11

Graft Preparation

11A. A Personal Approach to Ergonomics in Graft Production

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INTRODUCTION

Hair restoration surgery with use of micrografts and/or minigrafts is notoriously lengthy and tedious. One of the most time-consuming and effort-consuming stages in this procedure is the preparation of grafts. In our opinion, many of the mechanical methods implemented for the purpose of speeding up this process have done so at the cost of quality. It is not advantageous to save time in the production of grafts if this means sacrificing graft quality and potential graft viability. In simple economic terms, any innovation in graft preparation are only worthwhile if the surgeon and assistants have to work fewer hours to accomplish the same or better results. Applying ergonomic principles to mechanical and technical innovations can help in obtaining this goal.

VALUE OF APPLIED ERGONOMICS

High-quality equipment, an adequate surgical environment, manual skills, and pertinent expertise do not always ensure that work is done in the most efficient manner. Unnecessary maneuvers, incorrect movements, uncomfortable work positions, changes in sight fixation, and variations in lighting are factors that can lead to fatigue. *Fatigue* is the cumulative effect of work effort on mind and body. It has a negative effect on the subject's capacities and reduces quality and productivity compared with results obtained under optimal work conditions. With respect to graft production, which involves important but monotonous manual skills, it is essential to avoid fatigue, boredom, and inattention.

In an attempt to improve both work efficiency and results, we studied graft production from a rational ergonomic perspective. *Ergonomics* is the science that studies the application of biological and technical principles to workplace conditions. The application of ergonomics to the production of grafts is targeted toward simplifications at every stage of the process, with special attention to preserving workers' health and productivity. Thus, the time available is used more effectively and procedures are shortened. Physicians and assistants work in a more relaxed way and more treatments can be provided to a larger number of patients in the same amount of time. In brief, ergonomics contributes to better productivity with less fatigue and higher quality at lower operative cost.

Workstations (Fig. 11A-1) should be designed in a way that simplifies the production of grafts and takes into account the following principles:

- A good body posture should be maintained during work.
- Illumination should be generous but not too bright.
- Room temperature should be kept comfortable and not too high.
- The seat or stool should be comfortable, and the height should be adjustable.
- Optical magnification elements should be available and should facilitate a proper posture at work by location at an appropriate focal distance.
- Arms and wrists should rest on padded supports to prevent damage or injuries to joints from awkward or strained position (e.g., carpal tunnel syndrome).

In the search for more efficient movement, consider the following recommendations should be considered:

- Choose movements that involve the shortest distance and take the shortest time.
- Reduce the total number of movements.
- Reduce the duration of movements.
- Place all tools in a pre-established order before starting work.
- Place tools within the visual field, as close as possible to the place where they are going to be used.

The right tool placed at the right position at the right time is work simplification. Hair transplant technicians suffer from the same types of problems that afflict computer operators or other professionals who need to stay seated and perform repetitive

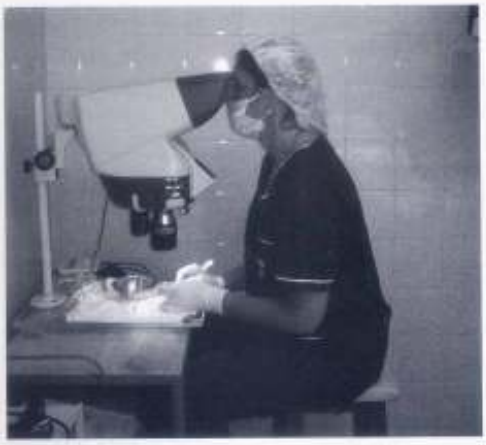


Figure 11A-1 Typical ergonomic workstation. Note the good body position, comfortable chair, and proper table and chair height, which provide comfortable positioning of arms and wrist on the padded support. The Mantis microscope enables the assistant to maintain a good body position by looking forward through the microscope rather than down.

movements for long hours. When ergonomics are applied and rigorously followed, the surgical team becomes more efficient and these problems are minimized.

GRAFT PRODUCTION FROM AN ERGONOMIC STANDPOINT

The graft production technique that we use can be broken down into three stages:

Stage 1 is the initial harvesting of the donor strip.
Stage 2 is dividing the donor strip into sections (or slivers) of variable widths according to the desired graft size. This has also been called *slivering* by Seager (1).
Stage 3 is further subdivision of the slivers into the final individual grafts of different sizes.

In this section, we discuss some of the ergonomically sound technical and mechanical innovations that we have included in our graft production process.

