INDEX

.

PROLOGUE

The present work has been motivated by my scientific restlessness (meaning: I am a believer in science and in its capability of solving people's real problems), physician (concerned about human health questions) and dedicated, for over 35 years, to general surgery and orthopedics, the most recent of them almost exclusively to hand and forearm and their relation with the computer mouse use.

Having reached the conclusion that the serious health problems which affect users of such an ingenious instrument occur exclusively due to mistakes, be it in their design or in their development and final shape, I had the urge to alert users, manufacturers, physicians and/or physiotherapists and those organizations closely related with this matter interested in finding a solution (OSHA, NIOSH, Secretary of Labor, AFL CIO, Ergonomic Programs of Universities, etc.).

I strongly believe that the only logical solution to prevent the already mentioned suffering is the Orthopedic Computer Mouse (OM) - (Clinical studies with over 400 volunteers, some of them with serious clinical problems, for over 9 years, have already demonstrated it).

For this reason, and from a strictly scientific point of view, this work (step by step in each evaluation) has references to the most prestigious, recent and renowned scientific authorities, researches and/or world bibliography about the subject, which include countries like United States, France, England, Sweden, Argentina, Brazil, etc.

The idea, development and practical use of the Orthopedic Computer Mouse and its enormous differences with former mice are fruit of deep analysis of medical concepts.

This study includes critical evaluation of four different mice models, two of them with important market share.

The conclusion is: with the scientific knowledge available nowadays, it is not to be forgiven to accept medical statistics referring to postural diseases and remain oblivious to them. There are concrete measures to change this situation drastically (it is not a divine punishment, nor an inherent and unsolved suffering).

We are talking about real suffering of millions of real people.

We must be responsible and cannot remain unmoved. Everyone involved must react with accountability.

The road is open, it is feasible to us.

Thank you.

Julio Abel Segalle; M.D.; Ph.D.

THE ORTHOPEDIC COMPUTER MOUSE

Introduction

In 1968 Mr. Douglas Engelbart and his team at Stanford University invented a device that realizes functions such as fetching and signaling on computers screen and on/off buttons for some variables. They created a device that complies with functional requirements and gave it the shape and movements that are similar to those of a mouse, hence the name. Today, 40 years later, the mouse technology has improved exponentially, yet the reasoning behind the creation of its shape has remained the same focusing primarily on commercial reasons and/or aesthetics. This document will make it clear that the Orthopedic Computer Mouse (OM) is the only logic solution to prevent repetitive strain injuries (RSI) stemming from the use of computer mice, an increasingly common problem in our modern society. First, it will explain why the conception of mouse design is wrong from the start and what the consequences of such a mistake are. Second, after answering a few important questions, it makes the important distinction between ergonomics and orthopedics. Third, the position of function, the medical concept on which the OM is based, will be thoroughly described. Fourth, it will define the different parts that constitute the OM. Finally, this work will analyses the important differences with regards to the OM.

In today's world, the notion that image is everything has gained much importance, maybe even too much. People will buy a given product based on its looks, therefore disregarding important characteristics raging from price to safety. The computer mouse serves as a good example to prove this point. More than a fancy peripheral to your computer, it is first of all a manual tool. This fact must not be overlooked during its design stage. As John Napier reports in his book "It should be a relatively simple matter to design a handle for a single-purpose tool. A careful analysis of the intended activity under all sorts of environmental conditions and situations, will determine the most efficient grip, whether precision or power. Errors of judgment, however, are still only too common... Humans have passed from tool-users to tool-makers and now-somewhat ironically-back to tool-users again. There are a few craftspeople left who make their own tools, but not many; tools are no longer personal creations of craftspeople (whose survival once depended on their effectiveness) but are the standardized products of commercial tool-makers. Tools made for the uncritical domestic market are the worst offenders; shapes of handles are more often chosen for their packaging and their modern design qualities than for their functional suitability. Early people in the throes of constructing hand-axes never made that mistake; their lives and livelihood depended on it."[1] The human hand is so complex and delicate that a small variation in the way in which it is used and/or supported is automatically detected. The fact that the mouse is a manual tool and that it can bring about serious consequences, if not built properly, is something to keep in mind. Unfortunately, the mouse does pose severe problems.

The existing shapes of computer mice and their use are the direct cause of numerous computer-related RSI problems (e.g. tendinitis, bursitis and Carpal Tunnel Syndrome – CTS). The statistics that support this claim are quite alarming:

- According to a 1995 study by the United States Occupational Safety and Health Administration (OSHA), "1 in every 6 users suffers from serious injuries"[2] (In a universe of 350 million, that would amount to 60 million users).
- "It is about helping real people suffering from real problems, problems like back injuries, carpal tunnel syndrome, tendonitis, not minor aids or pains, but serious, life alteringinjuries", says Alexis Herman – U. S. Labor Secretary. Every year, the department says, 8 million workers experience what are called muskulo-eskeletal disorders or MSDs, and a third of them are serious enough to require time off from work. "When more than 600,000 americans workers have to take time off from work to recover from MSDs, and over a million more experience less serious MSDs problems at work, we know that we have a national problem.", complements Charles Effres- OSHA Administrator. Information gathered in CNN News , 5 pm- 11/22/99.
- "Cumulative trauma disorders due to performance of repetitive tasks account for more than 50% of all occupational illnesses in the U.S.A. today. Employees affected by these disorders frequently experience substantial pain and functional impairment that may require a change in occupation. For the employer, these injuries result in loss of productivity and increased costs in the form of higher medical expenses and disability payments for injured workers."[3]

In addition to these data, both medicine and modern science bring invaluable information.

Pathophysiology and epidemiology

Pathophysiology (or physiopathology) is the scientific study of functional changes associated with or resulting from disease or injury. Epidemiology is the branch of medicine that deals with the study of the causes, distribution and control of disease in populations. Having said that, this section will have two main objectives: 1) to shed some light into the general development of RSI and 2) to make clear that, although intensity and repetition are important variables in the development of RSI, bad posture is the direct cause of such problems since it implies extra effort. "When force is applied repeatedly over a prolonged period to the same muscle group, joint or tendon, cumulative forces may cause soft-tissue microtears and trauma. The resulting injury and inflammatory response may lead to tendon and synovial disorders, muscle tears, ligamentous disorders, degenerative joint disease, bursitis, or nerve entrapment.

Carpal Tunnel Syndrome illustrates the biological plausibility of a CTD [Carpal Tunnel Disease] developing over time as result of repetitive task-related efforts. Pressure inside the carpal tunnel can increase from 3 to 30 mm Hg with the wrist in extreme extension or flexion, or with high force applied to flexor tendons. Repetitive wrist or hand motions can also cause prolonged, elevated pressure inside the carpal tunnel, which may diminish blood flow to the nerve and cause nerve block."[4]

Ribeiro Herval Pina explains in his book that “Under an etiopathogenic point of view, in the root of these processes would be the trauma caused by postures and movements – voluntary or not – varying in intensity, time and frequency which are disproportionate to the morphology and physiology of the tissues submitted to their actions.”[5]

Along the same lines, Dr. David Rempel informs us that "Preliminary studies have also indicated key risk factors for the development of these injuries. Work-related risk factors associated with CTD’s include: repetition high force; awkward joint posture; direct pressure; vibration and prolonged constrained posture."[6]

The shapes of existing mice force the user to adopt an awkward posture, which in turn requires repetitive effort from the user. The statistics are staggering and the evidence is overwhelming: the shape of the mouse is a direct cause of health problems.

The problem with the computer mouse is medical rather than technical. **The use of the mouse during prolonged periods is considered a form of immobilization of the hand and forearm (in function).** Therefore, the laws and medical knowledge that establish the basis to be considered in these processes must be respected. Evaluations that are deemed to judge the quality of such products (i.e. ergonomic devices) must be left to the hands of specialized medical doctors (orthopedists and/or hand surgeons).

We believe, however, that the imprinted circuit board may be a deterrent for manufacturers to “think outside of the box.” It is flat, with activating switches (usually two) for "mouse clicking" which require vertical movement. It is a standardized and mass produced part.

Classic Medical Knowledge, backed by modern medical science, enables a very different approach to be taken in order to solve that problem: "Physicians also have the opportunity to make a substantial contribution to the prevention of work-related CTDs."[7]

In addition to the medical knowledge, modern science provides information of the utmost importance. "These data may be useful in the design of tasks and hand tools in the management and prevention of CTS."[8]

In order to perceive and understand the difference between the OM and former mice, however, one must first understand the difference between these two different fields: ergonomic and orthopedics.

