white dots) on the ridges finely regulate the moisture in the furrow that maximizes the friction irrespective of whether a finger pad is initially wet or dry

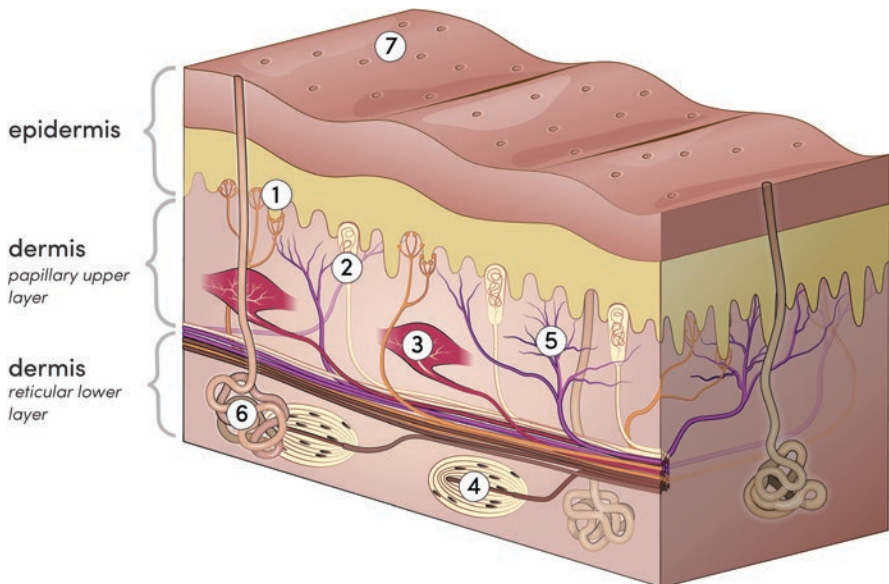


Fig. 3 Vertical section through the glabrous skin of the human hand. Locations of the different nerve terminals and other structural elements: (1) Merkel cell neurite complex (slowly adapting type I, SAI), (2) Meissner corpuscle (fast adapting type I, FAI), (3) Ruffini corpuscle (slowly adapting type II, SAI), (4) Pacinian corpuscle (fast adapting type II, FAI), (5) free nerve endings (nociception), (6) sweat glands, (7) sweat pores

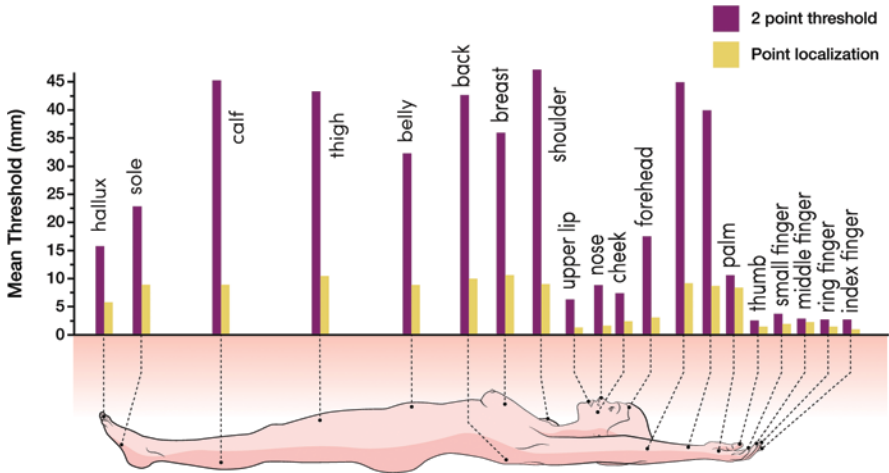


Fig. 4 Touch perception is mediated by mechanoreceptors, located in the dermis of the skin. Depending on the distribution of the different types of mechanoreceptors, two-point touch and point localization thresholds differ from various body sites. Although the threshold values of the latter are usually lower than the corresponding former ones, the measures are highly correlated. The results indicate that the more distal parts of the body are more spatially acute. The most sensitive areas for point localization are the distal phalanges of the thumb and index finger and the lips (figure adapted from [47])

by different afferent fibers. Slowly adapting afferents with a highly dynamic sensitivity (SA I) end in Merkel cell neurite complexes, however, SA II afferents with a less pronounced dynamic sensitivity and very regular sustained discharge terminate in the Ruffini type endings. The fast adapting units, preferentially sensitive to the rate of skin indentations (FA I type) are presumed to end in Meissner corpuscles, whereas the FA II units, which are highly sensitive to acceleration and respond not only when indentation is increased, but also when the stimulus is retracted, end in Pacinian corpuscles [7].

The more than 17,000 mechanoreceptive units innervating the glabrous skin of the human hand make the fingers and fingertips to the most pressure sensitive parts of the human body (Fig. 4) and, as hand and brain are close partners in two important and closely interconnected functions, to the best represented body part in the sensory cortex of the brain [20]. How touch perception and tactile tasks have an impetus to the redesign, or reallocation, of the brain’s circuitry and capacity to respond to experienced demands, has been described in numerous studies about cortical plasticity [21, 22]. An adequate model to study such human experience-related cortical plasticity is musical training [23, 24]. Similar to minimally invasive surgeons who operate at the very edge of their perceptual, cognitive, and psychomotor faculties, learning and playing an instrument involves several sensory systems and the motor system and requires fine-grained perception and motor control that is unlike other everyday activities. Magnetoencephalography (MEG) studies demonstrated how intensive music training has been associated with an expansion of the

functional representation of finger or hand maps. For example, the somatosensory representation of the lower lip in clarinetists or the left fifth digit in string players was found to be larger than in non-musicians [25]. Violinists who had begun training early in life (<13 years) demonstrated larger cortical representation of this digit compared to those who started to play their instrument later. This finding is reflected at a behavioral level in much lower two-point discrimination thresholds at the fingertip of musicians who started their training earlier [26].

Besides the tactile feedback of fingers and hands, the kinesthetic sense, allowing for control of muscle and tendon tension as well as joint positions, constitutes another basis for refined somatosensory perception and enables continuous monitoring of fine finger and hand movements during high-level performances such as microsurgical interventions.