Stage 1: Initial Donor Strip Harvesting

Until it is satisfactorily proven that hair follicle transection does not endanger graft survival, every care should be taken to protect the limited, nonrenewable donor supply from this form of trauma. To that end, attempts to preserve follicular integrity should start at the onset of donor tissue harvesting. During this maneuver, surgeons should try to preserve the integrity of the hair bulbs growing on both sides of the incision. Therefore, the cutting edge of the scalpel should be aligned parallel to the hair shafts and cut between the bulbs. We are convinced that interfollicular infiltration with tumescent anesthesia and a plasmatic expander (Fig. 11A-2) is essential for facilitating both initial donor tissue harvest and later dissection of donor tissue without transection of follicles. This maneuver separates the bulbs and creates a greater space between the hair shafts than that found in nature.

Because these steps require a certain amount of time, we prefer to use a solution that remains in the ex vivo tissue longer than the traditional standard saline tumescent solutions. We have selected Polygelatin, a preparation generally used as a blood replacement, which is known by brand name Haemaccel (Hoechst). It is hydrophilic, and this feature prolongs its tissue expansion effect. Polygelatin increases the interfollicular space and also creates a firmer donor strip, which allows neater and more accurate cuts on a more stable plane.

Once the donor strip is obtained, special attention should be given to appropriate temperature and humidity. Gandelman (1) has already reported that dehydration may pose a threat to the viability of the follicles. We therefore recommend that the donor strip be wrapped in *18μ polyvinyl chloride (PVC) foil* to preserve humidity. To avoid thermal damage, heat-producing light sources (e.g., regular and halogen incandescent lamps) should not be placed near the work site.

Stage 2: Initial Slivering of the Donor Strip

We believe that the use of magnification equipment is essential for the creation of slivers at this stage of graft production. Currently available magnification options include loupes; binocular microscopes; stereoscopic microscopes (Mantis) or video microscopes. Each of these options has relative advantages and disadvantages that can be compared in Table 11A-1, (where 10 is the best on a scale of 1 to 10).

Based on our experience, we consider the Mantis (Fig. 11A-1) and video microscope worthwhile investments because they combine correct magnification with a nonstressful work posi-

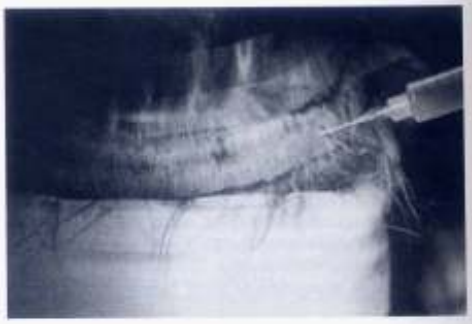


Figure 11A-2 Interfollicular infiltration with tumescent anesthesia and a plasmatic expander. Polygelatin (Haemaccel) facilitates both initial donor tissue harvesting and later dissection of donor tissue without transecting follicles.

Table 11A–1 Comparing Different Methods of Magnification

Instrument	Eye fatigue	Position	Work distance	Cost	Effectiveness	Speed
No magnification	−7	−7	−10	−10	−1	−10
Magnifiers	−7	−3	−10	−10	−4	−4
Binocular microscope	−3	−0	−5	−6	−10	−6
Mantis microscope	−9	−10	−10	−5	−10	−8
Videomicroscope	−8	−10	−10	−2	−10	−8

tion. The Mantis microscope uses a 6x lens with an ample depth of field. This enables the operator to focus on the entire width of the strip that is being dissected, without having to make frequent adjustments. The Mantis has its own good-quality light, which does not emit heat. It is mounted on a clear acrylic footplate designed by James Arnold, which allows the use of concurrent backlighting, if desired. The Mantis has a wide screen through which the work in progress can be clearly seen, with the observer facing forward and not having to bend the neck. This is an ergonomically sound position. It limits fatigue and lumbar-cervical pain, which can lead to decreased production, mood changes, a negative atmosphere within the team, and increases in absenteeism. We rely on a number of well-trained assistants, and it is cost effective to invest in equipment that keeps them healthy and productive.

