Systematic Review of Recent Developments Related to Microergonomics of Surgical Instruments

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Abstract

Researches are now being conducted on redesign as well as micro ergonomic interventions. Most micro-surgical tool designs concentrate on the manipulation of targeted tissue instead of the surgeon's hand, and this presents a new research opportunity for better fitting the equipment to the surgeon's hand. So the objective is to examine the advancements made in the last few years and provide a framework for ergonomic intervention framework regarding manufacturing systems. With the use of words like ergonomic design, intervention, and evaluation," the titles and abstracts of ergonomics publications were filtered to find relevant research. The paper describes the way that the concept of micro-ergonomics can enhance the design of the micro-instruments. Finally, an application of a new surgical instrument is stated as a pen needle holder designed by SOLIDWORK 22 which creating a wide range of possible uses for futuristic technology. In future, neurosurgical equipment design will incorporate concepts from surgical tool design together with penization, microergonomics, and electronics.

Keywords: Microergonomics, Redesign, Surgical Instruments

المراجعة المنهجية للتطورات الأخيرة المتعلقة ببيئة العمل الدقيقة للأدوات الجراحية

رنا عيدان عبد، صادق جعفرحمندي، منير خماس فرج

الخلاصة:

يتم الآن إجراء الأبحاث حول إعادة التصميم بالإضافة إلى التدخلات المريحة الدقيقة. تركز معظم تصميمات الأدوات الجراحية الدقيقة على معالجة الأنسجة المستهدفة بدلاً من يد الجراح، وهذا يمثل فرصة بحثية جديدة لملاءمة المعدات بشكل أفضل ليد الجراح. وبالتالي فإن الهدف هو دراسة التطورات التي تم إحرازها في السنوات القليلة الماضية وتوفير إطار لإطار التدخل المريح فيما يتعلق بأنظمة التصنيع. باستخدام كلمات مثل التصميم المريح، والتدخل، والتقييم،" تمت تصفية عناوين وملخصات منشورات بيئة العمل للعثور على الأبحاث ذات الصلة. وتصف الورقة الطريقة التي يمكن لمفهوم بيئة العمل الدقيقة أن يعزز تصميم الأدوات الدقيقة أخيرًا، تم ذكر تطبيق أداة جراحية جديدة كحامل إبرة قلمي جديد صُمم بـ SOLIDWORK 22 والذي يخلق مجموعة واسعة من الاستخدامات الممكنة للتكنولوجيا المستقبلية. في المستقبل، سيدمج تصميم معدات جراحة الأعصاب مفاهيم من تصميم الأدوات الجراحية جنبًا إلى جنب مع المواءمة الدقيقة والإلكترونيات.

1. Introduction

A primary goal of the presented work is to make surgical instruments more user-friendly. Incompatibilities between the expectations placed on surgeons and the capabilities of their instruments lead to musculoskeletal disorders, accidents, and injuries. [1-4] Focused attempts were made over the years to include ergonomic principles into the design of work systems and instruments. [5-7] In the past, the design of surgical instrument was heavily influenced by the ergonomics notion. Manufacturers redesigned them based on hand measurements taken by surgeons. The configurable shapes of human parts were the focus of this design. One of the main concerns was how to arrange the instrument such that the surgeon could be more comfortable performing their work (for example, an armrest-like microscope which helps with handwork). [8–10] The majority of surgical instruments are made with consideration for the target tissue as well as how to work with it. [11] Surgeons frequently report feeling pressure in their lower limb joints and hands, in addition to discomfort and exhaustion. [12, 13, 14, 15] The extended and repetitive use of certain ergonomic instruments could be blamed for such ailments. The broad ergonomic principles currently in use for hand tool design lack specificity, making them unsuitable for the design regarding laparoscopic instruments [14, 16]. Michael R. Abidin noted in the year 1989 that suture clamping through smooth needle holder jaws without teeth has been atraumatic and didn't change the mechanical strength of sutures, indicating that there are certain challenges with using surgical instruments through the surgeon [17]. The clinical observations of several surgeons, who claimed that clamping sutures with smooth needle holder jaws appeared to cut the suture, significantly lowering its strength, have been sharply at odds with the findings of such mechanical performance investigations [18]. Work-Related Musculoskeletal Disorders, or WMSDs, frequently drive businesses and employees to look for "ergonomic" tools. Certain tool manufacturers suggest that WMSDs could be avoided by using "ergonomic" tools. Identification of potential risk variables and an examination of the task for which the tools are being utilized must be the first steps in the prevention of WMSDs [19].