Ergonomics vs. Orthopedics

Ergonomics is “the applied science of equipment design, as for the workplace, intended to maximize productivity by reducing operator fatigue and discomfort.”[9] Some ingenious inventors have tried to improve mouse use and imagined various modifications to the conventional mouse (sizes, shapes, disposition, etc…) basically trying to adapt the pre-existing mouse to the user hand. Such products would eventually make the task *less stressful* and bring about *possible improvements but not necessarily perfection (from the orthopedic point of view)*. Any change improving the device’s use over the original one, for as little as it may be, will upgrade the device to the status of *ergonomic*. That does not, however, mean it will be *effective (innocuous)*. With previous mouse models, the user's hand had to perform *active compensation* of positions and/or movements due to the little or lack of ergonomics as well as the feedback that exists between sensory and motor functions. "If sensory function is impaired, the worker may adopt a more forceful grip, awkward posture, or other compensatory maneuver that can add further injury. It has been demonstrated that fingertip force applied to tools is increased under conditions of diminished sensation ...Increasing grip force can raise carpal tunnel pressures, worsen median nerve function and accelerate carpal tunnel syndrome."[10]

At the other end of the spectrum there is orthopedics, which is “the medical study and skill of treating bones which have not grown correctly or which have been damaged. An orthopedic device is one which helps people who have an injury involving the bones.”[11] According to this definition, the OM can be characterized not only as a pointing device but also as a *medical* one designed to avoid dysfunctions and/or deformations of computer users’ hands. With the OM, the user’s hand and forearm will suffer no strain of any kind since they will have *passive adaptation* (total rest). **The OM was specially designed and to fully comply with the following premise: the hand and forearm work and/or rest in the position of function** hence avoiding the usual problems common to users of the previous mice. The OM “forces” both the hand and forearm to adopt the correct posture, as an orthopedic device would.

From the above, it is possible to accept that there are various levels of ergonomics in any given device, and any change in the shape of a tool that improved its use is advancement. From the Orthopedic field point of view, any variant as small as would be to a prescribed shape (in this case: “the position of function”) is an intolerable aberration.

The "Position of Function"

Raoul Tubiana M.D., former president of the International Federation of Societies for Surgery of the Hand, points out in his book entitled The Hand (considered as "the Bible" of hand surgery) that **"Few concepts have been more useful in saving injured hands than that of the position of function."**[12]

"The term ‘position of function’ seems to have been used first by Kanavel (1925). This descriptive expression has been employed commonly and the concept it implies has been most useful in the prevention of numerous complications after immobilization of the hand. The position of function has been described by Bunnell (1948) as follows: **‘The**

hand at rest assumes a certain position. This is largely the midposition of the range of motion of each and every joint, including the wrist and rotation of the forearm. The muscles are all nicely balanced so that at their normal tone, when at rest, the position called the position of function is assumed...The forearm is half-way between pronation and supination. The wrist is in about 20° of dorsiflexion and 10° of ulnar flexion. The fingers are slightly flexed in each of their joints, the index being flexed least and the little finger most. The thumb is forward from the hand in opposition and its joints are also partially flexed' ... Each and every 'position of function' must endeavor to bring together a number of favorable conditions that are not always compatible with each other. They are those that place the joints in a position in which grasp is easy, in which stiffness is less likely to occur and finally, in which eventual stiffness, will permit preservation of movements of small amplitude, in a useful range. In practice the term position of function, as it is commonly used, is applied equally to two very different situations (Beasley and Kester, 1979). **On the hand, in a case of temporary immobilization, its main function is protection..."**[13]

A

Figure 53–6. The so-called position of function.

Fig. 1

The use of this concept as the basis of this work enabled the achievement of a shape such that the mouse itself supports the hand and forearm, while they adopt *the only correct and innocuous position for mouse use.*

The ORTHOPEDIC COMPUTER MOUSE

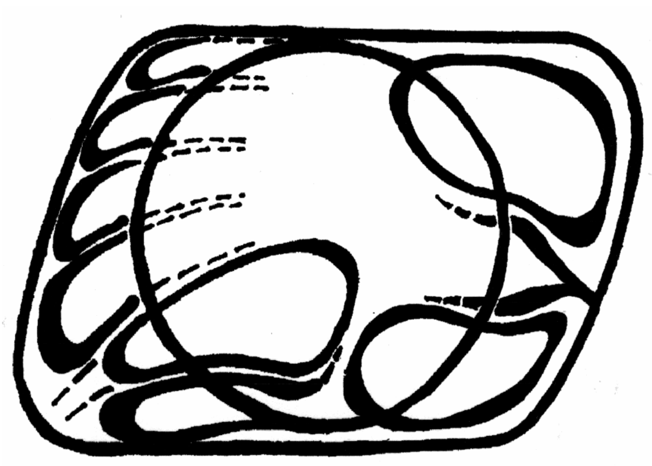
Instead of trying to adapt the pre-existing shapes, a totally new one which is based on the anatomical structure of the hand and forearm and which complies with the strictness of the classic medical knowledge and modern medical science was created.

Next, all the necessary mouse functions were incorporated to such new shape. It was then possible to build a mouse that is basically harmless: the OM.

The OM is not a collection of characteristics copied from other mice since it is its absolutely unique, precise and complete. Any small changes that may be contemplated to the position of function and hence to the final shape of the mouse, would invalidate the idea of a whole and integral function because**:** **"Each and every position of function must endeavor to bring together a number of favorable conditions that are always compatible with each other."**

Characteristics of the ORTHOPEDIC COMPUTER MOUSE.

The following is an analysis of the different parts that constitute the OM and how each one of them strictly complies with medical concepts.

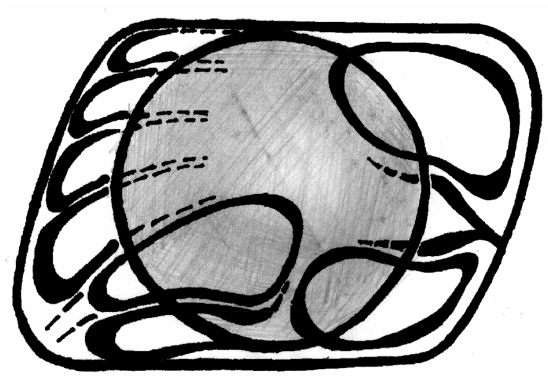


Schematic diagram showing the different parts that constitute the OM

Fig. 2

1) Basic shape, hemisphere:

That follows the suave reliefs of the human hand (in negative).



Schematic diagram of the OM. In evidence, the basic hemisphere

Fig. 3

Concepts that support this shape

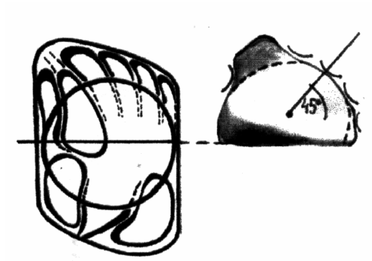
Perfect adaptation to the hole of the hand (palmar cup) in its exact anatomic location, on a longitudinal and on a transversal axis. The OM's central basic form is a hemisphere with the relief of the human hand (in negative) and the hand is supported basically curved (hemisferic) and inclined. *The fingers are in "slight flexion" and the metacarpophalangeal joints in 45^{o}*.

Figure 53–2. The "palmar cup." The palm of the hand can be cupped because of the mobility of the peripheral metacarpals. Immobilization that does not maintain the transverse arch of the metacarpals will cause flattening of the hand.

Fig. 4

Its inclination forces:

- *The hand to rest in an angle of 45º* with respect to the horizontal surface of support and displacement of the OM;

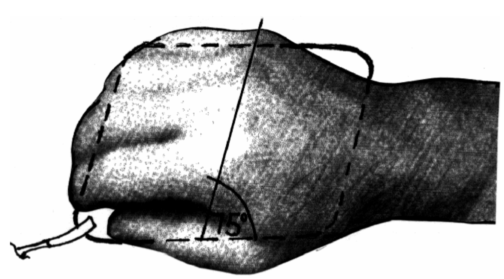


Schematic diagram showing a transversal cut through the basic hemisphere

Fig. 5

- *The forearm to assume a mid-pronation position of 45º* ... "Highest mean pressures (55 mm hg) were recorded in full supination and 90º MP [metacarpophalangeal] flexion *and lowest pressures (12 mm hg) were recorded at 45º pronation and 45º MP flexion* ... The extension/flexion and ulnar/radial deviation postures associated with lowest carpal tunnel pressure can now be expanded to include a forearm rotation angle near 45º pronation and an metacarpophalangeal joint angle of 45º. This set of postures should be considered during the design of hand-intensive tasks and hand tool in order to minimize carpal tunnel pressure during repetitive activity."[14]

Furthermore**,** when the hand is on the OM, *the metacarpophalangeal joints are at rest in an angle of approximately 75º* with respect to the axis.



Right hand on the OM showing the angle that is formed between the metacarpophalangeal joints and the axis.