Fixation of the donor strip to a cutting board and the subsequent application of steady lateral tension facilitate slivering. To that end, we have designed a specialized cutting board (Blugerman cutting board supplied by Ellis Instruments) that has two working surfaces positioned perpendicular to each other. The vertical surface, which is built from a block of silicone elastomer, allows the donor strip to be fixed with two 25-gauge hypodermic needles. The horizontal cutting surface is made of translucent *polyurethane* that makes backlighting possible. The horizontal polyurethane surface also has also a cup-like recession where the tissue slices can be stored in cooled saline. (Fig. 11A-3 and 11A-4)

After the strip has been correctly fixed to the cutting board, the 18μ PVC foil that we use to prevent dehydration is removed from the portion to be slivered (Fig. 11A-4). The distal end of the strip is secured with forceps and steady lateral tension is applied. We have observed that most forceps used to pull the strip at this stage of the surgery have sharp, smooth ends, which make them ineffective at grasping the tissue. We therefore recommend the use of specialized Miltex forceps (Miltex 18–854 supplied by A to Z) with spatula-shaped tips and little teeth in the distal border (Fig. 11A-4). Additionally, these forceps have a locking mechanism, which enables the assistant to grab and hold the tissue without squeezing it. This relaxes the assistant's hand and forearm muscles, dramatically reducing fatigue. An alternative method is to bend both tips of a regular jeweler's forceps so they will hook in and are able to grab the donor tissue during slivering.

For a cutting blade, we prefer a no. 15 bladed scalpel (Fig. 11A-4), because the cutting edge of this blade consists of multiple shapes. The blade has three areas—pointed, curved, and straight, which are most convenient at different times during slivering. The thickness of the slivers can be made the width of either one or two follicular units (FUs), and this decision is made based on the size of the grafts desired.

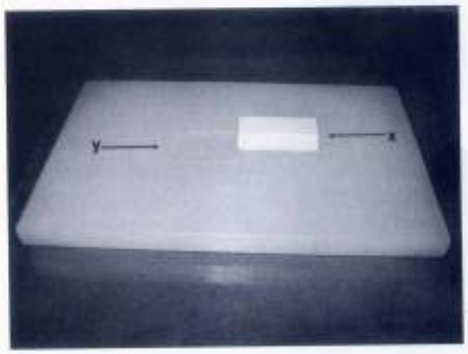


Figure 11A-3 Specialized cutting board (Blugerman Board) that facilitates slivering: "x" designates the silicone block for the fixation of donor strip. "y" is the location of the translucent polyurethane cutting surface with a cuplike recession, where slices can be stored in cool saline.

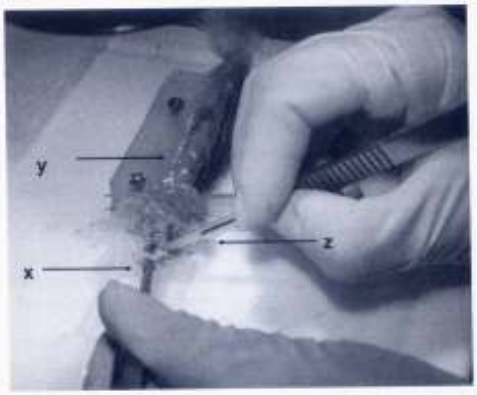


Figure 11A-4 A sliver is cut by attaching it to the board and applying lateral tension with the specialized spatula forceps (x); the 18-μmicron PVC foil (y) is wrapped around the sliver to keep it moist. (z), The no. 15 blade scalpel.

Stage 3: Creation of Individual Grafts from Slivers

The third stage in the preparation of grafts consists of the conversion of individual slivers into appropriately sized grafts. To facilitate this process, we have prepared a workstation that addresses different areas important to comfort and work effectiveness. The areas we have addressed include the following:

1. *Stool*
2. *Table surface and height*
3. *Lighting*
4. *Hydration*
5. *Transillumination*
6. *Appropriate cutting surface*
7. *Proper magnification*
8. *Containers for graft classification*
9. *Strict control of the number of grafts prepared*
10. *Specific instruments used*

Stool

The stool should be very comfortable and properly padded. Hands should not be used to regulate its height.

Table Surface

This surface should be washable and, occasionally, some padded supplements should be added for the forearms and, above all, for the wrists. These additions may reduce the incidence of carpal tunnel syndrome.

Lighting

Diffuse, cool light should be used to prevent graft dehydration and a rise in temperature.

Hydration

The damage that dehydration causes to tissue is well known by general surgeons and plastic surgeons. Marcelo Gandelman has presented a study that has clearly shown tissue dehydration to be one of the major causes of graft damage and potential loss during the hair transplantation process (2).