2.2 Tactile Sensing and the Threshold Concept

Even if tactile sensing is essentially sensory in nature and serves to effect contact between the passive hand and an object which may or may not be moving, it provides certain information about the properties of the object (e.g., surface texture) and, therefore, is important for fine tactile acuity, which allows us to manipulate microsurgical instruments with high precision. From the different areas of the glabrous skin of the hand, the fingertips show the highest density of the four types of mechanoreceptive units compared to the remaining part of the finger and the palm (Fig. 5). The receptive fields of SA I units (Merkel cell neurite complexes) are relatively small, about 2–3 millimeters in diameter, with local areas within the receptive field that are highly sensitive. They constitute the only receptor population that responds linearly (without adaptation) to skin indentations up to about 1500 μm , making them very sensitive to vibrotactile stimulation, decoding form, texture, and curvature very well. With 1.5 units per mm^2 in the fingertip, the FA I units (Meissner cell neurite complexes) are even more densely distributed than the SA I units. They respond well to transient skin deformation and low-frequency vibration which occurs during initial contact between skin and an instrument [27]. They are activated by the application of normal force and are most sensitive to tangential force components, providing critical feedback for precise grip control. As FA I units also signal forces that act suddenly on an instrument grasped in the hand, they are important to detect both actual slip between skin and an instrument and local microslip [28]. Type 1 receptors are located near the surface of the skin (Fig. 3) and responsible for the detection of the smallest intensity of pressure (absolute pressure threshold). For men, the normal mean values for absolute tactile sensitivity average about 0.158 g on the palm and about 0.055 g on the fingertip, while the corresponding values for women are consistently lower with 0.032 g and 0.019 g, respectively [29]. The traditional test to evaluate spatial acuity of the touch sense, known as the two-point discrimination, measures the smallest gap between two points contacting the skin that are experienced as two separate tactile sensations. The threshold values tend to be about 2–4 mm on fingertips and about 10–11 mm on the palm [29]. In

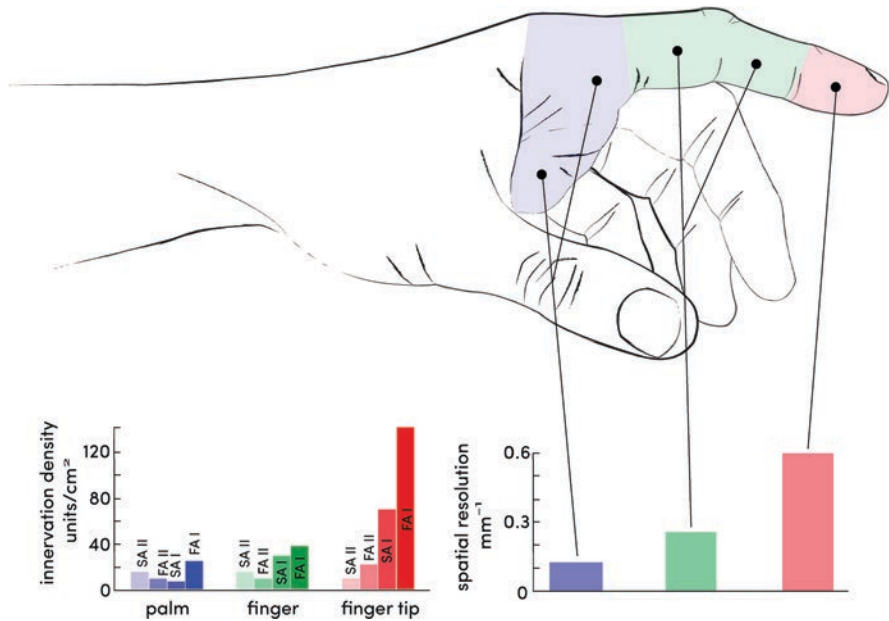


Fig. 5 The spatial resolution of different skin areas of the hand correlates with the distribution of the four types of mechanoreceptor units. Right graphic: Spatial resolution in a psychophysical test of two-point discrimination. The height of the columns gives the inverse of the two-point threshold in units of mm^{-1} . Left graphic: Histogram showing the density of innervation of the mechanoreceptive units of the glabrous skin. The spatial resolution increases roughly in parallel with the increase in density of FAI and SAI units (SAI, Merkel cell neurite complex; FAI, Meissner corpuscle; SAII, Ruffini corpuscle; FAII, Pacinian corpuscle)

general, tactile acuity of individuals is influenced by skin mechanical properties such as fingertip size [30], epidermal stiffness [31], and the spacing of fingerprint ridges [32] and declines of almost 1% per year from 12 to 85 years [33].

Type II receptors (Ruffini and Pacinian), located deeper beneath the skin in the dermis, are less densely distributed in the hand (about 350 per finger and 800 in the palm) with larger receptive fields compared to type I receptors. Hence, they are not useful to detect fine spatial details. However, as they are exquisitely sensitive to transient stimulation such as skin stretch, including vibration, SA II units play an especially important role in perceiving hand configuration and finger position and FA II units are very important for detecting more remote events, for example, those that occur with handheld instruments [17].

2.3 Dynamic Touch and Precision Grips in Periodontal Microsurgery

In contrast to the mainly sensory *touch perception*, with the fingers completely passive, active exploration of objects (*haptic touch*) and manipulation with instruments (*dynamic touch* as a subsystem of haptic touch) often result in flexed and extended

fingers and palms so that the dorsal skin becomes stretched, providing additional information in the form of kinesthetic inputs. The activation of the mechanoreceptors in the muscles, tendons, and joints of the hand, together with the type II units of the palmar skin creates movement-related skin-strain cues which may be used to assess the geometric properties of objects such as the handle of a surgical instrument [34]. Unlike tactile sensing, whole-hand haptic and dynamic exploration produces faster and more accurate identification of objects classified by their geometric properties than does manual exploration that is limited to a single finger [35]. That is why a discussion of haptic sensory feedback in the context of manipulating surgical instruments has to include prehensile activities involving grasping a handle. The properties of the instrument handle (e.g., size, weight, texture, and shape) and the task objective usually determine how the instrument is held, the contact between the handle and the hand, and the number of digits involved in the grasp (see Sect. 3). When, for example, both the thumb and index fingerpads are simultaneously used to explore a surface actively, the magnitude of sensory input perceived with the index finger is greater when two fingers are stimulated than when the index fingerpad is stimulated on its own [36]. These results suggest that a perceptual enhancement effect occurs due to spatial summation at these sites.

