An Ergonomic Solution to Surgeon Fatigue and Repetitive Stress From Lipoplasty

Ronald D. Shippert, MD

Introduction: *Surgeon fatigue and repetitive stress are disabling entities. They can occur secondary to repeated motion required during liposuction (lipoplasty) surgery. This article compares 10 liposuction handles in an effort to determine the handles that are the most conducive to reducing fatigue and repetitive-stress injury.*

Materials and Methods: *Ten popular handles broken into 6 groups (by shape) are evaluated, using 12 parameters, which included ideal ergonomic features, fatigue, and torque tests.*

Results: *The highest score was given to the biplane handle, which had a rating of 12/12. The biplane handle was given the highest rating because it met all the established parameters of an ergonomic handle and tested the highest in torque tests and fatigue tests.*

Discussion: *The most important factor in fatigue reduction appears to be the biplanar construction, which allows an efficient trapping effect with the fingers and thumb of the hand.*

An inventory of all of the liposuction devices on the market suggests that the industry does not need another cannula or another handle. There are hundreds of manual cannulas and multiple handles of all shapes and sizes. However, after a more meticulous examination of the instruments used in lipoplasty and the trauma given to either the patient or the operator, it is obvious that more refinements for existing products are still needed. In the high-technology thrust to solve the problem of hand and arm fatigue, we have all overlooked some easier solutions.

Liposuction (lipoplasty) is a very strenuous, fatigue-producing repetitive-action procedure for the surgeon. It can lead to repetitive-stress injury. In an effort to reduce fatigue and the possibility of repetitive-stress injury, the industry has jumped to high-technology devices such as oscillating, vibrating, ultrasound, and laser devices. These devices all have their place in liposuction and each device has its number of physician followers. They all aid in the reduction of fatigue, but the quantity of fatigue reduction has been disappointing. All are quite costly and, with some, there seems to be an additional vibratory stress. Also, these higher technology methods have new learning curves that are not short. The newer laser devices and water-powered devices under present investigation are yet to be proved to be helpful.

The old-style, low-technology handle cannulas also have their place. Common to all liposuction surgery is the need to taper and feather the periphery of the main suctioned area with very small-diameter cannulas to prevent a noticeable drop off deformity. This is best accomplished with the old-style, manual-powered cannulas with progressively smaller diameter cannulas. Also, small-diameter, manual cannulas are usually used near the skin surface to prevent ripple and divot deformities. Thus, most surgeons will agree that the old manual-type cannulas are still needed for at least the finish work and there are always those surgeons that shun high-technology devices.

The Author's Solution

The author's solution to the repetitive-stress problem is to improve the grip on all liposuction handles in an effort to minimize the trauma to the hand and arm. This article compares most of the handles on the market outlining the ergonomic features of these handles. From this study, the surgeon can then choose the handle that has the best ergonomic features. The production of the least amount of repetitive stress involves many factors, including positioning and the possible presence of preexistent disease. Thus, choosing the handle with the most ergonomic and comfort features is no guarantee of lessened repetitive stress. However, because an ergonomic handle dictates a normal hand position and an anatomical grip, it is logical to assume that fatigue and repetitive stress should occur to a lessened extent when ergonomic handles are used.

Received for publication March 15, 2003.

From the Department of Research and Development, Shippert Medical Technologies Corporation, 7002 S Revere Parkway, #60, Englewood, CO 80112.

Liposuction Statistics

Liposuction is increasing and will be with us for a significant period of time. In the past 5 years, liposuction (lipoplasty) procedures have continued to be in the top 7 cases that cosmetic surgeons perform. In 2001, the average cosmetic surgeon's fee was $2500 per case. In 2001, statistics from the American Academy of Cosmetic Surgery and the American Society for Aesthetic Plastic Surgery combined total almost 1 000 000 cases.[1,2] These numbers have been increasing more than 10% per year. As with most cosmetic surgery procedures, as the public becomes more aware of cosmetic surgery, the availability of quality surgeons increases, and the procedure's safety record improves, there is every reason to believe that these numbers will increase. With the increase in procedures, there will be an associated increase in repetitive-stress cases if some changes are not forthcoming.