Fig. 6

"The transverse axis of the palm, which corresponds to the metacarpophalangeal articulations, is not perpendicular to the longitudinal axis, represented by the median radius. Instead this transverse axis is oblique, more distal at the metacarpophalangeal joint of the index finger and more proximal at the fifth metacarpophalangeal joint. *Thus it forms an angle of approximately 75 degrees with the longitudinal axis."* [15]

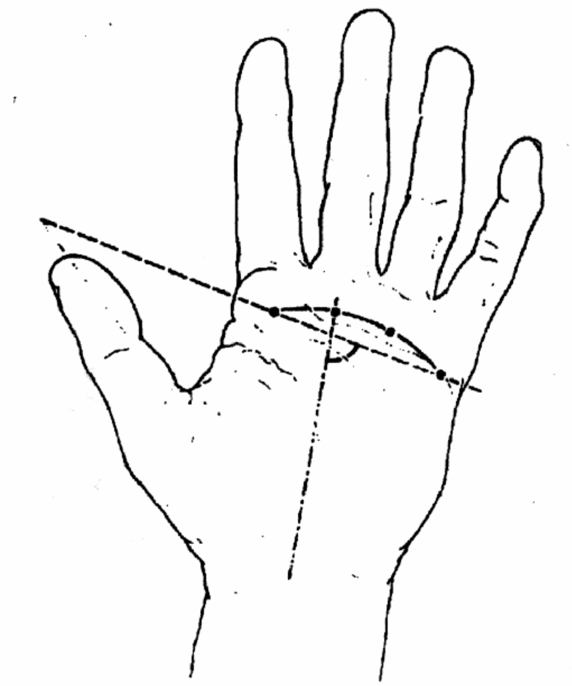


Figure 53–3. Obliquity of the transverse axis of the palm. The line passing between the heads of the second and fifth metacarpals is not perpendicular to the long axis of the third metacarpal but forms an angle of 75 degrees with it, the line being proximal on the ulnar side. The axis of the palmar gutter is still more oblique and follows approximately the distal part of the opposition crease of the thumb.

Fig. 7

The basic shape is in direct accordance with the palmar cup. "The skeleton of the hand has a double concavity – transverse and longitudinal that gives it the shape of a cup with a palmar concavity (Figs. 4 and 8).

It is essential for the grasping function of the hand that these concavities be preserved."[16] "It is essential for the prehensile role of the hand that these curvatures be respected in both their longitudinal and transverse axes."[17]

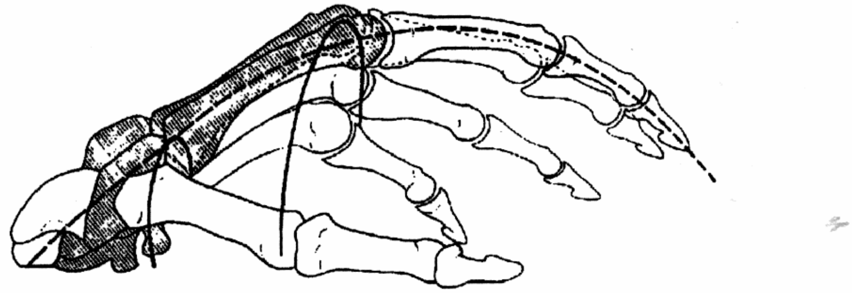


Figure 53–1. Arches of the hand. On a lateral view one can see the longitudinal and transverse arches of the hand. The part of the skeleton remaining in a fixed position is cross hatched.
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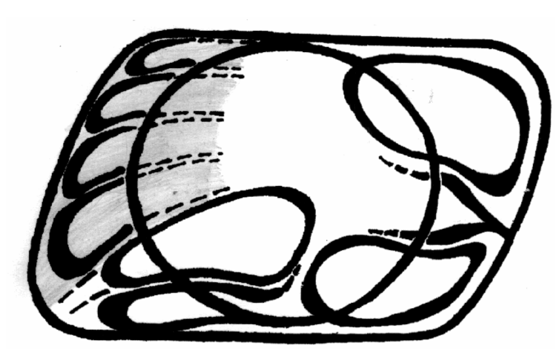
Fig. 8

The conventional mouse does not have any hemispherical surface to support the hole of the hand. The basic hemisphere collaborates with the other components of the OM so that the users' hand rests in the position of function.

2) Forward prolongation for fingers' support:

Is composed of an area that continues imperceptibly from the hemisphere onwards. It possesses the shapes, in negative, of the imprints of all the fingers. The necessary buttons are located (1,2,or 3) in these depresions. Said buttons are disposed in a general orientation of approximately 75º of antero-posterior inclination and about 45º of lateral inclination with respect to the horizontal plane. Therefore, the button activation happens in a generally horizontal position (10º to 20º). The forward end of said shape is slightly elliptical, with a predominant angulation of 75º in respect to the axis. Button terminations are semi-circular, and slightly concave much like the shape of the finger pulps.



Schematic diagram of the OM. In evidence, the forward prolongation for fingers' support.

Fig. 9

Concepts that support this shape

The OM further possesses the following characteristics of originality with respect to finger position:

- The shape of the buttons helps the fingers to find their exact location immediately through a proprioceptive sensitivity feedback.

Inclination between the distal phalanx and the horizontal plane ---------------- About 70-80º
Inclination between the medial phalanx and the horizontal plane----------------About 50-60º
Inclination between the proximal phalanx and the horizontal plane--------------About 20-30º
Inclination between the proximal phalanx and its correspondent metacarpal ------------ About 45º

"The fingers are slightly flexed in each of their joints, the index being flexed least and the little finger most."[18]

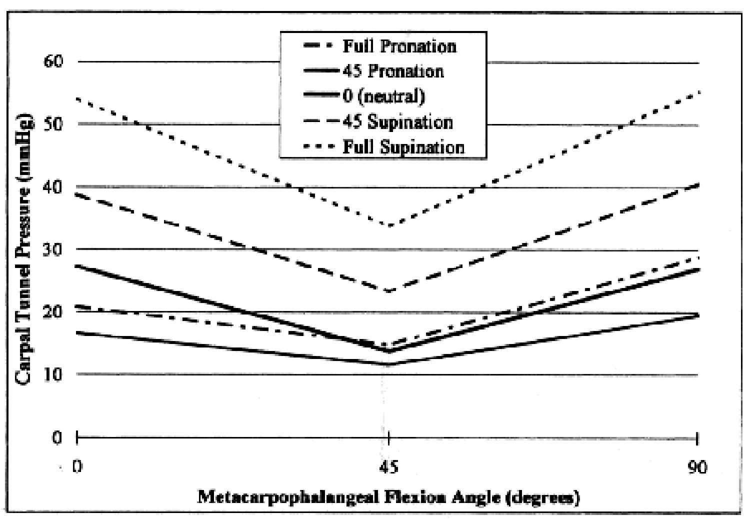
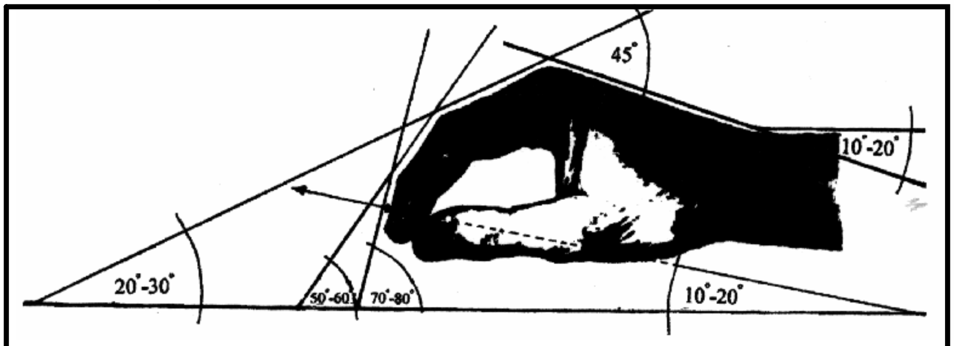


Figure 2. Graph of the mean carpal tunnel pressure versus metacarpophalangeal angle for 17 healthy test subjects at 5 forearm pronation/supination angles. These are the same data as in Figure 1.

Fig. 10

"Highest mean pressures (55 mmhg) were recorded in full supination and 90º MP (metacarpophalangeal) flexion *and lowest pressures (12 mm hg) were recorded at* 45º pronation and *45º MP flexion."*[19]



Position of the hand when at rest or working on the OM.

Fig. 11

Such characteristics, which are all equally important elements of "the position of function", fulfill the important function of allowing and forcing the fingers into a position of perfect muscular balance between the finger flexor and extensor muscular groups.