In general, there are two dominant prehensile postures, that is, the power grip and the precision grip (for taxonomy of grasps see [37]). The former is characterized by a large area of contact between the grasped object and the palmar surfaces of the fingers and palm and used when force is the primary objective (Fig. 6). In contrast, the precision grip involves grasping an object between the tips of the thumb and index finger, and sometimes also the middle finger, in such a way that there is precise control of the position of the object and the grasping forces. Related to the task and geometry of the object, different types of precision grip are commonly distinguished, characterized by the opposition of the thumb to one or more



Fig. 6 Mathieu needle holder fixed in the power grip, characterized by a large area of contact between the grasped instrument and the surfaces of the fingers and palm and by little or no ability to impart motions with the fingers. Hence, power grasps do not allow fine and accurate finger and hand motions. It is primarily the instrument design which dictates how an instrument is grasped and ideally manipulated according to its function

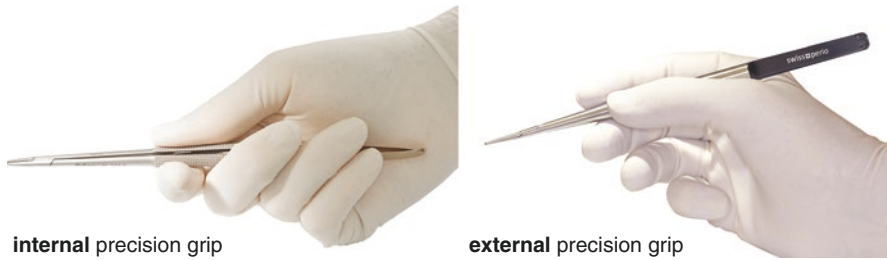


Fig. 7 Prismatic precision grips (taxonomy revised from [37]) are characterized by the opposition of the thumb to the index and sometimes the middle finger. Such grips allow precise control of grasping forces and the position of small objects such as microsurgical instruments. In the internal variant, the instrument handle is held by the tips of the thumb, index, and middle fingers, parallel to the work surface rather than at an angle to it. The hand is steadied by the little finger edge of the hand and perhaps knuckles resting or moving on the work surface. There is only a small range of movement (protraction and retraction) in using the instrument because of its angle, its butt hitting the palm, and the middle finger not being free to flex and extend. The external precision grip starts off with a pinch grip but has the two extra components of support for the instrument in the cleft of the thumb and support for the whole hand along its medial edge. It is of special importance for microsurgery

other fingers (tip, lateral and palmar pinch). In microsurgery, where instruments are manipulated by a grasped handle of well-defined shape, only one choice between two basic types of precision grip has to be made, namely between the internal and external precision grip (Fig. 7). The latter is the common and important one for all kind of microsurgery. It is characterized by at least three separate components, each worth considering in detail because of its implication for instrument design. These components are: (1) the tips of the semiflexed index and middle fingers, and thumb, providing grip and also rotation, (2) a knowledgeable patch of skin at the apex of the thumb cleft and along the side of the index finger, providing antitremor support, guidance, and information by touch and pressure about the position of the instrument and how much force it is exerting, and (3) support from the edge of the ring and little fingers, edge of the hand, wrist, and forearm, as they rest on a stable surface providing control of tremor.

For most tasks in periodontal microsurgery, grip forces generated at the fingertips securing an instrument handle in the precision grip should be very low. Higher forces (>1 N) increase the hand tremor and continuously degrade the fine sensory experience [38]. At very low forces, the fingertip contact area increases sharply with increasing normal force, but by 1 N it is almost 70% of the contact area at 5 N [39]. This means that the contact area increases rapidly with relatively small changes in grip force (Fig. 8). At force levels of around 0.5 N, it has been estimated that the receptive fields of approximately 350 tactile units would be stimulated, and about 66% of these would be FA I units. At 1 N, approximately 450 tactile units would be stimulated, most of them extremely sensitive to small skin deformations [40]. As the grip force increases further, there is little additional change in the contact area, and so the FA I and SA I units would be less effectively stimulated.

Remember that the extensive area of contact between the fingerpads of the thumb and index finger and the dense distribution of tactile units is a uniquely human

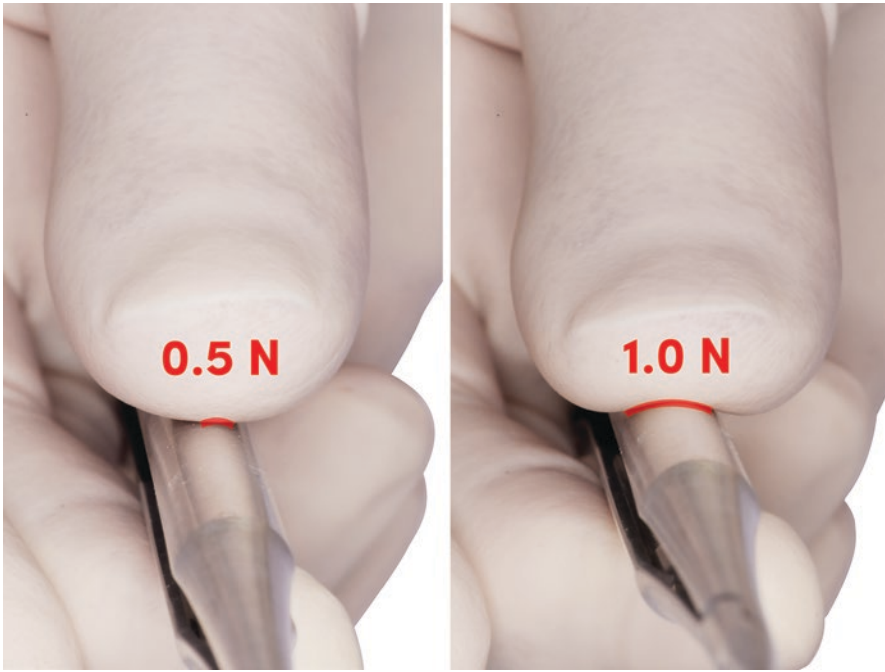


Fig. 8 Friction control, besides other variables, depends on handle curvature and fingerpad grip force which, at low levels ($\approx 0.3\text{--}1.0\text{ N}$), is directly related to an increase of the contact area. By 1 N grip force, when most of the tactile units are stimulated, the contact area is almost 70% of the one at 5 N. For most of the manipulations in periodontal microsurgery, grip forces between 0.5 and 1 N seem to be ideal. Higher forces increase hand tremor and do not help to control friction nor improve the perception in the receptive fields

characteristic, however, it is the development and elaboration of the central nervous system and not the specialization of the hand that provides the substrate for human manual skill [41].

Most manipulative surgical tasks require precise coordination of forces generated at the fingertips in order to hold the instrument in a stable grasp or to manipulate it with the required accuracy. As the intrinsic properties of the instrument (e.g., its geometry, mass, and surface texture) influence the grasping forces and the perceived instrument stability, the discussion of dynamic touch will continue in the following section about instrument design.