The Developmental History of Liposuction Devices

The history of liposuction instrument development is a good example of necessity being the mother of invention. Each problem that arises resulted in the development of improved devices to solve the problem.

In the early 1970s, Dr Georgio Fischer was instrumental in introducing the procedure. When liposuction was first done, it was done with crude, large-diameter instruments. Thus, the problem to solve was irregular skin surfaces. In the early 1980s, Drs Fomier and Illouz and many others helped solve the irregular skin-surface problem and further developed improved cannulas. More fat was now being removed with better cannulas and now bleeding became the problem to solve.

In the early 1980s, the author published an article in the American Journal of Cosmetic Surgery,[3] showing that a progressive cannula technique could lead to less blood loss. This was termed the progressive cannula technique and, although this lowered the blood loss considerably, it was not significant enough and more dramatic changes were still needed.

In the late 1980s and early 1990s, Dr Jeffrey Klein of California originated the tumescent technique, and he and Dr Patrick Lillis of Colorado and others published several articles on it.[4–7] This technique allowed large volumes of dilute epinephrine and Xyloealne to be instilled into the tissue with small-gauge cannulas or needles. The result was spectacular because the procedure could now be performed with very little blood loss. When the correct technique was used, the blood loss was minimal and the problem was essentially solved.

From the 1990s to the present, with the skin-irregularity problem solved and the bleeding problem solved, surgeons are removing more and more fat on more and more patients. Lipoplasty is becoming the most frequently performed cosmetic procedure. At this time, some surgeons are utilizing their liposuction device all day long, producing fatigue and repetitive stress of the hand, wrist, forearm, elbow, and shoulder. Fatigue and repetitive-stress injury became the new problems to solve.

High Technology Emergence

The first efforts to minimize the fatigue and trauma to the surgeon was the development of ultrasound for liposuction. In the early 1990s, Dr Zocchi of Italy began using an ultrasound unit to extract fat.[8–10] Ultrasound acoustically breaks the fat cell and the aspirator suctions out liquid triglycerides and cell-wall debris. Although the results overall have been promising, the learning curve is not short, the burn problem has not been solved completely, Drs Karmo and Milan claim more blood loss,[11] and fatigue has persisted.

The mid and late 1990s brought the new vibrating and oscillating devices. These devices were also designed to reduce the fatigue and stress to the surgeon's hand and arm. The thought behind this was that mechanical vibrating cannulas would replace the motion of the arm and hand. This turned out to be only partially true, as these units seemed to reduce the time in the operating room, a benefit that reduced overall surgeon trauma.[12–14] However, some of the vibrating devices produced a new vibrating-type stress to the hand and the arm that bothered some surgeons. Most of those that have tried to use the high-tech devices agree that they do lessen the time in the operating room but fatigue and stress factors still exist.

Three Constants Persist

This brings us to the present year. Throughout the developmental history, 3 factors remain constant. The first constant is the increasing demand for liposuction surgery. The second constant is the ongoing need for manual-powered cannulas of multiple lengths and small diameters. Even if the more expensive, high-tech devices are used, the manual cannulas are still needed. The areas in which they are needed are the thin fat layers of the neck and face and in the periphery of the surgical site for tapering and feathering. Some surgeons

just prefer the manual instruments. The third constant is the need for some way to produce lessened fatigue. The obvious area to improve is the handle, which, up to the time of this study, was not investigated. Whether one is talking about the manual-powered cannulas or the high-tech ultrasound or vibrating devices, all handles need ergonomic improvement. The scene is set for improvements and the problem to be solved is fatigue and potential repetitive stress.