The potential for dehydration during Stage 3 is higher when we work with tiny grafts that have a larger surface area to volume ratio, and, therefore, a greater relative amount of surface area exposed to the environment. The potential for dehydration is also increased by certain existing factors in the operating theater, such as air-conditioning, the microscope lights, and the absorbing surfaces used (e.g., wood, gauze). A phase of graft production that is not usually addressed, regarding vulnerability of follicles to dehydration, is the time they spend on the cutting surface during Stage 3. In our experience, grafts are on the cutting surface for a longer time when FUs are created with the binocular microscope than when minigrafts are produced with simple loupe magnifiers. It is interesting to note that the introduction of a new technique in the form of FUs and the binocular microscope has potentially increased the risk of dehydration during this phase of graft production. In an attempt to address this problem and the concerns raised by Gandelman's research, we started to analyze various ways of preserving the temperature and humidity of grafts during the time they spend on the cutting surface.

Our first approach was to try dissecting the grafts in a liquid element (i.e., the saline solution). We designed a small tray for comfortable dissection of FUs under a saline solution. This tray also permitted use of transillumination. Physicians considered the results to be amazing. Cutting the grafts under saline prevented dehydration and, in addition, offered other benefits such as the following:

Immersing the tissue in liquid causes a magnifying effect that adds to the existing magnification.
The subcutaneous cells hydrate. Thus, there is a greater distance between the hair follicle and the tissue, and, consequently, dissection is easier.
The subcutaneous cell becomes practically transparent with the addition of transillumination.

Our assistants did not like or easily adapt to the technique of cutting grafts under saline. Therefore, we tried another approach and developed a *humidified dissection chamber* (Fig. 11A-5). This is a dome made of transparent acrylic with two lateral apertures for the introduction of the assistant's hands. This device is equipped with an adjustable ultrasonic spray that sends a fine saline mist into the dome during graft dissection. With this new device we are able to preserve the hydration status of grafts to a similar degree as cutting under saline.

Transillumination (Fig. 11A-5)

Whenever possible, the technique of transillumination should be used, as this helps to make the hair bulbs visible by increasing the contrast between hair and subcutaneous tissue. This technique is especially useful when gray hair or salt-and-pepper hair is being cut. This type of hair is difficult to see, and we think that atraumatic dissection of this type of hair without the use of transillumination is almost impossible. The backlight used for this technique should fulfill the following specifications:

Strong white light (5000 minimum)
Small surface so as not to blind the assistant

Figure 11A-5 Humidified dissection chamber. (x), Backlighting with Visual Plus. (y), Three separate *pin cups* for selective storage of different sizes of grafts. (z), Mag-Eye magnification loupes.

Small amount of cabinet thickness
Cold or low heat-emitting light
C. C. power and long use resistance
Long life

Our preference is the Visual Plus Model VP-6050V, which can be obtained from A to Z.

Cutting Surface

The cutting surface used for transillumination should be as follows:

Translucent
Rough enough so the tissue does not slide
Soft enough to prevent cutting-edge blunting
Hard enough so material particles do not come out
Atoxic
Sterilizable
Economical
Nonhydrophilic to prevent absorption of fluid from grafts

This graft-cutting surface should be translucent, nonslippery, and sterile. It should preserve the scalpel's edge. It should be hard enough that small particles cannot scrape off and act as foreign bodies if implanted as contaminants. Various appropriate materials may easily be found on the market to satisfy these needs. After testing different cutting surfaces (glass, acrylic, marble, and silicones), we reached the conclusion that a white, rough, polyethylene surface is the best element because it fulfills the aforementioned properties.

Magnification

We think that magnification in stage 3 does not have to be as high as during stage 2. Occasionally, there is no need for it at all. We prefer to use Mag Eye magnification loupes (supplied by A to Z). They allow a good neck position, a good focal distance (27 cm, with 4x), and can be worn together with the surgeon's own glasses (Fig. 11A-5). They are lightweight and rest on the forehead, so they do not exert any pressure on the nose and ears. We regularly use a 2x or 4x magnification.