3 Instrument Design

3.1 Ergonomics of Microsurgical Instrument Handles

The room for error in microsurgery is so much less than in work on larger structures that it is necessary to look in critical and practical terms at the whole process of work by the periodontal surgeon. A simplified model of the surgeon at work shows

three primary components—the operator, the instrument, and the tissue. These three components determine two interfaces. The first of these is ergonomics, mainly dealing with the relation between hand and handle. Ergonomics, actually a subset of HF, is a term scarcely known to most surgeons, defined as the science of the interaction between humans and their working environment [42]. The second interface, between instruments and tissue, is closely related but can be separated as the study of bioengineering. This is concerned with the physical properties of tissue and how they relate to applied physical forces. An obvious example is the unwanted crushing effect of an occluding surgical forceps on the delicate papilla of an elevated buccal flap. The distinction is a useful one in sorting out a large number of interlocking factors so that they can be analyzed and managed one at a time. This section will refer to ergonomics of microsurgical instruments, while the aspects of the bioengineering interface will be discussed later on. Instrument properties may be hierarchically organized into two major categories, namely (1) material (e.g., texture, compliance, and thermal properties) and (2) geometry (e.g., size and shape), which occurs at both micro (fingertip) and macro (larger than fingertip) levels. Weight reflects the contribution of both material and geometric features since it is partly determined by object mass (product from object density and volume) [35].

3.1.1 Instrument Handle's Shape and Size

The adoption of an external precision grip as the predominant hand posture in periodontal microsurgery requires a certain instrument length so that the instrument can lie in the surgeon's saddle between the thumb and the index finger (Fig. 7). Ideal instrument length, based on an average hand length of 19.3 cm for males and corresponding 17.2 cm for females [43], ranges from 12 cm to 24 cm, depending on the field of application. Such a size enables a primary support by the distal phalange of the middle finger and a secondary one on the base of the thumb in order to overcome gravity and stabilize the instrument without generating load between the thumb and index finger (Fig. 9). Shorter instruments are grasped with the fingertips of the thumb and the index finger and as there is no secondary support, a certain grip force must be exerted and maintained, approximately proportional to the weight of the instrument, to prevent the instrument from slipping between the fingers. These grip forces must be controlled at a constant ratio which requires a coordinated pattern of muscle activation in the hand and arm muscles [44]. The forces have to be large enough to prevent the instrument handle from slipping but not excessive, as this may cause muscle fatigue and tremor.

Besides good instrument support, the external precision grip allows fine motor manipulation of the instrument handle. Depending on the form of the handle, flat or cylindrical, rotational movements can be executed, known as one of the most precise movements that the human hand is able to perform. To precisely rotate the handle of a microsurgical instrument, the applied grip force must be minimal but exceed the slip force, defined as the minimum force at which the handle begins to slip. The slip force, in turn, is proportional to the load (tangential) forces and varies as a function of the friction between the instrument handle and the skin, or intraoperatively, the surgical glove. The friction between the glove and the instrument being grasped depends on the material of the handle, the amplitude of the grip force



Fig. 9 The external precision grip is characterized by the support of the instrument by the middle finger and the cleft of the thumb. In this way, the instrument is stable in the hand without applying any force between the thumb and index finger to overcome gravity. Such a grip allows the best possible control of grip force to finely sense the vibrations transferred from the tip of the instrument to the receptive fields of the fingerpads. Such a size enables a primary support by the distal phalange of the middle finger and a secondary one on the base of the thumb in order to overcome gravity and stabilize the instrument without generating load between the thumb and index finger. Shorter instruments are grasped with the fingertips of the thumb and the index finger, and as there is no secondary support, a certain grip force must be exerted and maintained, approximately proportional to the weight of the instrument, to prevent the instrument from slipping between the fingers. These grip forces must be controlled at a constant ratio which requires a coordinated pattern of muscle activation in the hand and arm muscles [44]. The forces have to be large enough to prevent the instrument handle from slipping but not excessive, as this may cause muscle fatigue and tremor

at low forces (<1 N), and the contact area [45]. For cylindrical instruments, the curvature of the handle, inversely related to the radius, directly influences the contact area between handle and fingertip (Fig. 8). Measures for handle diameter providing good tactile sensing and fitting within the fingertips range from 7 mm to 12 mm [46–48]. A handle diameter of about 10 mm reveals ideal shape by skin indentations so that responses of adapting mechanoreceptors (FA I, SA I units) are directly mapped to the pressure gradient on the skin [49]. A thinner handle may allow more sensitivity because the feedback of touch is not diluted over as large an area, but there is loss of control of position within the fingertips. Wider handle diameters offer only reduced tactile feedback and shape perception reflects more the contribution of kinesthetic inputs.

To summarize the geometric features of an ideal microsurgical instrument handle: The shape should be cylindrical with a diameter of approximately 10 mm. Even if the curvature has little or no effect on the magnitude of the grasping force, it influences the safety margins that are used to prevent microslip. A handle diameter of 10 mm provides an ideal curvature to prevent slips by minimally applied grip forces. Slip responses are detected by FA I and SA I mechanoreceptors and if an instrument begins to slip between the fingers, there is an automatic increase in grip force, which occurs within 70 ms of the slip, resulting in a more stable grasp [27]. Thereby, it does not matter if the shape of the handle consists of a convex or concave surface as compared to those with flat surfaces which provide much lower safety margins

related to slip prevention [50]. Besides the poor control of rotational movements, another reason why surgical blade holders with flat surfaces should be considered as obsolete.

3.1.2 Materials and Weight of Microsurgical Instruments

The predominant material for microsurgical instruments from a metallurgical point of view is martensitic stainless steel. Just for needle holders, forceps, and scissors there is an ongoing discussion about whether the instruments should be made of stainless steel or titanium, the latter being harder, lighter, and capable of being anodized to reduce glare, but more brittle, expensive, and difficult to machine. Titanium instruments tend to maintain their fine tips even after long and intense use. Additionally, they are lighter in weight than equivalent stainless steel instruments and as titanium is a nonmagnetic metal, they do not cause the light microsurgical needles to dance about. Thus, stainless steel instruments periodically need to be demagnetized by passing the instrument through a specially designed electrical coil. Despite some apparent advantages of titanium, many operators like the feel of a stainless steel instrument as titanium needle holders very often have not the same ease and smoothness of movement as steel has.