Unwanted Damaging Effects of Repetitive Stress

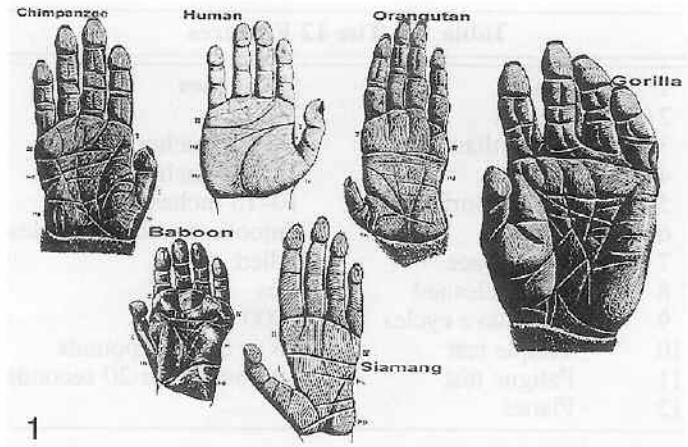
It is not uncommon for the surgeon with a busy schedule to have his or her operating hand and arm in motion 6–12 hours on surgery days. No wonder the surgeon's handwriting quality decreases. One of the most common complaints by the surgeon is fatigue of the operating hand and arm. This can be the precursor to repetitive-stress injury, which can affect the hand, the elbow, and the shoulder. Tendinitis, bursitis, or synovitis can occur due to stretching or shear stress from recurrent direct trauma to the respective areas, as described by Rettig, Arndt, and Stone.[15–18] Overuse-stress syndromes can also take the form of neurovascular syndromes, resulting in inflammatory-induced compression problems with the median, ulnar, and superficial branch of the radial nerve or to the ulnar and digital vessels supplying the hand. Treatment usually involves splinting, icing, and nonsteroidal antiinflammatory drugs in acute cases and surgical decompression for chronic recurrent cases.

The Surgeon Must Be Proactive in Prevention of Repetitive Stress

Prevention of repetitive stress must be the rule. When fatigue and repetitive stress lead to disability, it is a serious problem for surgeons. Unlike many other professions, the surgeon cannot pay an assistant to perform the surgery. Also, even if the surgeon is not disabled, lesser inflammatory conditions can still be inhibiting to running a full practice. If the surgeon is having pain or paresthesias after a full day in surgery, he or she is less enthusiastic about scheduling another full day. The surgeon must have proper positioning of the patient, proper positioning of the surgeon's hand, and the best ergonomic equipment available.

Human Hands Have Planes That Are Different From Other Primates

The primate hand was studied in an effort to gain more knowledge about the human hand (Figure 1). All the primates shown have 4 fingers and 1 thumb. The



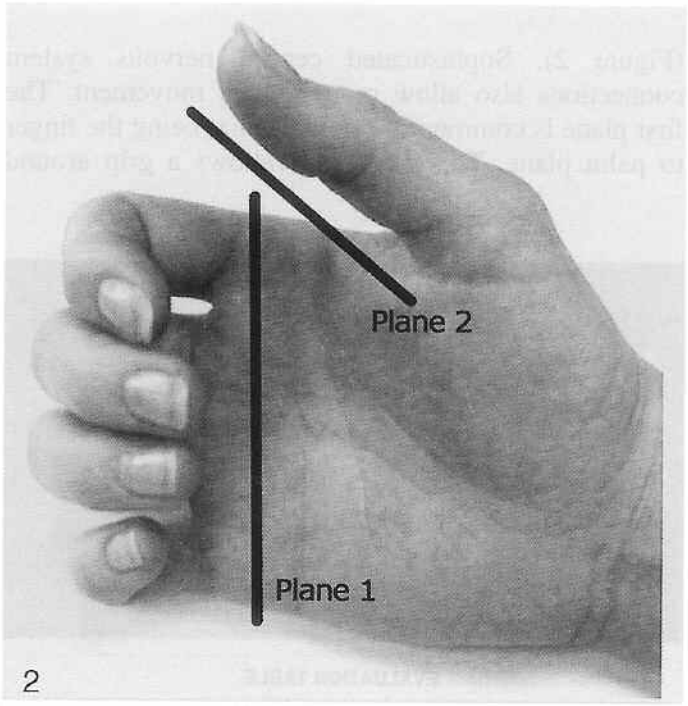


Figure 1. *The different primate hands. Note that all have 1 thumb and 4 fingers but the location of the thumb is different in the human. The tip of the thumb is positioned to allow a 2-planed grip and trap effect.*