2. Method

According to D. De Ridder and T. Menovsky, the inherently rigid nature of conventional microinstruments like bayonet microneedleholders makes them difficult to use for microsuturing in deep or narrow operating spaces. The shape memory alloy nitinol is used to create the innovative flexible as well as 360° rotating shaft microneedleholder which is described in this technical note. The inner shaft, including the tips, may spin 360 degrees, making the shaft unique in a way that it could be freely bent in all directions [20]. According to Carl-Fredrik, the goal of the research has been to create a novel needle holder known as Frimand needle holder (FNH) and assess how surgeons felt about it. It has been created to get over the aforementioned drawbacks, making palm as well as finger grip suturing easier. Additionally, this study assessed attitudes on using the finger and palm grips as well as suture precision. Comparing FNH to a typical Crile-Wood needle holder (CWNH), a total of 32 surgeons made sutures on postmortem porcine skin as well as small bowels using both the finger grip and palm grip. Utilizing an assessment form, the participants evaluated the FNH. By allowing the surgeons to complete 20 sutures using the finger and palm grips on a polyurethane pad with designated exit and insert sites, precision was ascertained. Using a digital sliding measurement scale, the exact distance between the planned exit point and the actual exit site has been determined. [21] When it comes to using such biomedical equipment during medical treatments as well as surgical procedures, the physician in the clinic could benefit greatly from the guidance of highly qualified specialists and engineers. Patients may experience less physiological disturbance and tissue damage from well-designed biomedical and surgical tools. To raise the standard of biomedical care, researchers are looking into minimally invasive medical and surgical instruments. [22] A subsequent study revealed that 390 questionnaires have been distributed to surgeons within the Spanish Health System. Also, the questionnaires have been categorized into four areas: dissector assessment, demographics, additional information, and needle holder assessment. It was ultimately discovered that a response rate of 30.26% was attained. They came to the conclusion that some ergonomic flaws were found in (a) the design of instruments, (b) the surgeons' posture, and (c) the operating tables. [23] Another portion of the questionnaire addressed discomfort and pain after or during surgery. [24]

From previous research, it is clear to us that there are certain concepts that must be followed for the purpose of development and redesign of instruments, including the geometry, the materials used, weight and also the measurements of the surgeon's hand.

Lastly we can summarize some researches ideas as in Table 1.

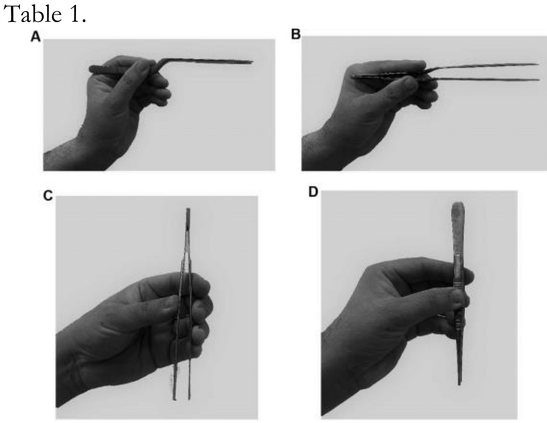

Figure (1): Bayonet forceps griped by surgeon hand like a pen between thumb and index fingers.

Table (1): Ideas of some researches

T. Menovsky et. Al [20].	2011	They demonstrated how a small craniotomy's small range of movement could make it more difficult to suture the execution such that the shaft could bend freely in either direction.

