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Optimisation of a laparoscopic tool handle dimension based on ergonomic analysis

Alfonso González Gonzalez [a,*], David Rodríguez Salgado [b], Lorenzo García Moruno [c]

[a] *Department of Mechanical, Energy and Materials Engineering, University of Extremadura, Mérida, Spain*
[b] *Department of Mechanical, Energy and Materials Engineering, University of Extremadura, Badajoz, Spain*
[c] *Department of Graphical Expression, University of Extremadura, Mérida, Spain*

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ABSTRACT

The techniques of Minimally Invasive Surgery (MIS) have quickly entered everyday surgical practice, and are steadily displacing traditional procedures. The reason is the advantages they have for the patient, both during surgery and in postoperative recovery. However, poor ergonomic design of the instruments used in MIS causes surgeons muscle fatigue and injuries (such as paraesthesia, etc.), forcing them to refrain from performing operations for several days or even weeks, which supposes costly losses of time and money.

The objective of the present study was to optimize the handle size of a laparoscopic grasper tool. The study was conducted with the participation of 135 surgeons. Each participant performed a series of trials in which they executed the same action several times with the same tool (same in terms of the geometrical form of the handle) but of different dimensions (size) in order to determine the optimal diameter. The results were then subjected to a statistical analysis to study the relationship between the size of the surgeon's hand and the perceived optimal diameter of the handle from an ergonomic point of view.

There stands out among the conclusions drawn from the study that there is indeed a relationship between the size of a surgeon's hand and the optimal handle size for them to use in surgery. In this sense, one of the most relevant results is that it is necessary to consider four different handle sizes groups (XS, S, M and L) instead of the three groups proposed by Greiner (1991). Another interesting result is that all surgeons in the smallest handle size group (XS) were women, and in the L group were men. Also it was interesting to note that, for the intermediate hand sizes (S and M), the sex of the surgeon conditioned the optimal handle size, and that the surgeon's experience and surgeon's handedness were not factors affecting the optimal diameter of the handle.

Relevance to industry: The results of this work can assist designers of grasping tools in developing better handles and provide required sizing for improved comfort, performance and lowering the risk of cumulative traumatic disorders. It is important to note that it is not necessary to design the handle of the grasper tool for each surgeon hand, but also with four hand size categories is possible to offer an appropriate handle size for all surgeons independently of their hand sizes.

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1. Introduction

The optimal design of the handles of precision tools has been the object of study for several decades. For example, Zanella and Gubian (1996) described a conceptual model for design management, which has subsequently come to be widely used. Welcome et al. (2004) developed a methodological approach to the measurement of the contact force at a tool's hand/handle interface, and to identify the relationship between this force and the grip and push forces. Kong and Lowe (2005) analysed the maximum grip force on cylindrical aluminium handles to evaluate the relationships between handle diameter (25–50 mm), perceived comfort, and the finger or phalanx force distribution. Other works have presented interesting analyses of different tool handles, for example, Björing et al. (1999) studied the optimal surface material

* Corresponding author. C/ Sta. Teresa de Jornet 38, 06800 Mérida, Spain. Tel.: +34 924 289300.
E-mail address: agg@unex.es (A.G. Gonzalez).

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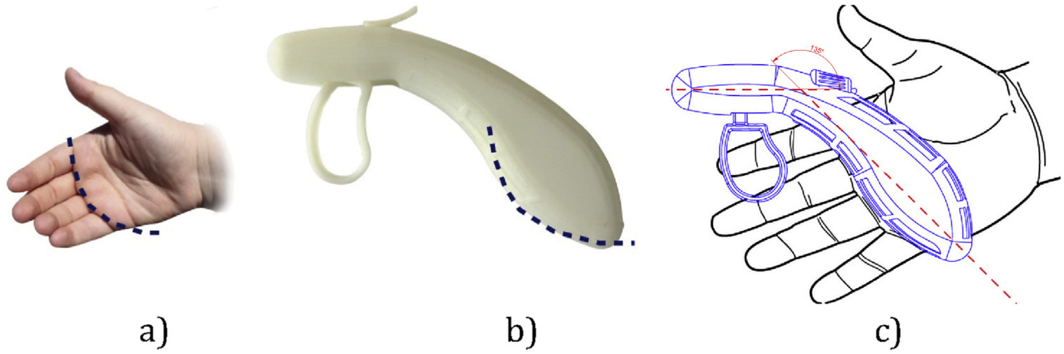