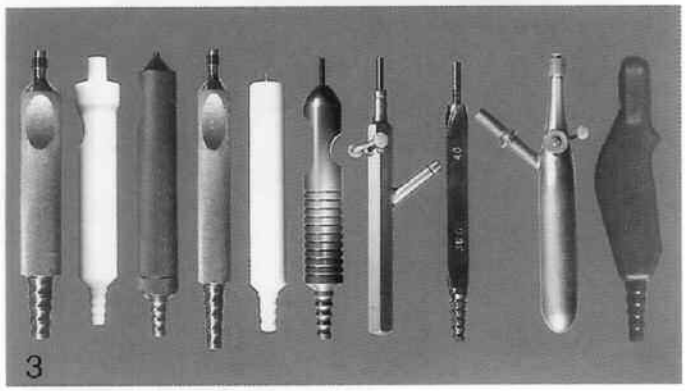
Figure 2. *The 2 planes of the human hand. These 2 planes contribute to the trap effect seen when the hand grasps using both planes. This biplanar characteristic is common only to* Homo sapiens, *and when both planes are used, it allows control with a more relaxed grip.*

anatomical difference is the location of the thumb. The *Homo sapiens* (human) is the only primate hand that has the tip of the thumb at the level of the metacarpal phalangeal finger joints. This positioning allows a grip in 2 natural anatomic planes, forming the biplanar grip

Table 1. The 12 Features

1	Length	5–7 inches
2	Weight	3–6 oz
3	Width/diameter	.75–1.0 inches
4	Height	1.0–1.5 inches
5	Square Surface	10–15 inches squared
6	Contour	Smooth, no abrupt angles
7	Dead space	Filled
8	Easily cleaned	Yes
9	Autoclave cycles	2000
10	Torque test	45 to 65 inch pounds
11	Fatigue test	40 pounds for 20 seconds
12	Planes	2

(Figure 2). Sophisticated central nervous system connections also allow more refined movement. The first plane is common to primates, that being the finger to palm plane. This first plane allows a grip around a cylinder (or a limb for the lower primates) and the second plane allows a trapping effect around the cylinder. This second plane, entitled the finger-to-thumb plane (or trapping plane) is at 35–55° to the first plane. The human can use the biplanar grip to his or her advantage, as it allows the trapping effect that will reduce fatigue.



3

EVALUATION TABLE

MEASURE	GOAL	HANDLES									
		Cylnd 1" SS	Cylnd 1" Delrin	Cylnd 1" Alum	Cylnd 3/4" SS	Cylnd 3/4" Delrin	Glynd Cutout 1" Alum	Hex 3/4" SS	Square 1/2" SS	Oblong/ Oval SS	Biplane Ergnmc Radel
Weight	3 to 6 oz	x	x	x	x	x	x				x
Length	5" to 7"	x	x	x	x	x	x	x		x	x
Width/Diameter	.75" to 1.0"	x	x	x	x	x	x	x		x	x
Height	1.0" to 1.5"	x	x	x			x			x	x
Edges	Smooth	x	x	x	x	x	x	x			x
Surface Area	15 to 20 sqrin										x
Fill Space	Yes										x
Clean Ease	Yes	x	x	x	x	x	x	x	x		x
Torque	45 to 65 in/lb						x				x
Pull-Fatigue	> 20 sec						x				x
Plane Number	Two										x
2000 Autoclaves	Yes	x	x	x	x		x	x	x	x	x
Number Goals Met		7	7	7	6	5	9	5	2	4	12