Carl-Fredrik et. Al [21].	2014	They warned that there could be a chance for the needle to move erratically and lose precision. The goal of this research was to create a novel needle holder known as the FNH and assess how surgeons felt about it.
Marcos Lucas et. Al [23].	2014	This research examines the issues and repercussions of using needle holders for extended periods of time. Based on the largest Spanish survey, some ergonomic flaws were uncovered, the primary one being the "instruments' design."
Gonzálezaet A.G. et. Al [32].	2015	Using CAD 3D SolidWorks software, a tweezer was designed and constructed. To reduce weight, the design's geometry as well as materials were slightly altered.
Gabriel Bo¨rner, Agneta Montgomery [34]	2020	They developed a suture tool and compared to ordinary too by the ratio of suture length to wound length.

3. Penization

The concept of penization is enhancing the instrument shape like pens, enabling manipulation similar to that of writing as in Fig.1.

Power of Hand Motion

Supination is the most crucial movement a surgeon does throughout surgery, and the hypothenar eminence of our hands is the most powerful part of supination. It is best to have a component attached to the hand area in instruments in which we need power in order to generate greater power. This idea could be stated in terms of simple machine lever mechanics. The lever's pivot is represented by the hand's hypothenar eminence. The 3rd-class lever type, where the attempts are situated between load and fulcrum, is exemplified by the surgeon's hand-held needle holder. Less attempt is required for moving the load in the case when the fulcrum is closer to the load, and the weight will move farther more readily when the fulcrum is closer to the effort. [25]

4. A few requirements of handle design

• Two controls must be included on the handle: one for sideways orientation and the other for opening and closing the tip.

• The instrument must demonstrate its available control options and use the handle to indicate the tip position such that the handle is self-explanatory [26].

• Because the surgeon holds the arthroscope in other hand, the handle must be operated with one hand, which might be either right or left hand.

• In order to use the handle while keeping a stable grip, the control switches must be accessible to the index or thumb finger [27, 28].

• The handle's design ought to accommodate different hand sizes [29].

• When using the handle, the joint excursions must stay within permitted bounds throughout operation.

The grip orientation determines the stresses on the skin and this permit the surgeon to use the tool with more range of motion and more comfortable as in Fig. 2.

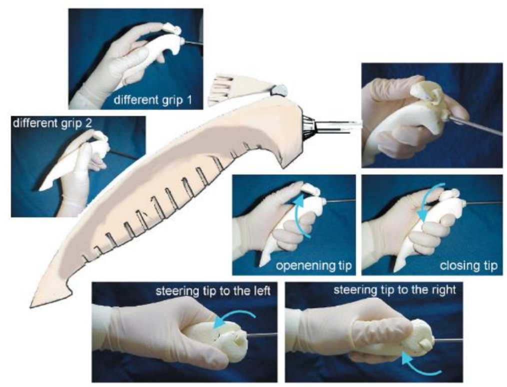

Figure (2): The picture state the surgeon grip like a lever for more freedom.

The objectives could be considered in redesigning the surgical instruments:

- The locations are more quickly reached. 2. There are less inter-punch exchanges
- Less tissue damages
- Less forces are applied to the incision because to smaller shaft movements.
- The learning curve is steeper compared to traditional instruments.
- Visual inspection can be used to understand the working principle.
- The position of the lever indicates the tip's position. Minimal errors made when using the handle
- The handle requires little mental effort to operate.
- The wrist excursions stay within the permitted range.
- Holding the handle provides greater comfort.
- The handle operates in a more pleasant manner.