The consequences are:

- *Elimination of accidental clicks;*
- *Button activation function is carried out without muscular effort or complex neurological coordination* between the antagonist muscular groups since it start from a position of absolute anatomic and functional rest. " 'This so-called position of function,' says White (1960) in a humorous manner, 'has all the wisdom of parking a bulky old car with a weak battery on a hill. From this position, it is easy to get started again.' "[20]
- *Only instantaneous flexor contraction is required to activate the buttons* (muscular group that accepts overload better than the extensors). "Movements of extension of the fingers and of the hand itself, under a functional point of view, are philogenetically subordinated to the previous relaxation of the flexor muscles that are destined to the act of grasping and that are much more potent than their antagonists, the extensors. (See fig.12). The alternation between flexion and extension and the musculotendinous tensions cannot go beyond certain limits in terms of strength or time interval between movements without jeopardizing the functional and morphological integrity of the tissues."[21]

In other mouse models, the orientation of such movements is a predominantly vertical. The generalized position of the fingers in horizontal extension on such mouse models (of variable levels) forces a permanent contraction of the extensor muscles. They must hence fight against a) the force of gravity and b) the flexor muscular tone (much more powerful than its opponent, which seeks equilibrium with the previous. (See fig.12) in order to remain in this position while avoiding accidental clicks.

For the strengths of the extrinsic muscles of the hand, the figures most often quoted are those of Lanz and Wachsmuth (1959) who themselves cite Fick (1921). These are their values in kilogram-meters (Boyes, 1962):

Muscle	Strength (kg-m)
Brachioradialis	1.9
Pronator teres	1.2
Extensor carpi radialis brevis	1.1
Extensor carpi radialis longus	0.9
Extensor carpi ulnaris	1.1
Flexor carpi radialis	0.8
Flexor carpi ulnaris	2.0
Palmaris longus	0.1
Flexor pollicis longus	1.2
Extensor pollicis longus	0.1
Abductor pollicis longus	
as a wrist flexor	0.1
as a wrist abductor	0.4
Extensor pollicis brevis	0.1
Flexor digitorum superficialis	4.8
Flexor digitorum profundis communis	4.5
Extensor digitorum communis	1.7
Extensor indicis proprius	0.5

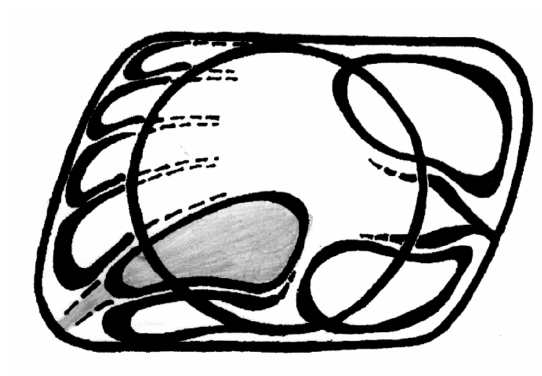
Fig. 12

"A number of forces are brought into play: a) the forces to which a solid object is subject, principally gravity and occasionally kinetic forces and b) the forces generated by the hand itself."[22]

The former mice do not have any forward prolongation from the hemisphere for fingers support.

The forward prolongation for fingers support collaborates with the other components of the OM so that the user's hand rests in the position of function.

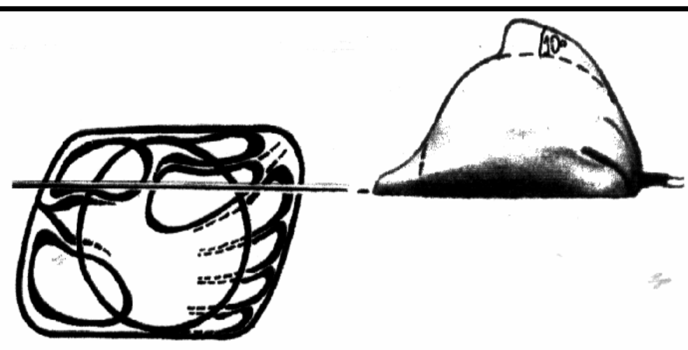
3) The Fork :



Schematic diagram of the OM, in evidence, the fork.

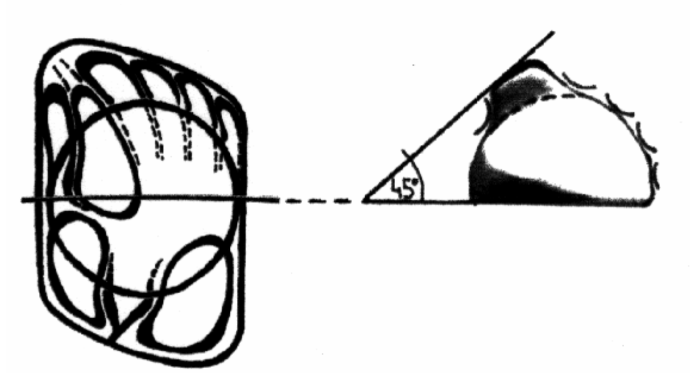
Fig. 13

Located near the top of the hemisphere in the antero-internal region, this predominantly triangular shape area (with three different sides) has the following characteristics: its sides and angles are slightly rounded. Its shorter side is posterior and descends until the back, where it blends imperceptibly with the internal region of the posterior prolongation. Its two longer sides describe arches of internal concavity descending on a curve until they imperceptibly blend with the antero-internal angle of the OM Its antero-posterior inclination and curvature are about 10º higher than that of the basic hemisphere.



Longitudinal cut that includes the fork.

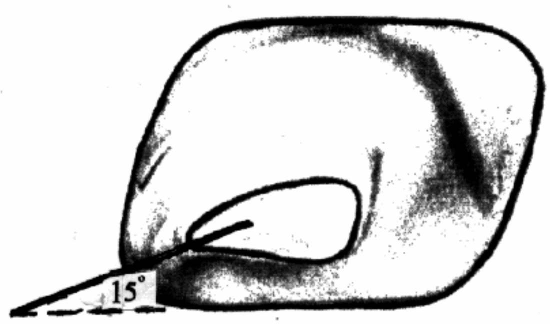
Fig. 14



Transversal cut through the basic hemisphere showing the inclination of the fork and the finger position.

Fig. 15

The lateral inclination is of approximately 45º and its general position follows an angle of about 15º with respect to the axis of the OM.



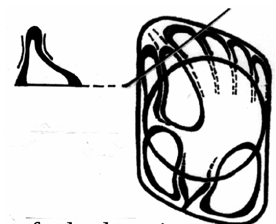
Top view showing the angle between the fork and the axis.

Fig. 16

The fork sides present a slight concavity to form the support surface for both the index finger (outward) and the thumb (inward). Such surfaces are opposed and get closer together as they go forward and downward.

Concepts that support this shape:

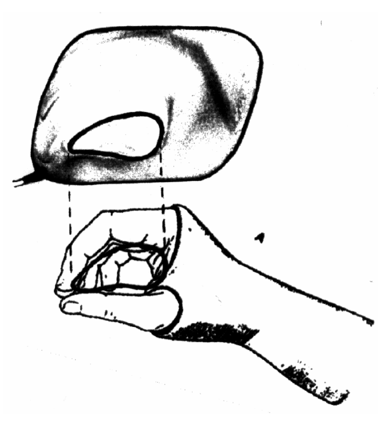
The fork has been especially designed to provide the most perfect possible "opposition" between the index and the thumb, and additionally, that both fingers are placed in a "pincer position", performed with "precision grip". These three concepts are fundamental components of "the position of function".



Cut through the fork showing the perfect opposition between the thumb and the first finger.

Fig. 17

"Perhaps the most important movement of the human hand is opposition. The movement of the thumb underlies all the skilled procedures of which the hand is capable. The hand without a thumb is at worst, nothing but an animated fish-slice and at best a pair of forceps whose points don't meet properly. 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. One cannot emphasize enough the importance of finger-thumb opposition for human emergence from a relatively undistinguished primate background. Through natural selection, it promoted the adoption of the upright posture and bipedal walking, tool-using and tool-making that, in turn, led to enlargement of the brain through a positive feed-back mechanism. In this sense it was probably the single most crucial adaptation in our evolutionary history... Opposition is a movement by which the pulp surface of the thumb is placed squarely in contact with – or diametrically opposite to – the terminal pads of one or all of the remaining digits."[23]



The above drawing shows the perfect correspondence between the fork area of the OM and the pincer position in the position of function

Fig. 18

"The thumb is forward from the hand in partial opposition and its joints are also partially flexed."[24] (See fig. 19).

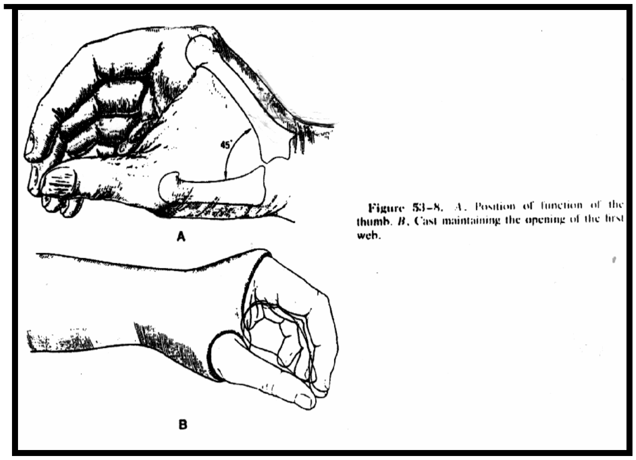


Figure 53-8. A. Position of function of the thumb. B. Cast maintaining the opening of the first web.