4

Figure 3. *The 10 handles tested: There are 6 basic shapes for liposuction handles. The 10 handles tested had representative handles from each basic shape group.*

Figure 4. *Graphic results: Note higher scores for the biplane and the thumb cutout type.*

Table 2. Torque Tests

Square haudle	30 inch-pounds average
Cylinder $^3/_4$-inch handle	35 inch-pounds average
Cylinder 1-inch handle	39 inch-pounds average
Oval/oblong handle	39 inch-pounds average
Octagonal handle	39 inch-pounds average
Cylinder with thumb cutout	51 inch-pounds average
Biplane handle	62.5 inch-pounds average

Why Repetitive Stress Occurs During Liposuction

In addition to the usual patient positioning and hand and arm positioning, the surgeon should take all measures possible to reduce fatigue. Fatigue occurs when the muscles contract at a rate faster than the muscle's ability to recover from the contraction. This routine fatigue can be minimized by slowing down and working at a slower, steady pace. The fatigue that could be helped by a better ergonomic handle is, for the most part, from an overcompensated grip. This overcompensation grip is inevitable with the popular cylinder 1-plane handles. The human hand is constructed in 2 planes and functions best when both planes are used.

Handles that have 1 plane, such as the conventional cylinders, do not allow a biplane grip and will result in an overcompensated grip in an effort to control the cannula. This, in turn, leads to premature fatigue and possible repetitive trauma.

For example, during liposuction, several variable forces work against the cannula. These are the incision edges, the connective tissue, the fat, the nerves, and the

Table 3. Fatigue Tests

Square handle	2 seconds, ended with slippage
Cylinder $^3/_4$-inch handle	5 seconds, ended with pain
Cylinder 1-inch handle	5 seconds, ended with slippage
Oval/oblong handle	10 seconds, ended with pain
Octagonal handle	5 seconds, ended with pain
Cylinder with thumb cutout	17 seconds, ended with slippage
Biplane handle	20 seconds, ended with slippage

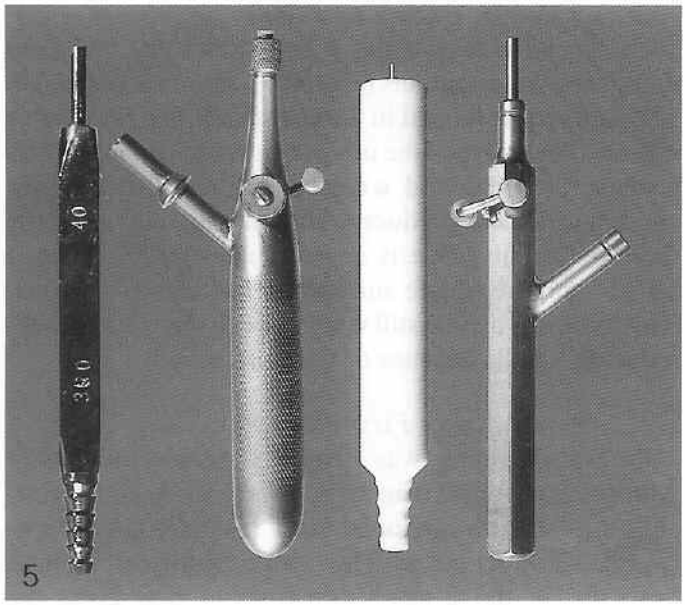


Figure 5. *Fourth-place handles. These handles scored low on the tests because they did not fulfill many of the ergonomic and comfort features tested.*

suction itself. When the proprioceptors in the surgeon's hand sense variable forces, that message is sent to the brain. The brain has learned via previous action that, to prevent loss of control, it must increase the grip. The grip is increased to regain control but this grip is now an overcompensated grip and unnecessary fatigue results. Over a period of time, this can result in repetitive stress. In some individuals, for reasons unknown, it can become a disabling repetitive-stress injury complete with inflammatory response, edema, and scarring.

The advantage of a form-fitting comfortable ergonomic biplane handle is to allow better control of the cannula so that this overcompensated grip becomes unnecessary.