5.Control of hand movement and tremor

Complex skilled movements are accurate because of a "program" in central nervous system that provides intermittent corrections during the movement, which is covered later under the topic of "skill acquisition." This applies fast to little activities that are easy to repeat, rely on kinesthetic feedback instead of visual; once finger movements are practiced, one such work is producing a loop of suture material for a knot under a microscope. Glencross observes that the kinesthetic feedback loop (125 msec) is faster than the visual feedback loop (190msec-260msec). In spite of the significantly smaller distances which must be covered, controlled movements in microsurgery are performed far more slowly than in normal surgery because most activities require constant and visual feedback. The idea of leverage could improve movement accuracy; however, in contrast to Archimedes' original intent, the leverage decreases movement rather than increases force. In the same way that Archimedes needed a long enough lever and a sturdy surface to balance the world, a microsurgeon need a fulcrum near the work in order to reduce the instrument tip's arc of movement. A fulcrum of this type could be the middle fingertip (see to "precision grip" below), an additional tool, or the anatomical structure being dissected's vicarious support. In the case when the instrument tip aligns with fulcrum, extreme accuracy can be attained. Drawing a straight line with a ruler is a basic illustration of this. Although the lever concept cannot be used to slow down spin, the flexibility of fingertip pulp could be used for limiting and controlling rotation if two fingertips that are opposite each other are kept in contact when gripping a fine instrument. But tremor poses a greater challenge to the microsurgeon than precision, particularly in the beginning [30]. With the use of dissector, the majority of the causes-related problems yielded higher values as shown in Fig.3. In the case when employing the dissector, the risks associated with extended static postures, precise repetition of movements, overuse of force, and extreme joint positions are increased. Additionally, utilizing the dissector increases the prevalence of musculoskeletal diseases in the back, neck, and wrists, hands, and fingers. One possible explanation for the significant distinctions between dissector and needle holder is how frequently tasks involving the former are carried out. But in the case when the two instruments are used, such musculoskeletal disorders in elbow-forearm as well as shoulder-arm are extremely comparable. Pain and paresthesia in the wrists, hands, and fingers, together with shoulder-arm weariness, are identified as annoyances that need to be reduced or eliminated in the two surgical instruments [31].

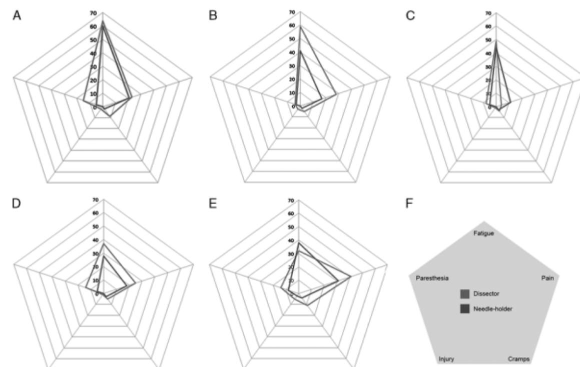

Figure (3): The following factors can lead to issues with different body parts: (A) prolonged tension; (B) extended static postures; (C) precise repetition of movements; (D) extreme force; (E) excessive joint positions; and (F) caption

Next, list the primary dimensions that should be taken into account while designing the instrument's handle as shown in Fig.4.

- Hand's width at metacarpal (c)
- Palm's length (b).
- Hand's length (a).
- Width of index finger, distal
- Width of index finger, proximal (e).
- Length of index finger (d).
- Thumb's width [32].

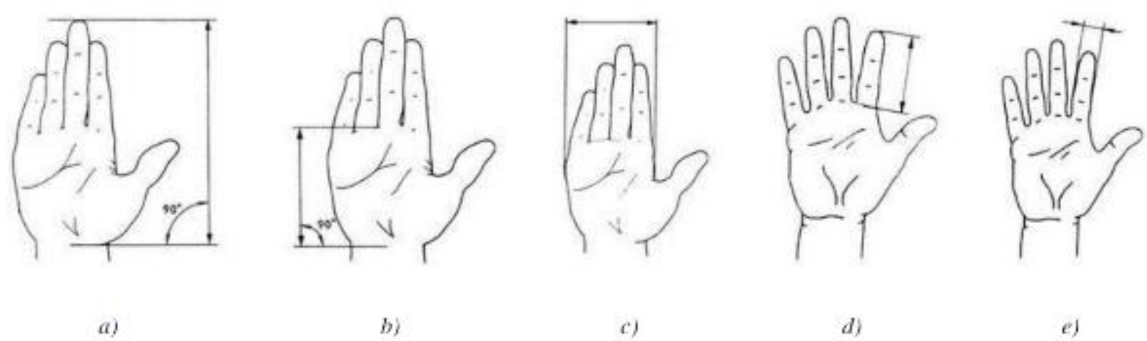

Figure (4): Dimensions of the hand that considered in designing the handle.