The weight of the instruments should not be so great that they dilute what feel is available to the fingers from tissue resistance. As previously described, the fingertips can sense a force down to about half a gram (an olive pip weighs about a gram), and instruments weighing less than about 40 g (the weight of a ballpoint pen) will allow an appreciation of tissue resistance that would be lost with heavier ones [38]. Both materials, stainless steel and titanium, allow the fabrication of microsurgical instruments within this low level of weight.

Regarding ergonomics, researchers have demonstrated that haptic weight perception is strongly influenced by the instrument's size and shape, which are geometric properties. This distortion of weight perception is known as the size-weight illusion [51], including both visual and haptic inputs. With low-mass objects, such as microsurgical instruments are, haptic weight perception is also influenced by object material, although less than previously noted with object size. This material-weight illusion is the result of using the cutaneous inputs to judge instrument material, which in turn influences judgments of weight [52]. Such illusions of perception might play a role when comparing and selecting surgical instruments but have a minor effect on performance in the surgical theater when the surgeon's hands are gloved.

More important than the subjective weight perception is the instrument's center of mass as it has an impact on ergonomics [53]. An instrument hold in the external precision grip is supported by the distal phalange of the middle finger and a knowledgeable patch of skin at the apex of the thumb cleft. As the center of mass lies on the grip axis, there is no torque tangential to the grip surface, and consequently, no risk for instrument rotating in the hand. To provide instrument stability, the center of mass has to be between the two supporting areas; otherwise, the instrument will tilt to either one or the other of its ends. Depending on the application requiring different instrument lengths distal from the handle, the center of mass can be adapted

Fig. 10 Examples for manufacturer-specific instrument designs, influencing weight distribution, and handling characteristics. (a) Proximal counterweight of a surgical forceps (S&T AG, 8212-Neuhausen, Switzerland). (b) Proximal stiffness adapter in microsurgical needle holder (Geister Medical Technology, 78532-Tuttlingen, Germany). (c) Distal counterweight of a blade holder (American Dental Systems GmbH, 85591-Vaterstetten, Germany)



to the preference of the surgeon by instrument design, thereby influencing the weight distribution of the instrument held in the precision grip (Fig. 10). In periodontal surgery, some specific intraoperative tasks such as tissue manipulation in posterior aspects do not allow perfect hand support and thus, a slightly tip heavy balance of the instrument facilitates the precise manipulation of the instrument in the oral cavity.

3.1.3 Fine Surface Texture and Roughness of the Instrument Handle

Surgical instruments are not only passively supported in static hand positions but must be firmly stabilized in different kinds of manipulations. During rotational movements such as penetrating coarse tissues with a curved needle, fixed in the needle holder, the grip forces have to be large enough to prevent the instrument from slipping between the fingers. To penetrate the oral mucosa with a microsurgical needle, depending on the size and configuration of the needle and the site specific properties of the soft tissues, very low forces are needed (<1 N). As mentioned above, the minimum force at which the instrument handle begins to slip between the fingers, known as the slip force, varies as a function of the friction between the fingers (or gloves) and the instrument handle. Thereby, the term “safety margin” describes the difference between the slip and the grip force. If an adjustment in grip force is required due to instrument microslip, there is a delay of about 70 ms which

represents about half the latency of a voluntarily initiated change in force that can be elicited by cutaneous stimulation of the fingers and twice the latency of the fastest spinal reflex in intrinsic hand muscles [54]. In general, there are large interindividual differences in grip force even if the corresponding slip forces are equivalent. The safety margins tend to be smaller the more dexterous the surgeons are and represent an important aspect in the microsurgical training.

Friction between fingers and the instrument handle plays crucial role as decreasing frictions require higher normal forces to maintain instrument stability, which in turn decrease haptic perception such as, e.g., sensing tension applied to the wound margin is. Additionally, low frictions not only influence the dynamics of prehensile force control as described above, but also affect the more proximal musculature in the arm, such as the elbow and shoulder muscles that are involved in fine motor movements during microsurgical interventions [55].

In the clinical setting, surgeons rely on friction of the instrument handle against the skin to optimize grip force, independent of whether the friction comes from macroscopic or microscopic features of the handle or a coating between the handle's surface (water, saliva, talc) and the skin [56]. Basic research in ergonomics has been done to evaluate how friction is influenced by surface parameters (dot width, interelement spacing, spatial period, ratio of element width to gap width) and the manner in which the surfaces contact the skin (force, relative speed) [36, 57, 58]. Results have shown that people are remarkably good at fine texture perception (dots and bars only a fraction of a micron high) which is mediated by vibration (PC channels; Pacinian corpuscles), whereas coarse texture (roughness) perception is not. Macrottextures are mediated by the volumetric deformation of the skin and seem to have a minor influence on friction. For a set of incised metal gratings varying in groove width from 0.123 to 1 mm (constant ridge width of 0.25 mm) no effects were found related to friction when the surfaces were either dry or lubricated with detergent [59].

To summarize the surface characteristics of an ideal instrument handle and how it affects friction: For stainless steel or titanium surfaces of a cylindrical instrument of a given diameter of around 10 mm, friction mainly depends on the contact area between the fingers and the instrument. Surface structures such as grooves or dots reduce the contact area and thus have a negative impact on friction (grip forces <1 N). Ideal microsurgical instrument handles are macroscopically smooth. Different microscopic surface textures comparable to silk, suede, and sandpaper may increase friction but the main effect is reduced to the rate with which the normal force changes during preload and loading phase (grasping the instrument), whereas the time course of the change in tangential force is similar for all surfaces [40].

3.2 Influence of Surgical Gloves on Tactile Sensitivity, Finger Pad Friction, and Surgical Performance

The manner in which the hand makes contact with the environment affects the type of information that can be extracted and the actions that can be performed. It is therefore important to expand the discussion of instrument design now to consider the impact of surgical gloves and how they affect ergonomics.

The most prominent material used for glove production is natural rubber latex, a highly deformable elastomer, allowing easy conformation to the shape of the hand [60]. The most common alternative is nitrile, characterized by a different elastic loading response which means that the conformability to the hand is perceived to be inferior to that of rubber latex. Until 2000, powder was used to coat the interior surface of gloves, allowing a reduced friction coefficient for donning. However, due to the rise in the incidents of latex allergies, there have been concerns over the proteins in latex rubber being airborne upon the removal of the glove. Consequently, in 2010 the National Health Services in the UK and many other countries released guidelines stating that rubber latex gloves must be free of powder.