Materials and Methods

The ideal ergonomic handle is a handle that will reduce fatigue and repetitive stress. It must fit comfortably into the hand and the surgeon must be able to grasp with a minimal amount of energy. The goal is to reduce the amount of energy to keep the handle comfortable and under control.

Twelve features measured were adopted as ideal after examining the popular cannulas presently on the market and working with additional clay models (Table 1). The measurements listed are based on average internal human hand measurements in gripping position. Some features were subjective and some objective as

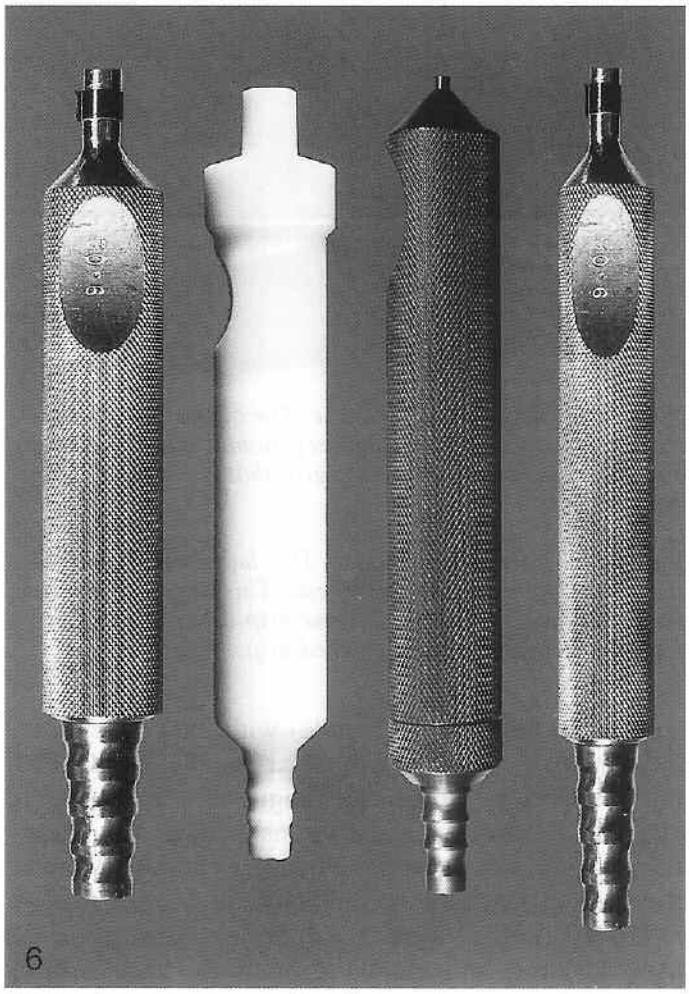


Figure 6. *Third-place cylinder handles. These are the most commonly used handles. They have a 1-plane grip characteristic, which prevents them from scoring higher and being classified as ergonomic.*

measured by repeatable testing. All features were assigned a value of one. Ten handles used for liposuction were then selected and broken into 6 groups based on shape (Figure 3). These 6 shapes included square, hexagonal, oval/oblong, cylinder, cylinder with deep thumb cutout, and biplane.

Results

Torque and Fatigue Tests

The torque test (Table 2) measures the inch-pounds that are necessary to cause grip slippage. The fatigue test (Table 3) measures the time it takes for a 40-lb weight to slide from the grip of the hand. The results are repeatable and significant. When comparing the two highest scoring handles (the cylinder with deep thumb