Fig. 1. a) Hand line used in the definition of the handle shape, b) correspondence between hand line and handle shape, c) Virtual mock-up showing the correspondence obtained in the handle design (ERGOLAP project).

and cross-section of power tool handles, and Sancho-Bru et al. (2003) studied the ideal diameter of a tool handle for men and women using a biomechanical model of the hand. More recent works, as the published by Dong et al. (2007), studied the design of a periodontal instrument, and found that a handle with a tapered and rounded shape with a diameter of 10 mm, required the least muscle load and pinch force when used by the periodontist. Garneau and Parkinson (2012) proposed a decision-making strategy to help designers configure multiple sizes of a product to ensure optimal performance in terms of comfort, safety, etc., across a given population of users or to maximize the satisfaction of the greatest number of users. Recently, Rossi et al. (2012) found that the relationship between the hand length/handle diameter ratio and the maximal grip force fit a U-inverted curve with maximal values observed for a handle diameter measuring 17.9% of the hand length; Harih and Dolšak (2013) developed an anatomically-accurate static digital human hand model based on magnetic resonance imaging (MRI) and an optimal power-grasp posture with undeformed soft-tissue and Harih and Dolšak (2014) showed that a badly-shaped handle area can have great impact on the overall comfort rating of the handle.

The focus of the present study was the design of the handle size of a laparoscopic grasper. The handle design (shape) of this instrument (Fig. 1) was developed in collaboration with the Jesús Usón Minimally Invasive Surgery Centre (JUMISC) of Cáceres, Spain (González et al., 2010, 2011; Ergolap Project, 2010). This handle design is based on the results of the ERGOLAP project, in which the authors and the JUMISC worked (2007–2010). As result of this Project, the handle of Fig. 1 was designed. This handle (shape) was developed using rapid prototyping techniques and its design was tested and valeted using a trial an error methodology. Fig. 1a and b shows how the handle shape has correspondence with the hand line represented, and Fig. 1c shows a virtual mock-up of the correspondence between hand and handle design.

The final shape of the handle was obtained after a trial-error design process. The evolution of the shape of the handle was carried out in the ERGOLAP project. For this purpose, different tests were used to obtain information: analysis of the EMG signals corresponding to the activity of various muscles with CyberGlove, analysis of the signals from goniometers; and the opinion of surgeons using questionnaires and interviews. Fig. 2 shows how these tests were conducted.

The widespread and increasingly extensive use of laparoscopic surgery has highlighted specific injuries related to the use of the tools developed for the technique. Although this surgery is relatively recent, there have already been studies about problems related with injuries suffered by surgeons during surgery (Berguer et al., 2003; Smith et al., 1998; Hemal et al., 2001; Quick et al., 2003; Berger et al., 1999; Matern et al., 1999; Van Veelen and Meijer, 1999).

These studies together with surveys of surgeons (Ergolap Project, 2010) show that the current instruments used in

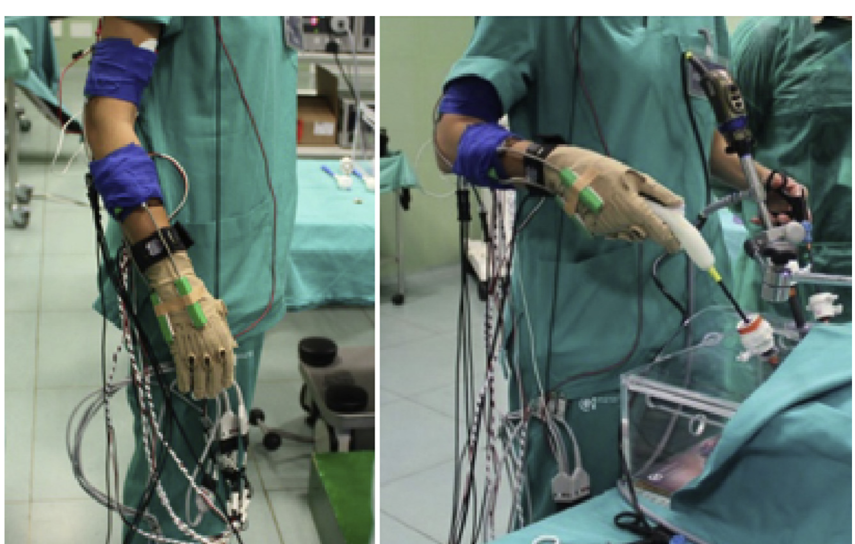

Fig. 2. Tests made for the determination of the handle shape.

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