3.2.1 Touch Sensation and Haptic Perception Thresholds

The literature regarding the influence of gloves on touch sensation is conflicting as between the studies many variations in the methodology are present. While some authors report a reduced tactility when gloves are worn compared to the bare hand, some others found that there was no change in the sensitivity (for overview see [61, 62]). Besides the distinction of two different points as a method to assess touch sensation, sandpaper was used to evaluate the detection of surface roughness [63]. It was shown that subjects could perceive roughness differences when moving their gloved fingers across sandpaper, but not when statically pressing. Conversely, in both the dynamic and the static tests, there was a significant difference in perceived roughness between the ungloved condition and the two gloved conditions (thickness of a single glove of 0.27 mm). Thereby, glove thickness positively correlated with a loss of cutaneous sensibility. Such increase in sensory thresholds may be explained by a disruption of the FA I mechanoreceptor function [64] which, together with SA I afferents, are important in precision grip control [28]. Interestingly, even if latex rubber is damping the vibrations caused by dynamic touch and weaken the signals to the FA I receptors, SA I mechanoreceptor function was not disrupted [64]. Traditional views of the segregated role of FA I mechanoreceptors in precision grip have been challenged and there is increasing evidence that cortical integration is multimodal, involving inputs from multiple receptor types [65]. Accordingly, the contributions of FAI and SAI afferents to grip control may overlap and involve complex interactions with other afferent subtypes [66].

In general, it is not well investigated as to how much surgical gloves affect the tactile sensitivity of a microsurgeon in different specific tasks, but it is clear they are having a negative effect. When comparing glove thickness, studies have found that the thinner gloves provide more sensitivity [67–69]. That is why gloves marketed as microsurgical gloves have a thickness of about 0.17 mm in the fingertips and 0.14 in the palm.

3.2.2 Fingerpad Friction and Grasp Force

As described above, latex rubber gloves reduce the tactile sensation, which unconsciously has an impact on grip force, which in turn is imperative for instrument control. Many of the mentioned studies appear to see an increase in grip force as beneficial, but do not look at the effects of this increase in grip, however slight, on hand fatigue and reduction in the stimulation of tactile units. Such over-gripping effect could be due to a reduced friction coefficient between the instrument and the

hands when gloves are introduced [70] and has a psychophysical impact on manipulative tasks in which force control is required. Gloved hands employ a higher safety margin above the minimum force required to hold the instrument. With the use of thinner gloves a relatively low grip force level is maintained for slippery and non-slippery surfaces and a better efficiency of force and temporal control in precision handling of small objects is provided [71].

Reliable information from studies regarding frictions and slip control between gloved fingers and the instrument is scarce. Intraoperatively, surgical gloves act as a barrier to protect from bodily fluids such as blood, saliva, and water. None of the frictional tests incorporates simulative bodily fluids into the systems to assess how frictional properties may change, which will affect sensitivity and dexterity. Including fluids into assessments would provide a greater significance to the results of any of the friction and grip studies being conducted.

There is just one study found, investigating static friction of wet latex rubber gloves on a variety of dental tool patterns [72]. Greater friction coefficients for tools with medium to coarse knurled surface patterns were observed compared to annular or macroscopically smooth instrument surfaces. As the goal of the study was to determine whether a modified instrument surface texture could reduce the high pinch forces required to perform root scaling, an applied force of 40 N between gloved fingertip and instrument handle was chosen for study purposes. Such an amount of force is far above the required ones for precise manipulations in periodontal surgery, and therefore, the conclusion that knurled surfaces provide more friction cannot be used to design ideal surface textures of microsurgical instruments (Fig. 11).

3.2.3 Influence of Gloves on Surgical Performance

Surgeons express criticism for glove materials that are different from their preferred choice by claiming that the gloves are too thick, slippery, and ill fitting [62]. Most studies suggest that sensitivity, friction, and grip are affected when medical gloves are worn but, surprisingly, objective performance perception does not [73–75]. Further study is needed to understand these results, to isolate the effects of material, fit, and thickness, and to identify the critical factors in glove design which affects clinicians' ability to perform dexterous tasks [63].

As mentioned above, no major differences regarding performance could be noted for normal surgical tasks with gloved compared to bare hands, tested in laboratory conditions. Nevertheless, there is a tendency for improved performance in microsurgical tasks when thin elastic latex rubber gloves are worn instead of thicker ones or those made of nitrile [76].

3.3 Instrument use and How it Affects Hand Representation in the Brain

Instrument manipulation in periodontal microsurgery represents complex tool use that converts movements of the hands into qualitatively different mechanical actions (e.g., rotating hand into penetrating needle through mucosal tissues).

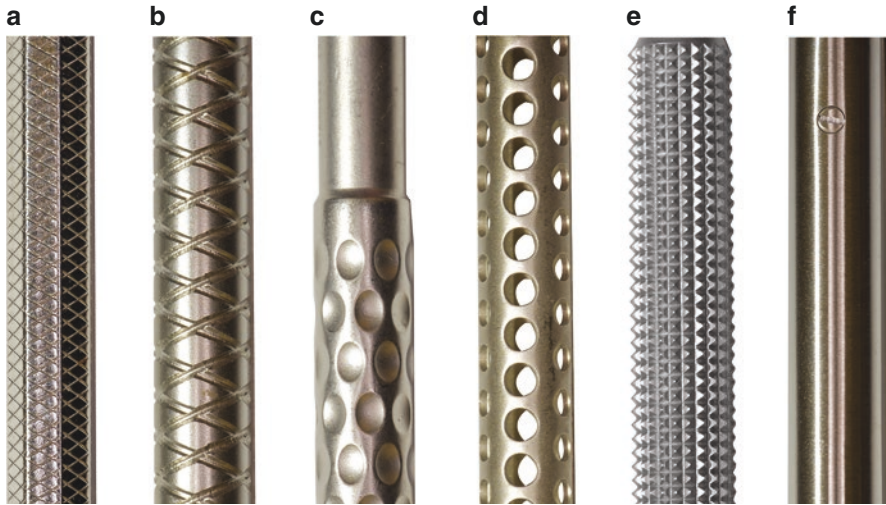


Fig. 11 Different macro- and microtextures of microsurgical instrument handles. (a) Hexagonal cross-section of the handle with micro furrows (Deppeler, 1180-Rolle, Switzerland), (b) annular crossed furrows (Hu-Friedy, 60618-Chicago, United States), (c) macro indents (Hu-Friedy, 60618-Chicago, United States), (d) perforations for friction control and additional weight reduction (Geister Medical Technology, 78532-Tuttlingen, Germany), (e) medium knurled surface pattern (Aesculap, 34212-Melsungen, Germany), (f) fine smooth surface (Hu-Friedy, 60618-Chicago, United States). The surface designs (a) to (d) seem to have no substantial positive impact on friction dynamics under wet gloved conditions. Medium to coarse knurled surface patterns (e) increase the friction between gloves and handle when very high grip forces are applied (<30 N). Smooth handles (f) provide the largest contact area between finger and handle when low grip forces are applied and, thus, the best precondition for friction control