Fig. 19

The greatest sensibility in the hand with respect to position and movements is obtained in its maximum expression with the *precision grip*. This position is similar to the one assumed when holding a pen to write and/or draw, or the one that the thumb and index fingers adopt when leaning on the OM. *"Precision grip is employed when delicacy of handling and accuracy of instrumentation are essential and power is a secondary consideration."*[25] The functions that the mouse must perform require tremendous precision, thus the use of such a grip is vital to avoid unnecessary and harmful efforts.

The evolution of the written language, in virtually all cultures, led man to use feathers first and then pencils between the cushioned areas of the thumb and index fingers. The greatest number of peripheral nervous termination is found in this area. Large areas of the cerebral cortex, which give them unusual sensibility and special power to locate (proprioception), represent them in a way that cannot be found anywhere else in the human body, endowing this labor and/or function (i.e. writing) of great dexterity and precision. "The pulp is richer in sensor nerve endings than any other part of the body."[26]

"In other words, the number of cortical cell analyzers is proportional to the receptor concentration of the territory. ... Along these lines, in man, the hand occupies an extremely large area between that of the face and lower limbs. Tactile discrimination can therefore be represented by a point-by-point projection in a defined region."[27] The function of discrimination capacity is performed using Weber's two-point discrimination test, which shows the capacity of the finger pulp. (See fig. 20).

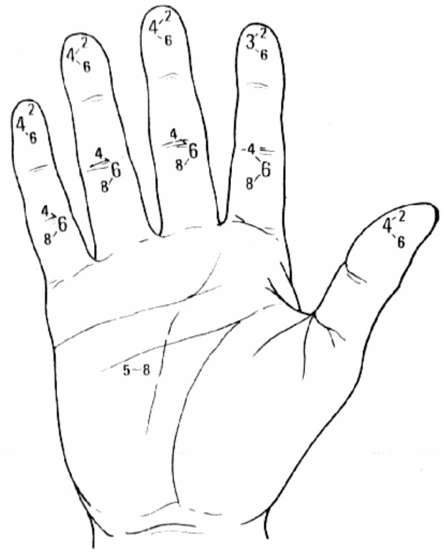
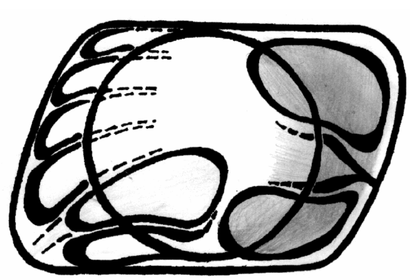


Figure 58–42. Values of discriminations in the Weber test in millimeters in the different zones of the palm. The largest figure indicates the average values, the two others the minimum and maximum values (after Moberg).

Fig. 20

Former mice do not have any fork that provide support, forcing the user’s hand in the form of “the pincer grip” and/or to work the pulps of the thumb and the first fingers in real “opposition”. The fork collaborates with the other components of the OM so that the user's hand rests in the position of function.

4) Posterior prolongation of the hemisphere for the support of the metacarpus:



Schematic diagram of the OM. In evidence posterior prolongation of the basic hemisphere for the support of the metacarpus

Fig. 21

It consists of a slightly convex area of triangular shape that continues imperceptibly from the hemisphere backwards, with an inclination of 45º with respect to the axis, reaching the posterior border. Said elevation falls towards the posterior-external angle in an accentuated concavity and towards a posterior-internal angle in a slight concavity. Said prolongation separates the two resulting concave surfaces: a) the internal on a higher level and b) the external descending to reach the bottom surface. The rear end of said shape is slightly elliptical with a main angulations with respect to the axis of approximately 75º.

Concepts that support this shape:

This area was especially designed to accommodate the metacarpus, wrist and forearm in "the position of function"

The metacarpal region possesses, as a continuation of the hole of the hand towards the wrist, two predominantly muscular eminencies separated by a depression. This shape of the hand perfectly corresponds to the shape of the posterior prolongation, where the thenar eminence meets the internal depression, the hypothenar eminence meets the external depression and the center of the posterior prolongation meets the furrows formed between these two eminencies.

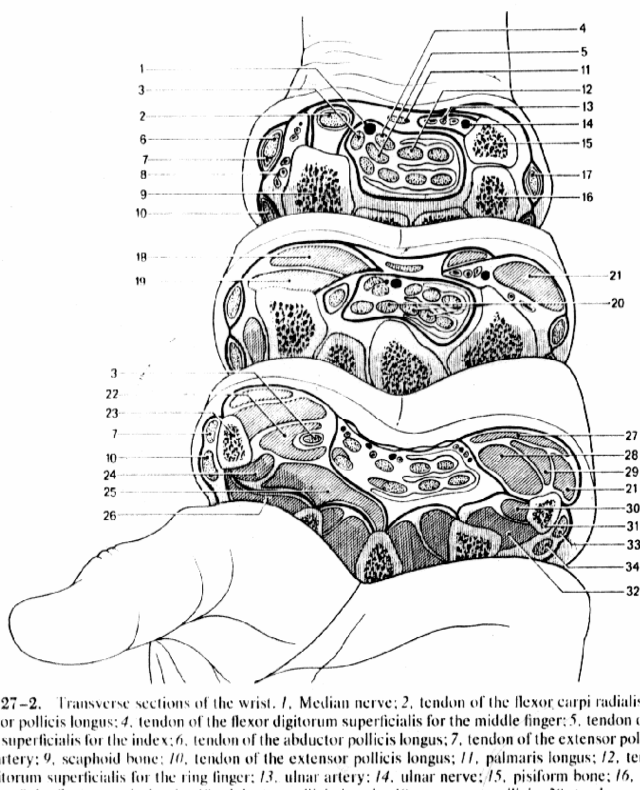


Figure 27–2. Transverse sections of the wrist. *1*, Median nerve; *2*, tendon of the flexor carpi radialis; *3*, tendon of the flexor pollicis longus; *4*, tendon of the flexor digitorum superficialis for the middle finger; *5*, tendon of the flexor digitorum superficialis for the index; *6*, tendon of the abductor pollicis longus; *7*, tendon of the extensor pollicis brevis; *8*, radial artery; *9*, scaphoid bone; *10*, tendon of the extensor pollicis longus; *11*, palmaris longus; *12*, tendon of the flexor digitorum superficialis for the ring finger; *13*, ulnar artery; *14*, ulnar nerve; *15*, pisiform bone; *16*, triquetrum; *17*, tendon of the flexor carpi ulnaris; *18*, abductor pollicis brevis; *19*, opponens pollicis; *20*, tendons of the flexor digitorum profundus; *21*, abductor digiti minimi; *22*, flexor pollicis brevis; *23*, first metacarpal; *24*, adductor pollicis—oblique head; *25*, adductor pollicis—transverse head; *26*, first dorsal interosseous; *27*, palmaris brevis; *28*, opponens digiti minimi; *29*, flexor digiti minimi brevis; *30*, palmar interosseous of the fourth space; *31*, metacarpal V; *32*, dorsal interosseous of the fourth space; *33*, extensor digiti minimi; *34*, extensor digitorum.

Fig. 22

The perfect support achieved with such a disposition is fundamental for the innocuous work of the hand on the mouse since these areas support most of the weight on the OM.

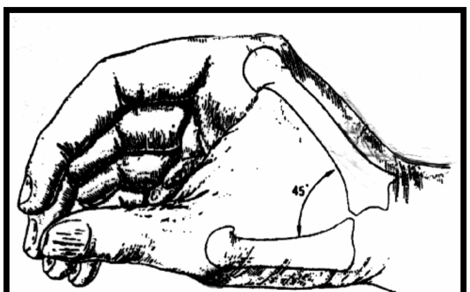
(The hypothenar is predominant in such a function on the OM, perfectly adequate since its function, by nature, is to support pressure). It is also desirable to possess two large cushioned surfaces to divide the weight that it supports. "We retain the five apical pads on the end of the fingers, three inter-digital pads and a hypothenar pad. The thenar pad has disappeared, the pad or "mount" of the thumb being largely a muscular eminence ... The hypothenar pad serves to cushion the pressure exerted by the handles of tool and weapons held in a power grip."[28] The special disposition in two height levels and the suave declivity in posterior direction of the delimited areas in the posterior prolongation determine that:

- *The carpus' inclination must be of 45º with respect to the horizontal plane.* (The inclination of wrist and forearm remains unchanged). (The same). (See fig. 23).