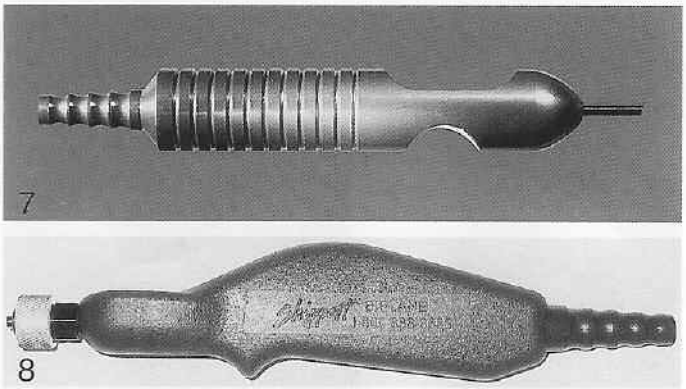


Figure 7. *Second-place handle. The cylinder with deep thumb cutout scored 9/12 in the ergonomic and comfort tests. The deep thumb cutout gives a grip that is superior to the plain cylinders.*

Figure 8. *First-place biplane. This handle scored 12/12 in the ergonomic and comfort tests. This handle's superior construction allows a full 2-plane grip with a trap of the 2 planes allowing a more relaxed grip.*

cutout and the biplanar handle) with the conventional cylindrical handles, the biplanar handle had a 30% improvement in torque and fatigue-time extension of 40%. These findings should translate into less energy being required to control the handle. For the 10-handle comparison, all features, see Figure 4.

The 10 handles were tested, compared with the 12 ideal features, and graded 1 point for each feature. Thus, a score was given to each group as *X*/12. The lowest score would be considered the least and the highest score the most desirable handle to promote comfort and lessened fatigue.

Last Place

Four of the tested handles were rejected on the basis of a 4/12 rating (Figure 5). They had too many features that would lead to an overcompensated grip and excessive fatigue. This included the hexagonal, the oblong/oval, the 3/4-in cylinder, and the square.

Third Place

All of the popular common 1-in-diameter cylinders rated third with a 7/12 rating (Figure 6). Although these would be adequate for those surgeons doing an occasional liposuction, because of their 1-plane type construction, they will allow only a 1-plane overcompensated grip. This 1-plane-type grip will lead to an overcompensated grip and unnecessary fatigue.

Second Place

Of special note was the 1-in cylinder that had deep thumb and finger cutouts (Figure 7). This handle rated 9/12 and finished second in the evaluation; the reason this one rated so high and the other cylinders rated lower was because the deep and wide cutouts changed the grip enough to almost produce a 2-plane grip. Although the finger-to-thumb plane is angled somewhat, it is not at 35–55° and the square surface contact area is minimal. However, this handle still would be considered a fatigue-reducing handle because of its construction.

First Place

First-place rating was given to the biplane handle with a 12/12 rating (Figure 8). The handle is comfortable, has smooth contours, is of ideal weight, beight, length, and diameter. The most important feature, however, is the 2-plane construction that gives the surgeon the ability to use both natural planes of gripping, accompanying the trapping effect and reduction of fatigue.

Discussion

With the advent of liposuction surgery, various problems have arisen. First, irregular surfaces were solved by better technique and better cannulas. Second, excessive bleeding was solved by utilizing the tumescent technique. With more fat being suctioned from more people, surgeons began having fatigue and repetitive-stress injury. This should be a solvable problem. First, proper positioning of the patient is important, and second, proper positioning of the surgeon's hand and arm. Third, the surgeon must use the most ergonomic equipment available.

This study has found that most of the conventional cylindrical-shaped cannulas function in 1 plane and the human hand grips most efficiently in 2 planes. Having a 1-plane construction disqualifies a handle as ergonomic. Assuming the patient and the surgeon's arm are positioned ergonomically, the most important factor in reducing fatigue and repetitive stress is the matching of the internal dimensions of the surgeon's clenched biplanar hand to a biplanar handle of like size and ergonomic construction.

The human biplane grip consists of a fingers-to-palm plane (the same as other primates), and the additional second index finger-to-thumb plane. This second plane forms a trap. The trap is angled at 35–55° to the first plane and essentially traps the hand around the grasped object. This trap is crucial because it allows a more relaxed grip during lipoplasty. A more relaxed grip

means less overcompensation and less fatigue. Less fatigue caused by overcompensation means less chance of developing repetitive stress problems.