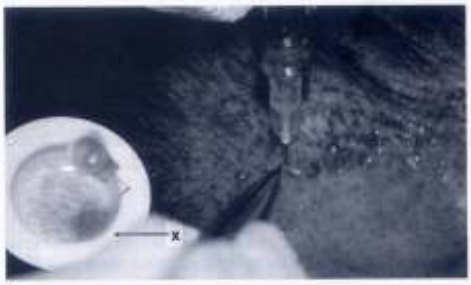
Graft Containers

For more than 4 years, we have been placing our grafts in small containers, called *pin cups*, which are small, disposable, sterile plastic cups filled with cold saline solution to keep the grafts hydrated (Figs.11A-5, 11A-6, and 11A-7). They are used for graft separation and classification according to size during graft production. They are also used to keep the grafts cool and moist during graft insertion. When we initially looked for a graft container, we searched for one with the following properties:

Keeps grafts wet
Prevents germ contamination
Prevents adherence of substances such as talcum, powder, latex, gauze etc.
Leaves the hands free when working
Keeps grafts available at a short distance from the insertion place
Prevents graft crushing and handling
Diminishes graft air transport with the implied risk of dropping

With these properties in mind, we came up with the idea of using a small, lightweight, disposable, sterile plastic container.

a



b

Figure 11A-6 (a), (x), Pin cups pinned to the recipient area. (b),(x), Close-up of pin cups pinned to the recipient area.

Figure 11A-7 Electronic counter for enumerating incisions and cuttings of grafts.

The container that we call a pin cup is 31 mm in diameter, 10 mm in depth, and 2 g in weight. The plastic material is thin enough to permit the passage of a small-gauge needle. This in turn allows the cup to be secured or *pinned* to the patient's scalp during placement.

During the cutting stage, the cups are filled with cold saline solution and placed between the cutting surface and the operator. Three cups are used per workstation so that grafts can be separated by size. This facilitates selective use of different sized grafts in specific areas later during insertion (Fig. 11A-5).

When the grafts are to be inserted, a pin cup containing grafts of the desired size is taken and *pinned* into the scalp skin in a place near the area where they are to be placed (Figs.11A-6a and 11A-6b). By doing this, we observed fewer visual changes and fewer head and arm movements. Reduced movement resulted in less fatigue of the surgical staff and shortened the time for insertion of grafts. In summary, the main advantages we find for the pin cup are as follows:

Double function of container and dispenser
Keeps the grafts wet and cool
Has reduced dimensions
Is lightweight, sterile, and disposable
Saves time and effort
Leaves hands free for working
Reduces contamination and allergic risks

Economical

Graft Counting

Throughout our practice and in visits to our colleagues, we have noticed a certain difficulty in keeping track of the number of grafts that are manufactured and those that are placed. To make this task a lot easier, we have designed an *electronic hair graft counter* (Fig. 11A-7). *The* counter is formed of the following two components:

Viewfinder
Shutter

The viewfinder is digital and easy to read. Mainly, it counts the electric impulses triggered by the shutter. This shutter may include the following components:

Foot switch
Contact sensor
Photoelectric cell

The counter can be used by the physician when creating incision sites or by the assistant when producing grafts. It is also possible to use the counter during graft insertion to be completely sure that no holes have been left partially filled or empty.

It is very useful to have an accurate count of grafts produced by assistants for the purpose of approximating the number of grafts that will be obtained from the harvested donor strip. By counting the number of slivers we obtain from the initial donor strip and multiplying that by the number of grafts obtained from one sliver, we obtain an early estimation of the total amount of grafts that may be produced. From this calculation, we can assess the number of slits or holes to be made.

This small instrument is useful from a medicolegal standpoint because it supplies a record of the number of grafts in a photograph of the viewfinder of the instrument placed next to the operative field. The counter is also useful for figuring out the surgeon's fees if they are directly related to the number of grafts made.

In summary, the main advantages for the use of the counter are as follows:

Exact evaluation of the number of holes or slits made
Quick evaluation of the number of grafts to be obtained from the donor area
Insertion control in all the incisions
Photographic record of the work done for medicolegal and commercial purposes

Specific Cutting Tools

The two tools that need to be mentioned with respect to preparing individual grafts from slivers are:

Type of forceps used to hold and manipulate the donor tissue
Cutting blade used to dissect the donor tissue

We prefer to use forceps such as the Forester 61–6041 (supplied by A to Z) or a 5 or 5A jewelry forceps. A number of cutting blades may be used according to the assistant's preference. Some prefer no. 10 Personna scalpel blades, whereas others prefer Prep Blades. Some assistants prefer regular razor blades mounted on special handles. No matter which blade is used, at this stage of the process it is most comfortable to place the slivers at a 90-degree angle with respect to the worker's body, as previously suggested by Arnold. It is also very important to change the cutting blade regularly to preserve the graft quality and diminish the force necessary to cut scalp tissue, which in turn keeps the assistants from succumbing to fatigue.