Cut through the posterior prolongation showing the perfect adjustment between the latter and the carpus and the final inclination of 45**º.**

Fig. 23

- *The opening between the first and second metacarpi must be of 45º* (The fork cooperates). "In this position, the angle between the first and the second metacarpal is about 45º."[29] (See fig. 24).



Position of function of the thumb.

Fig. 24

- *The angle of extension of the wrist must be between 0º and 20º.* "In 12 normal subjects, Gelberman and ass. observed that passive extension or flexion of the wrist caused the CTP to increase on average *from 2.5 to 30* mm hg."[30] "The lowest CTP occurred at mean wrist angles of 0º or 15º extension."[31]

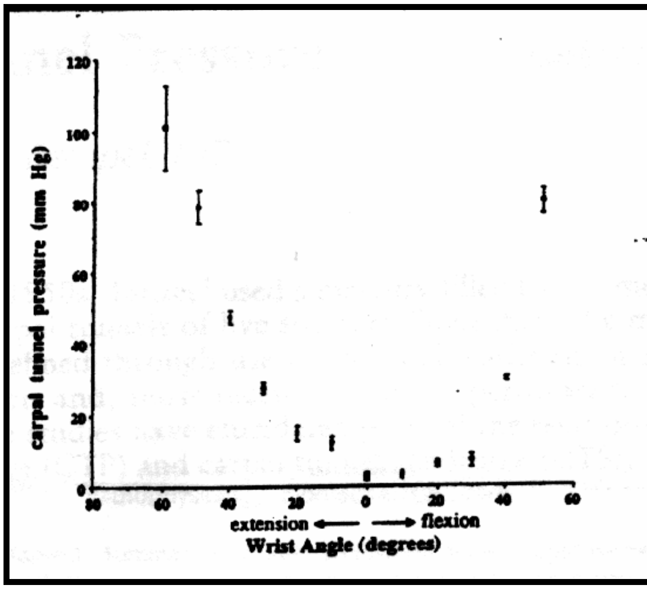


Fig. 1 Example of carpal tunnel pressure as a function of wrist extension-flexion in one healthy subject (error bars represent standard error). (Reproduced with permission from Weiss N, Gordon L, Bloom T, et al: Wrist position of lowest carpal tunnel pressure: Implications for splint design. *J Bone Joint Surg*, in press.)

Fig. 25

- *Ulnar deviation is too simple and elective* (about 10º)."In similar parabolic relationship is observed for ulnar-radial deviation and an example is presented in fig. 26."[32]

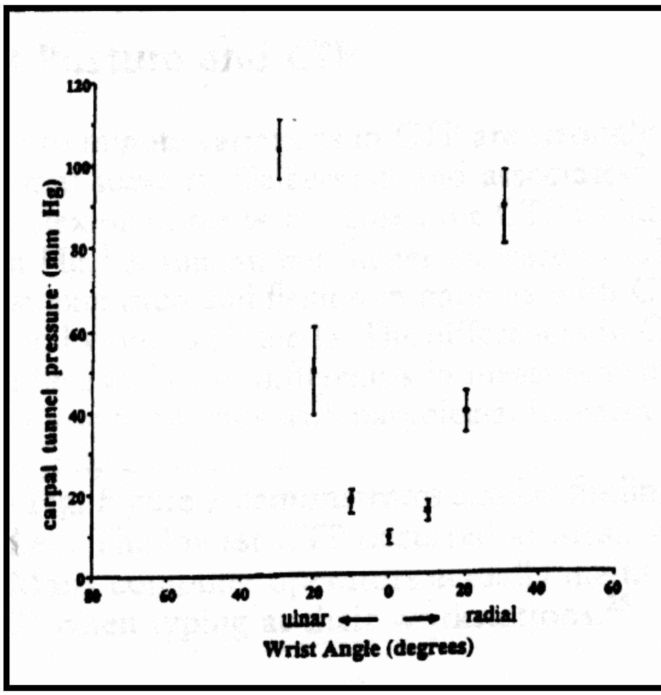


Fig. 2 Example of carpal tunnel pressure as a function of wrist ulnar-radial deviaton in one healthy subject (error bars represent standard error). (Reproduced with permission from Weiss N, Gordon L, Bloom T, et al: Wrist position of lowest carpal tunnel pressure: Implications for splint design. *J Bone Joint Surg*, in press.)

Fig. 26

- *Forearm inclination must be 45º (mid-pronation).* "...And lowest pressures (12 mm hg) were recorded at *45º pronation* and 45º MP (metacarpophalangeal) flexion. These data may be useful in the design of tasks and hand tools in the management and prevention of CTS"[33]

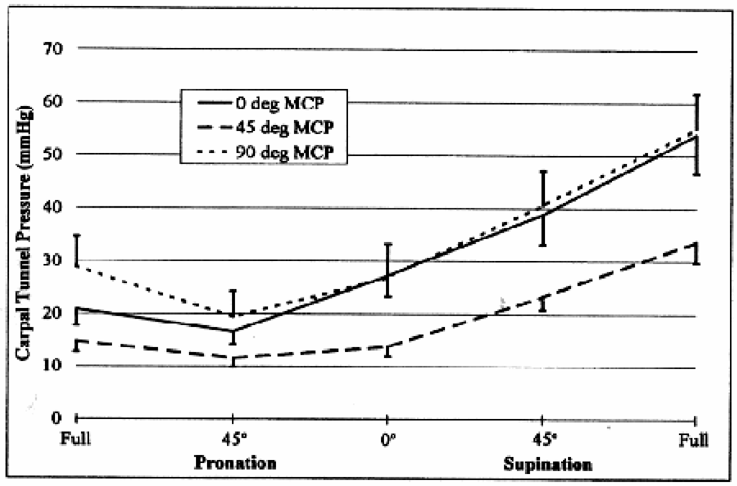


Figure 1. Graph of the mean carpal tunnel pressure versus forearm pronation/supination angle for 17 healthy test subjects. The data are shown for 3 different metacarpophalangeal (MCP) angles. The error bars represent standard errors. deg, degrees.

Fig. 27

- *Total support of the forearm on the same work surface of the OM must be possible.*

  The conventional mice do not have any posterior prolongation of the hemisphere to support the metacarpus.

The posterior prolongation of the hemisphere to support the metacarpus collaborates with the other components of the OM so that the user's hand rests in the position of function.

5) **Bottom surface:**

Its shape presents two sides: a) internal, which corresponds to the radial side of the hand and b) external, which corresponds to the ulnar side of the hand. They are both straight and parallel to each other. It further possesses two extremities: c) anterior, which corresponds to the fingers and d) posterior, which correspond to the wrist, both of which are slightly curved and also parallel to each other, with an inclination of approximately 75º. There are four slightly rounded angles:

- Antero-internal (roughly 75º) corresponding to the exit of the cable and/or transmitter and/or preferential location of movement sensors since it coincides with the union of the index and thumb pulps (point of maximum tactil and proprioceptive sensibility) and maximum range of movements with respect to:
- Antero-external (aabout 105º) which corresponds to the extremity of the little finger;
- Postero-internal (about 105º) corresponding to the thenar eminence (in location and shape).
- Postero-external (about 75º) which corresponds to the hypothenar eminence, in location and shape (point of main support and inflexion of the hand during the use of the mouse).

Such characteristic shape is not a particular design choice, it is strictly associated with the anatomy and functions of the human hand. Any increase in the bottom surface area is superfluous and not necessary to support the hand in the desired “position of function”. Any reduction necessarily implies in eliminating the anatomical support with respect to the shape of the hand needed for maintaining “the position of function”. (See fig. 30).

General aspects.

It is clear that the final design and conception of each and all of the elements that constitute the OM concur to a single possible function: the hand and forearm work and/or rest in the position of function. “The extension/flexion and ulnar/radial deviation postures associated with lowest carpal tunnel pressure can now be expanded to include a forearm rotation angle of 45º pronation and an MP (metacarpophalangeal) joint angle of 45º. This set of postures should be considered during the design of hand-intensive tasks and hand tools in order to minimize carpal tunnel pressure during repetitive activity. These postures can also assist in planning rehabilitation for patients with CTS. Splint designs and usual daily hand postures that prevent prolonged, elevated pressure will provide maximal blood flow and nutrient supply to the tissues in the carpal tunnel. If carpal tunnel pressure plays a role in the cause of activity-related CTS, then redesigning tools and tasks to minimize carpal tunnel pressure might decrease the risk of developing CTS."[34]

There is yet another functional anatomical concept in which the fork, the basic hemisphere and the prolongation for fingers are mutually involved. The *arches of opposition existing between the thumb and each one of the fingers* are fully respected by the OM in both shape and function. The first arch, under a pincer grip, fulfills the requirement for precision (fetching and signaling on screen). The last arch, under a power grip, fulfills the requirements of force (ampler and heavier movements such as greater horizontal displacements of the mouse). "*The oblique arches of opposition.* The thumb forms with the other digits four oblique arches of opposition. The most useful and most functionally important arch is between the thumb and the index finger for precision grip. The farthermost arch, between the thumb and little finger, assumes a locking mechanism on the ulnar side of the hand in power grips."[35] (See fig. 28).