The author fully recognizes that ergonomic and comfort features of an instrument do not guarantee a fatigue-free or a stress-free result. However, most will agree that one should anticipate less fatigue and repetitive stress when the handle matches perfectly with the internal grip of the hand.

Conclusion

Liposuction is a procedure that will increase in the coming years. Problem solving has gone from irregular skin surfaces to excessive bleeding to solving surgeon fatigue factors. Manual liposuction instruments are most commonly used and high-tech liposuction devices are being used less often. All device handles with ergonomic and comfort features can help to reduce fatigue and repetitive stress. Ten handles were tested against 12 ergonomic, comfort, and performance features. Four handles were classified as completely unacceptable, with a rating of 4/12. Four 1-in diameter cylinder handles were classified as barely acceptable with a rating of 7/12. The 1-in cylinder with deep thumb and finger cutout was classified as acceptable with a 9/12 rating and the biplane handle was classified as superior with a 12/12 rating. Surgeons who utilize low-technology, manual instruments or surgeons that utilize high-technology devices should be choosing handles that have ergonomic features. The ergonomic choice should reduce fatigue and reduce the potential for repetitive-stress injury.

Commercial Interest Declaration

The funding for this study was provided by Shippert Medical Technologies Corporation, a business entity privately owned by the author. In this presentation, the author evaluates the features of most common handles on the lipoplasty market so that the reader can make informed decisions about lipoplasty handles. The author's company manufactures and markets 1 of the 10 handles studied and presented. The author takes great effort to accurately represent all products.

References

1. American Academy of Cosmetic Surgery. 2001. Statistics. Available at: http://www.cosmeticsurgery.org/Media Center/stats/statistics.html.

2. American Society of Plastic Surgeons. 2001. Statistics. Available at: http://www.plasticsurgery.org/public_education/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=1907.

3. Shippert RD. Progressive cannula technique. *Am J Cosmet Surg*. 1984;1:15–18.

4. Klein JA. The tumescent technique. *Dermatol Clin*. 1990;8(3):425–437.

5. Klein JA. Tumescent technique for local anesthesia. *West J Med*. 1996;164(6):517.

6. Lillis PJ. Tumescent technique. *Dermatol Clin*. 1990;8(3):439–450.

7. Lillis PJ. Liposuction and the tumescent technique. *Dermatol Nurs*. 1991;3(4):255–260.

8. Zocchi M. Ultrasonic liposculpturing. *Aesthetic Plast Surg*. 1992;16(4):287–298.

9. Zocchi M. Ultrasonic assisted lipoplasty. *Clin Plast Surg*. 1996;23(4):575–598.

10. Zocchi M. Basic physics for ultrasound lipoplasty. *Clin Plast Surg*. 1999;26(2):209–220.

11. Karmo FR, Milan MF, Silbergleit A. Blood loss in major liposuction procedures: a comparison study using suction-assisted versus ultrasonically assisted lipoplasty. *Plast Reconstr Surg*. 2001;108(1):241–247.

12. Fodor PB. Power assisted lipoplasty (PAL). *Aesthetic Plast Surg*. 1999;23(6):379–385.

13. Coleman WP III, Katz B, Bruck M, et al.The efficacy of powered liposuction. *Dermatol Surg*. 2001;27(8):735–738.

14. Katz BE, Bruck MC, Coleman WP III. The benefits of powered liposuction versus traditional liposuction: a paired comparison analysis. *Dermatol Surg*. 2001;27(10):863–867.

15. Rettig AC. Wrist and hand overuse syndromes. *Clin Sports Med*. 2001;20(3):591–611.

16. Rettig AC. Elbow, forearm and wrist injuries. *Sports Med*. 1998;25(2):115–130.

17. Arndt R. Work pace, stress, and cumulative trauma disorders. *J Hand Surg (Am)*. 1987;12:866–869.

18. Stone WE. Occupational repetitive strain injuries. *Aust Fam Physician*. 1984;13(9):681–684.