EMG data was utilized in order to compute the cumulative muscular workload (CMW), which measures the amount of muscular energy used while doing a task. The dominant arm's flexor carpi ulnaris, triceps, extensor carpi radialis, trapeze muscles, and deltoid were all assessed. [33]

6. Application

Redesign the needle holder to a new Pen Needle Holder shown in Fig.5. The pen needle holder is made to resemble a pen so that the surgeon may grip it with ease. It replaces the traditional needle holder.

cutting the sutures inside the needle holder without using a different pair of scissors.

The problems could be solved with the proposed Pen Needle Holder illustrated as it is that instead of using the entire hand in pistol grip, our instrument design allowed the user to hold it with pencil grip between the index finger and the thumb.

While the pencil grip allows the instruments to be positioned with fine finger motions, pistol grip necessitates using elbow, coarser wrist, and shoulder movements to handle the instruments.

Pen Needle Holder design follow the FDA requirements as the definition of a medical instrument by its intended use and indications and the classification as part 878 -- general and plastic surgery devices, subpart E - Surgical Devices, Sec. 878.4820 Surgical instrument motors and accessories/attachments [35].

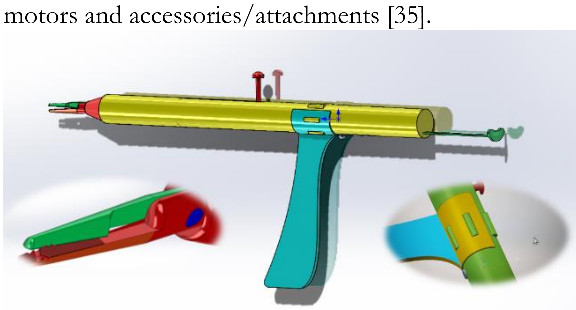

Figure (5): The proposed design of pen needle holder in SOLIDWORK 2022.

7. Discussion

We need to study the designs of well-known instruments, assess them based on microergonomic criteria, and after that adapt them for making the surgeon's hands use them more effectively. For instance, the principle of penization, a part of microergonomics, will alter how the instruments are handled because writing is the most complex task the hand performs; writing is the hardest task for the hand to perform and takes years to become proficient at. We could move it effectively and with little effort in any direction by using the pen. Electronics integrated with surgical instrument might involve attaching unique electronic circuits to the instruments for carrying out specific electronic tasks and enable the surgeon to conduct their work with minimal effort and precise outcomes. As an example, consider our effort in constructing a pen-shaped needle holder—a modification of the traditional needle holder that allows the surgeon to simply control it with their hand—in accordance with the penization concept. Additionally, according to EISI, some motors could be implanted with the needle holder. Those motors feature sensors for high resistance, or if the needle is going through tough tissue; they will hammer the needle to make it go through the tissue more easily. This helps the surgeon avoid using too much force by lifting the needle holder with their hand.

8. Conclusion

The goal of creating new microneurosurgical instruments and transforming their form into pens will be the focus of future instrument design. It is possible to combine instruments to form a single component. For example, a needle holder with scissors at the base might be made so that the surgeon may cut and tie the knot by themselves. Although the phrases "penization," "microergonomics," and "electronics integrated with surgical instruments (EISI)" do not exist in the English language, we proposed utilizing them to characterize a recent trend in the development of microsurgical tools. In order to facilitate the use of these instruments on rough tissues, the upcoming neurosurgical instrument generation will be hybrid devices with integrated electric motors.

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