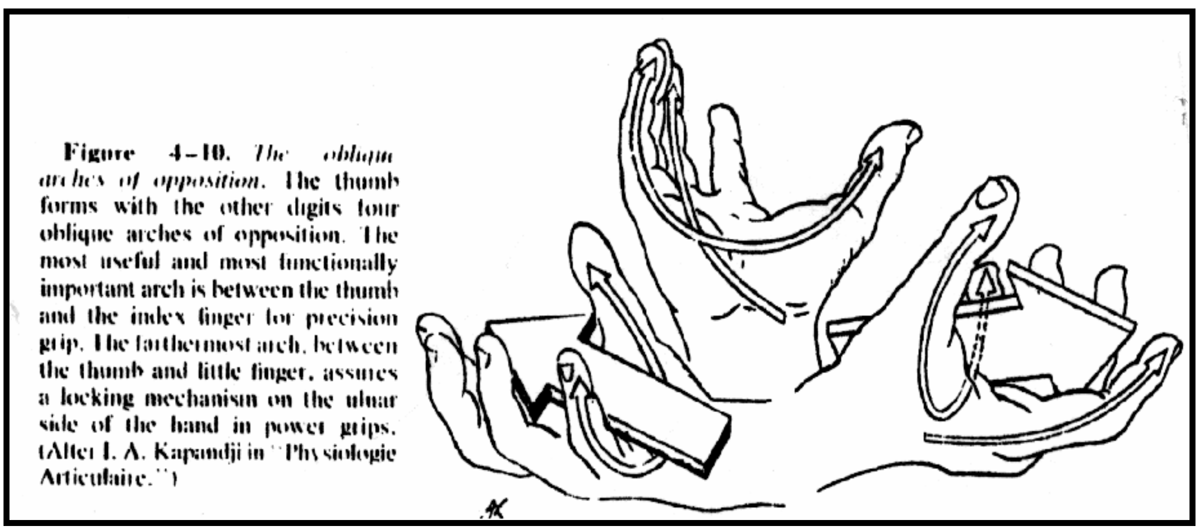


Fig. 28

The differentiated territories of the nervous terminations of the hand show that the median nerve responsible for the distal areas of the thumb, index and annular fingers, is defined as precision. The ulnar nerve, responsible for the little finger and the hypothenar eminence is defined as power. (See fig. 29).

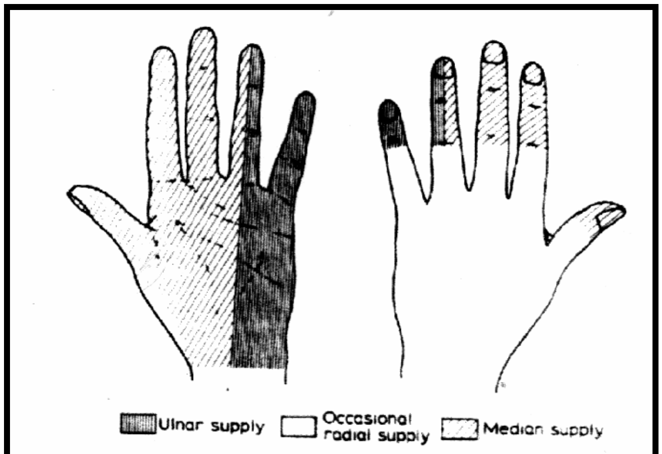


Figure 1.5 **Sensory supply** *of the* **hand** *as* **deduced** *from clinical studies in peripheral nerve injuries*

Fig. 29

"Very broadly speaking, the median nerve is most important for precision and the ulnar nerve for power."[36]

"Precision and power grips are functional concepts, but they are to some extent discrete as far as their nerve supply is concerned. The brunt of a paralysis affecting the median nerve falls on the muscles responsible for the precision grip, so this is the "nerve of precision". The ulnar nerve supplies the bulk of the power grip to muscles and can be referred to as the "nerve of power. "[37]

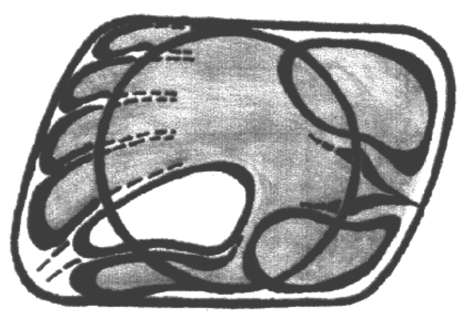
Another characteristic of the OM, is that *the mouse supports the total surface of the palm of the hand***.** "When there is a possibility of the object slipping over the skin, a resistance, namely friction, intervenes which *is proportional to the area of the surfaces in contact*. It is different in different cuttaneous areas and is more marked over palmar skin and over the pulp of the fingers.

The skin is in fact characterized by small concentric epidermal crests, the same papillary ridges as in the finger prints. These crests act on the object in the same way as the tread of tire on the road."[38]

The fact that the different elements in the OM provide several different forms and/or combined forms of grips presents yet another factor that influences the way the human hand uses the OM in terms of comfort and safety. "The effect of the actual act of gripping is that the solid is fixed in a state by what physicists call bonds. A bond is said to be *unilateral* when movement of the solid is impeded in one direction only ... The bond is *bilateral* when two movements are impeded and *multilateral* when movement is prevented in several directions."[39] With respect to that premise, specifically, *the bond in the OM are multilateral,* constituted by:

- Precision grip, formed by the thumb and the index finger in "pincer position". (In the only perfect "opposition").
- Grasping grip, formed by the thumb and middle finger (in opposition).
- Grasping grip, formed by the thumb and annular finger (in opposition).
- Grasping grip, formed by the thumb and little finger (in opposition).

The quantity and quality of grips offered by the OM, and the total support of the palmar surface make the OM the maximum expression in sensitivity and control. "The number of pincers available determines the capacity of the hand to control an average object."[40] A good example of a mouse is a mouse which supports the hand evenly, through a larger area." David Rempel- University of California, San Francisco, School of Medicine (Ergonomic Scientist). Information gathered in CNN News, 5 pm-11/22/99. (S ee. Fig.30).



Schematic diagram of the OM.
In evidence the total support of the palmar surface on the mouse.

Fig. 30

Total asymmetry, like as in the human hand, must be taken into account as another characteristic of the OM. Wearing the same shoe for both feet is not admissible. The same criterion must be used for any function of the hand, since the hand is much more delicate. In the words of Sir Charles Bell, " ´...we must confess that it is in the human hand that we have the consummation of all perfection as an instrument."[41]

CONCLUSION

OM, an Original Concept:

This section will show a) the originality of the concept underlying the OM and b) that there is absolutely no way to attain the result of "the position of function" with a “copy/paste” approach (i.e. copying different features from previous mouse models).

The OM possesses *unique and original structures,* which do not appear in other mouse:

- basic semisphere
- fork
- prolongation from the semisphere for finger support
- posterior prolongation from the semisphere for metacarpus support
- quadrangular asymmetric bottom surface.

Furthermore:

1) Never before was *medical knowledge* on construction of hand tools used *uniquely and strictly* as the basis to develop a computer mouse shape.
2) Never before was the *orthopedic concept used as the basic idea* for the development and function of a mouse and how the mouse would harmonize with the hand and forearm to protect them from wrong postures and efforts (i.e. causing great pain or harm) obliging hand and forearm to assume a correct posture, much like an orthopedic device.
3) Never before did mouse manufacturers avail from the idea of a “*mold of the hand*” as the basis for the development of the device . The new shape created from such mold has characteristics, which have never been seen before, and that cannot be duplicated; the hand that uses the mouse molded the support surface of the OM;
4) Never before was *"the position of function" used as a mandatory and fundamental reference for the creation of a mouse* considering that it is a manual tool and that it should be innocuous.
5) The OM is the only mouse that *supports the whole palmar surface , creating different and combined forms* of grips, making it the *maximum expression in sensitivity, control and innocuity*.

6) The only one that is *totally asymmetric, emulating the shape and proportions of the hand that uses it.*
7) The only one with *absolute lack of edges or abrupt reliefs in its support surface*;
8) The only one with *"precision grip "* in "*pincer position*".

<u>Medical questions:</u>

It is necessary to emphasize fundamental aspects of the former mice with respect to the OM. The essentially wrong shapes (from the orthopedic point of view) of former mice will never offer support for the hand to rest upon, and, therefore, require of the hand ACTIVE participation in supporting itself, with the aggravating factor that this obliged effort occur in a position totally different from the recommended by medical knowledge for the use of manual tools, and, in consequence, will demand anatomic and functional COMPENSATION.