Recent studies with “proficient” tool users such as amputees with prosthetic arms [77] and “non-proficient” tool-users such as healthy but blind-folded subjects using a blind cane to explore the environment [78] have proposed different concepts of tool-use and its modifications on the sensorimotor system and the plastic changes at the level of the body representation (for review see [79]). In general, tool-mediated sensing still is a poorly understood aspect of the daily human experience. Nevertheless, it might be of importance when surgical instruments are newly designed, in order to optimize the information process through the instrument at the sensory and motor level.

Instrument use extends the peripersonal space (PPS), defined as the space immediately surrounding the body, now generally accepted as a region of integration of somatosensory, visual, and auditory information [80]. It is a privileged interface for goal-directed actions with nearby objects such as tissue manipulation during microsurgical intervention is.

Different than the PPS and other body representations (body image, body structural description), which are conceptually and functionally difficult to disentangle, the body schema (BS), essentially *sensorimotor* in nature, seems to be universally accepted and well described, with a relatively unifying definition. BS

is defined as a highly plastic representation of the body parts (including hands), in terms of posture, shape, and size, that can be used to execute or imagine executing movements accurately [81]. The BS allows for execution and constant monitoring of our actions and appears to be fed mainly by proprioceptive, but also tactile and kinesthetic, information [82]. It is interesting to discuss the concept of BS in the context of surgical instrument use as it has been shown that, comparing the activity of parietal bimodal cells (i.e., cells responding to both tactile and visual stimuli) before and after instrument use, after tool use, the visual receptive fields were enlarged along the tool axis (from the hand to the working end of the instrument). Thanks to the BS we are capable of locating our hands in space, knowing exactly where the fingers are, without vision. This information is refreshed instantaneously at every single movement of the hands. A rich array of vibratory signals from the instrument are transduced by mechanoreceptors (Pacini corpuscles) into neural response patterns that preserve the location-specifying information. The population response starts within milliseconds, which means that this time course is in line with responses of mechanoreceptors during object manipulation with the hand, suggesting that the nervous system can extract sensory information from an instrument with a similar speed as the hand itself [83, 84]. These results clearly show that a handheld instrument functions as a sensory extension of the user's body and point to the existence of an embodiment of the instrument, rather than sensory distalization or sensory projection [84]. Nevertheless, full embodiment requires the existence of three layers, namely the affective one (individual shows the same affective reactions as for his/her own body), the motor one (moves as a body part and is perceived as under one's control), and the spatial one (the space it is located in is processed as body space) [85]. The use of the above described microsurgical instruments fulfills at least the latter two criteria of embodiment. But it is important to mention that different tools or the way how they are held in the hand or how the functional end of the instrument looks like extend the BS in different ways [86]. This, in turn, underlines the importance of instrument design in order to refine the functional coupling between the instrument and the surgeon's hand.

Scientists have only recently begun investigating how handheld instruments are treated by the nervous system as sensory extensions of the body. Actual data confirm that effective motor control of instruments involves both a tool-specific expansion of the body schema (BS plasticity), and a mapping that captures how movements of the hands are transformed into actions of the instrument's end-effector (representations of the so-called motor-to-mechanical transformation). By working surgically with handheld instruments we turn from grasping the instrument to using the instrument to manipulate the tissues, while at the same time, many neurons code the movements of the end-effector of the instrument, rather than that of the hand.

To further elucidate how haptic feedback to the operator's hand can be improved by instrument design and at the same time be perfectly associated with the tissues of his or her visual attention, in depth research is needed, including specialists in manufacturing instruments, behavioral psychophysics, structural mechanics, and neuronal modeling.

4 Basic Set of Instruments for Periodontal Microsurgery

4.1 Description of Microsurgical Instruments

An ideal basic set of instruments for periodontal (plastic) microsurgery is depicted in Fig. 12. Even if at the first glance, many instruments from different manufacturers have a similar look, they widely vary in quality, price, delivery times, and back-up services. The instruments presented here are characterized by high quality standards, which not only refer to instrument design but equally to high precision in product fabrication. As many surgeons have their own preferences in instrument design and decisions to buy are often made on the basis of the catalogue price alone, it is important to have objective standards for assessing instruments for purchase. The sharpness of scissors can be tested by trying to cut thin gauze or glove rubber with them, and their stiffness can be tested by pressing them onto a simple scale for weighing letters. In a similar way forceps and needle holders can be checked for their stiffness and grip. The SwissPerio instrument set contains two scissors, one for soft tissue dissection and one for cutting threads (Fig. 13). The inclined working ends of the latter one have smooth cutting edges and allow access to difficult areas even far distal to molars in posterior zones. The tissue scissor is finely serrated which improves the cutting properties when mucosal tissues tend to slip sideways.

The needle holder, characterized by non-serrated, smooth working ends and optimal stiffness, is unmatched in its precision. It allows a firm seat for smaller needles



Fig. 12 Basic set of microsurgical instruments (SwissPerio, Hu-Friedy, 60618-Chicago, United States) with needle holder, forceps, scissors, and different elevators, designed for minimal traumatic flap mobilization and retraction in the palatal, buccal, and interdental areas of the oral cavity. The design of the instruments fulfills the criteria for optimal ergonomic handling, and even if the instruments are offered as microsurgical tools, they are equally suitable for interventions on a macrosurgical basis, using suture materials in the sizes of 5-0 and 6-0

Fig. 13 Two scissors for different applications, cutting threads and tissues, belong to the SwissPerio basic instrument set. One cutting edge of the tissue scissor is finely serrated to avoid mucosal slips sideways (**a**). The suture scissor with inclined working ends allows easy access to all areas of the oral cavity (**b**). The distance between the two branches of the opened suture scissor is less than 3 mm which improves instrument stability when sutures have to be removed. Both the instruments have rounded edges and are handmade with highest precision



and provides an easy handling of suture diameters in a range of 5–0 to 9–0 (Fig. 14). The instrument is equipped with a lock that facilitates finger rotation without applying pressure, leading to a more precise execution of finger and hand movements. Additionally, the low locking forces reduce hand tremor while grasping the needles.