On the OM, the hand and forearm must not, in any way, make any efforts, and the hand will remain in PASSIVE ADAPTATION (full rest) , since it has been designed to follow this quality premise: the hand is allowed and forced in “the position of function”.

Comfort itself has not been the primary concern while designing the OM. **Its main purpose is to strictly respect the orthopedic laws, hence: innocuity, hence: comfort.**

That implies comfort is a consequence of the use of the OM, but not its objective.

The use of the mouse during prolonged periods is considered a form of immobilization of the hand and forearm (in function). Therefore, the laws and medical knowledge that establish the basis to be considered in these processes must be respected, and it is essential to apply them to mouse design, otherwise, the statistics of occupational diseases will be even more serious. It is unacceptable, given the medical knowledge available nowadays, that mouse design should remain oblivious to it. The consequences are calamitous, with a growing number of casualties everyday, everywhere. Disregarding medical knowledge about conception and development of the manual tools (in this case of mice) is producing a truly pandemic affliction.

The basis is clear and not controversial. Years of extensive worldwide labor-related orthopedic and/or traumatological experience have long led us to a definite conclusion***:*** *the unique, desirable, non-substitutable, and invariable position for the innocuous use of any manual device is "the position of function".*

- "The position of function" is the *unique* position for the hand and forearm that allows an exact balance of all the muscles involved (agonistic, antagonistic, extensors, flexors, supinators, pronators, abductors and adductors);
- It is *adequate and desirable* because it is the only position that will not cause trauma to the organs that are applied to its use;
- It is *non-substitutable* since only a genetic mutation could alter it;
- It is *invariable* because any change, as small as it may be, necessarily implies in loss of a positional and/or functional aspect, which are both relevant.

All treatments involving immobilization of the hand and forearm, such as fractures, sprains, tendinitis etc., are generally made in "the position of function". If that directive is ignored in bandages or plaster casts it will be considered *mala-praxis* medica (i.e. medical malpractice).

By nature, the position of function involves each and all of "the positions of function" of all articulations of the hand, wrist and forearm, including fingers. They are all vastly known and based on solid medical knowledge. Only by complying with all of them, in "the position of function", is it possible to accept that there is a general "position of function" of the hand and forearm. Any alternative or variant, for as little as it may be, will cause the hand to cease being in "the position of function" *because* ***"Each and every position of function must endeavor to bring together a number of favorable conditions that are not always compatible with each other."***

In this case, the whole is more than the simple sum of the parts since they all come together to perform a unique function, which in the OM is: support the entirety of the hand surface in "the position of function", including wrist and forearm (whether the user is operating the device or not).

Statistical tests and results:

Eight years of clinical tests with patients suffering from different forms of RSI and healthy individuals have shown that the OM is basically innocuous.

The tests were carried out with prototypes "ad-hoc" made

The volunteers were instructed about the OM' use with the following instructions:

Orthopedic Computer Mouse

You are about to experience a product that is new both in terms of conception and use. The Orthopedic Mouse is different from all known devices and is specifically aimed at protecting your health. For optimal results, however, we urge you to pay attention to a few details concerning the device operation, which have been chronically distorted due to the lack of ergonomics of previous devices; users have had to perform *active compensation* of positions and/or movements, which ultimately caused undesired consequences (i.e. tendinitis, bursitis, articular and/or muscular pains among others). The risk and seriousness of injuries vary with the time and/or use.

With the Orthopedic Mouse, unlike previous devices, **your hand and forearm should not, under any circumstances, realize the least amount of effort at any time. The conduct of *passive adaptation* (total rest)** is natural since the mouse was especially designed to comply 100% with one important premise of quality. “The hand works and/or rests in "the position of function", which is the only position that medical science knows and accepts in which all muscles and articulations of the hand and forearm are in perfect equilibrium.” This is how we avoid the usual problems that regular pointing devices are known to cause.

How do we achieve this? Although simple, it may take a couple of days to get used to what we like to call the change of habit.

One should ensure that the forearm is resting on the same table where he/she is working and/or displacing the Orthopedic Mouse; the elbow should be at an approximate 90º and the arm falls from the shoulder up to 45º of the vertical. In such fashion, the whole hand, fingers, wrist, and forearm will automatically assume "the position of function” just by resting on the Orthopedic Mouse. Remember: the only conduct is TO RELAX!

Statistics (first 21 cases)

CASE	NAME	SEX	AGE	HAND SIZE	HISTORY	PERIOD	USE	SYMPTOMS	SENSATION
1	J A	M	56	Med P	Healthy after 15' pain in forearm with common mouse	10 months	3-5 hours/dayay	Without symptoms	Comfortable +++
2	M F	F	36	Med	Healthy No comments	10 months	3-4 hours/day	Without symptoms	Comfortable ++
3	B S	F	8	Small	Healthy No comments	10 months	Discont.	Without symptoms	Comfortable +++
4	J C	M	25	Med L	Some discomfort during extended periods	2 months	6 hours/d	Without symptoms	Comfortable +++
5	B F	M	66	Med	Healthy No comments	1 month	Discont.	Without symptoms	Comfortable +++
6	A C	M	46	Med L	Healthy No comments	1 month	Discont.	Without symptoms	Comfortable +++
7	M C	M	38	Med	Healthy No comments	1 month	Discont.	Without symptoms	Comfortable +++
8	M S	F	30	Med	Serious tendinitis	3 weeks	7 hours/day	Without symptoms	Comfortable +++
9	C M	M	32	Med L	Healthy No comments	2 weeks	2-4 hours/day	Without symptoms	Comfortable ++
10	S L	M	36	Large	Eventual discomforts	2 weeks	6-8 hours/day	Without symptoms	Comfortable +++
11	M L	F	34	Med	Serious discomfort	2 weeks	3-4 hours/day	Without symptoms	Comfortable +++
12	F V	M	58	Med	Serious discomfort/serious tendinitis	2 weeks	3-6 hours/day	Without symptoms	Comfortable +++
13	M T	F	42	Med	Serious discomfort/serious tendinitis (bilateral)	3 weeks	6-10/ hours/day	Some symptoms	Comfortable +++
14	M L	F	34	Med	Some discomfort during extended periods	10 days	4-6/ hours/day	Without symptoms	Comfortable +++
15	G C	M	65	Med L	Healthy No comments	2 weeks	4-6/ hours/day	Without symptoms	Comfortable +++
16	A C	M	28	Med L	Healthy No comments	2 weeks	4/ hours/day	Without symptoms	Comfortable +++
17	M K	F	26	Med	Some discomfort during extended periods	2 weeks	4-8/ hours/day	Without symptoms	Comfortable +++
18	N R	M	26	Med	Healthy No comments	2 weeks	4-8/ hours/day	Without symptoms	Comfortable +++
19	C T	M	31	Med	Healthy No comments	2 weeks	6-10/ hours/day	Without symptoms	Comfortable +++
20	E A	M	40	Med	Eventual discomforts	3 weeks	2-4 hours/day	Without symptoms	Comfortable +++
21	J P	M	32	Med L	Healthy No comments	2 weeks	4-6/ hours/day	Without symptoms	Comfortable +++

FIGURE'S REFERENCE

The figures were taken from:

1) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 497.
2) Private material.
3) Idem.
4) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 495.
5) Private material.
6) Idem.
7) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 495.
8) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 494.
9) Private material.
10) David Rempel, M.D., Joel M. Bach, Ph.D, Richmond, CA., Leonard Gordon, M.D., Yuen So, M.D., PhD., San Francisco, CA. "Effects of forearm Pronation/Supination on Carpal Tunnel Pressure." Journal of Hand Surgery. 1998, 23 A, pg.40.
11) Private material.
12) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 4, pg. 38.
13) Private material.
14) Idem.
15) Idem.
16) Idem.
17) Idem.
18) It is a superposition taken fig. 53-8 from: Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 498, and private material.
19) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 498.
20) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 58, pg. 646.
21) Private material.
22) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 27, pg. 267.
23) Private material.
24) Raul Tubiana, M.D., "The Hand" ; Vol II, Chapter 53, pg. 498.
25) Noah D. Weyss, M.D., Leonard Gordon, M.D., Todd Bloom, Yuen So, M.D. and David Rempel, M.D., San Francisco, California. Position of the Wrist Associated with the Lowest Carpal-Tunnel Pressure: Implications for splint Design. 1995. The Journal of Bone and Joint Surgery. Pg. 1696.
26) Idem.
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30) Private material.

[1] John Napier. Hands , Chapter three. “Function of the hand". Prehensile Patterns and Tool Handle Design. pgs.69/71. Princeton University Press. 1993.
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