Two different types of forceps (surgical one with micro teeth/anatomical one with smooth surfaces), both configured with very fine working ends, allow firm grasping of the oral mucosa without traumatizing flaps unnecessarily, precise tissue manipulation, and fluent suturing with knot tightening.

The set is completed with four different kinds of elevators, whereof one is specifically designed as a double-end instrument to elevate papillae and interdental tissues under ultimate controlled conditions (i.e., pulling the papilla with the stiff, sharp microelevator and pushing the col. tissues with the dull pushing end). All SwissPerio instruments are coated for a harder, smoother surface for optimal edge retention and enhanced lubricity. The distinct black finish enriches the contrast and the visual acuity at the surgical site. Additionally, in the highly illuminated surgical working area, the light reflection of the instruments is reduced by matte finished handles and the black working ends.



Fig. 14 The needle holder with its requirement for functionality and ergonomics is a key instrument in periodontal microsurgery as suturing has an important impact on wound stability and integrity. The instrument has smooth working ends which provide a firm seat of the grasped threads and needles. Equipped with a lock, the instrument allows finely controlled rotating movements. The lock opens and closes by just applying a minimal amount of finger pressure which contributes to good hand stability. It is suitable for the manipulation of sutures in the range of 5-0 to 9-0

4.2 Sterilization Process and Caring for Microsurgical Instruments

In order to prevent damage, microinstruments should be stored in a special perforated sterile container or tray. The tips of the instruments must not touch each other during sterilization procedures or transportation (Fig. 12). The practice staff should be thoroughly instructed about the cleaning and maintenance of such instruments, as cleaning microinstruments in a thermodisinfector without fixing them in place may cause irreparable damage to their tips. It is highly recommended to follow the manufacturer's instructions for instrument cleaning.

The ease of cleaning is also affected by the surface characteristics of the instrument. That is why overall smooth surfaces and only minimally knurled or as well smooth handles have a positive impact on the cleaning process. During surgeries, tissue fluids should not be allowed to dry on instruments and assistants must keep the instruments moist and frequently clean them with sterile watery solutions or mineral-free distilled water.

Before sterilizing the instruments and re-use, a regular general check-up is recommended to guarantee the perfect functionality of the microsurgical instruments. Such a list includes the following checkpoints: (1) General appearance. The surfaces should be clean and smooth, and edges well finished without burrs. (2) Joints should work easily. It should not take more than 100 g applied to the fingerpads to close the instruments. (3) The tip of the instrument should not be hooked nor snag. They should meet accurately before the rest of the jaws when inspected against the light and preferably using a magnifier. (4) Locking and unlocking forces of needleholders should not exceed 150 g until the ratchet is locked.

Provided that the rules and recommendations for proper instrument handling and care are followed, microsurgical instrument keep their functionality and high quality properties over a long period of time independent of the frequency of use.

5 Conclusions

Periodontal microsurgery is performed by means of surgical microscopes or high magnifying loupes which guarantee an ideal visual presentation of the structures to deal with. Besides the visual sensory inputs, the tactile signals from the whole hand and their transfer to the brain in millisecond precision are of utmost importance as meticulous execution of precise hand movements depends on corresponding haptic sensory inputs.

The interface between the instrument and the gloved surgeon's hand is primarily influenced by the design and the surface characteristics of the microsurgical instrument and especially the handle of the instrument. That is why microsurgical instruments must meet the criteria to be held and manipulated in the external precision grip. Rounded handles of about 10 mm diameter seem to ideally transfer mechanical forces into vibratory stimuli, decoded by the mechanoreceptors of the skin of fingertips and palm. Additionally, smooth rounded handles provide best friction control when low gripping forces are applied. It should be noted that literature findings regarding microslips between gloved hands and microsurgical instruments under clinical conditions are scarce.

Similar to other medical faculties, in periodontal surgery the tasks dictate the design of the instruments which has been previously described. But as the oral mucosa is a very delicate soft tissue, all surgical manipulations on the oral masticatory, lining and specialized mucosae should follow the rules of minimal invasiveness and, as such, there should be no distinction between macro- and microsurgical instrument design. The only differences consist in the configuration of the working ends of anatomical forceps and needle holders when very fine suture materials are preferred or in the surface textures of instrument handles when higher gripping forces are required such as the ones for scaling and root planing. Otherwise, the instruments for periodontal microsurgery are equally suitable for periodontal and periimplant surgeries applied in a conventional manner. Or expressed in a better way, in periodontal and periimplant surgeries, an approach based on magnified vision and executed with microinstruments, providing the best tactile feedback and optimal transfer of motor activity into mechanical action, should be the rule rather than the exception.

6 Key Points

1. The sense of touch of the human hand

In periodontal microsurgery, the interface of the human hand and the instrument is of utmost importance (discipline of human factors). To understand the essence of the sensory feedback for precise instrument manipulation, firstly, we must be familiar with the anatomical features of the hand and the psychophysics of touch, tactile, and haptic sensing.

2. Instrument design

Psychomotor execution of precise hand movements depends on visual and tactile sensory inputs. The latter ones are transferred via the instrument to the surgeon's skin. That is why instrument characteristics from a macroscopic (e.g., form, size, weight) and microscopic (e.g., texture, surface roughness) perspective are important features when it comes to ergonomics in periodontal microsurgery.

3. Precision grip in microsurgery

In surgery, the tasks dictate the instrument designs and the way the instruments are held in the hand. In the taxonomy of grips, the external precision grip is the dominant hand position in periodontal microsurgery. It is characterized by at least three separate components, each worth considering in detail because of its implication for instrument design.

4. Instrument use and brain plasticity

Instrument use seems to extend the peripersonal space, defined as the space immediately surrounding the body, now generally accepted as a region of integration of somatosensory, visual, and auditory information. Findings from recent studies support the hypothesis that handheld instruments function as a sensory extension of the hand and point to the existence of an embodiment of the instrument.

5. Surgical gloves and their impact on precise hand movements

Surgical gloves interfere with the transfer of mechanical stimuli to the mechanoreceptors of the fingers and the palm of the gloved hand, thereby, impairing friction control. It is important to discuss the factors which influence the control of microslips between instrument and fingers and how ergonomics can be maintained even with gloved hands.

6. Basic instrument set for periodontal microsurgery

The basic instruments are described and recommendations for selection are given. Additionally, there are guidelines and checklists how to care for the instruments and how to avoid damage.

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