We are working on a padded ergonomic *workstation* that enables operators to support their thorax, head, and forehead (Fig. 11A-8). This workstation is highly ergonomic and dramat-

Figure 11A-8 Experimental cutting station for the final phase of graft production with use of backlighting (still in development).

ically reduces fatigue as well as neck and back pain (in the cervical and lumbar-dorsal areas). With this workstation, the stools will not have wheels, which will enable the whole body to rest completely on padded elements without the stool remaining immobile. At the time of this writing, the workstation is not available, but it seems worthwhile to present the concept.

11B. Classic Microscope Dissection of Follicular Units

David J. Seager

INTRODUCTION

Follicular unit (FU) micrografts are so small and fragile that the aid of microscopes for their dissection from donor hair into micrografts is mandatory to obtain optimal yield, particularly when minigrafts are used exclusively and in large numbers.

To obtain the benefits that the binocular Stereoscopic Dissecting Microscope has to offer, a specific, elaborate dissecting technique, which is described in detail later in this chapter, has to be employed. This technique was originated and developed by Dr. Bobby Limmer of San Antonio (1). Dr. Limmer invented and practiced classic microscope dissection and follicular unit hair transplantation (FUHT) years before anyone else ever understood the concept, although he did not publish anything about his novel method until some years later.

Controversy exists among physicians over the benefit of using the stereoscopic dissecting microscope. Many long-established hair transplant physicians have simply purchased the appropriate microscopes but have then proceeded to dissect the donor tissue into micrografts with microscopic visualization, using exactly the same technique they had been using for years with the naked eye. In this scenario, unfortunately, "old techniques with new instruments" produces no benefit whatsoever. As stated earlier, to benefit from use of the microscope, a specific dissecting technique is needed in addition to the use of the microscopic magnification. This is one factor that has led many operators to conclude that the claimed benefits of microscope-aided donor dissection are exaggerated, and that they have detracted from the general adoption of microscope use in hair transplantation.

Another popular misconception that has also contributed to the slowness of the majority of hair transplant physicians to adopt microscope dissection is the misconception that microscopically dissected grafts should enhance the cosmetic appearance of a hair transplant. An individual FU created by microscopic dissection appears no different after it grows out than an FU created without the microscope. This point has been used by detractors of the microscope to ask the question, Why should the microscope be used to prepare FUs? The main benefits of classic microscope dissection for FUs, as are described later, are "hidden benefits mainly regarding conservation of hair." These advantages become apparent only by evaluating the maximum amount of hair that can be successfully transplanted in one session, or the total amount of hair that will be ultimately available to treat the area of baldness that usually enlarges as the patient ages.

Having examined some of these invalid (but understandably hypothesized), frequently quoted reasons for not using the microscope for dissection of FU micrografts, let us now methodically examine some of the very real and legitimate advantages of classic microscope dissection for FUs.

General Principles for Dissection of Follicular Units

Follicular units are more fragile than standard grafts and minigrafts and therefore more easily damaged. Standard grafts and minigrafts generally have more protective skin around their pilosebaceous units, which affords them greater protection against trauma and drying. On the other hand, FUs lack this extra protection and therefore need to be treated with greater care than their larger "cousins" if they are to achieve full survival. Care must be taken to adhere meticulously to the following points:

1. Minimize time out of the body between harvesting and planting grafts.
2. Minimize physical trauma during handling of the grafts.
3. Keep the grafts cool and moist while they are out of the body between harvesting and planting.
4. Minimize transection and wastage (discarding) of hairs during the graft preparation process.

The most crucial of these points for graft survival is the minimization of trauma, transection, and wastage of hairs by using specific microscope dissection techniques. Slivering, the key special technique used to dissect donor hair into FUs, is described in detail later in this chapter.

Advantages of the Use of the Binocular Stereoscopic Dissecting Microscope for Dissection of Follicular Units

There are several advantages to using the binocular stereoscopic dissecting microscope (hereafter referred to as the stereoscope) for the preparation of all grafts in procedures that involve exclusive use of larger numbers of FUs. These are conservation of donor hair, ease in viewing nonpigmented hair, greater accuracy in producing actual single-haired grafts for the hairline, and the ability to more precisely dissect ideally sized and shaped FU micrografts. I believe that the more precise the size and shape of FU micrografts, the higher the quality of the grafts. The resulting is better growth owing to increased survival and inclusion of telogen bulbs.

Conservation of Donor Hair

The main advantage of using the stereoscope is less wastage of donor hair. Between 10% and 30% more hairs are able to be harvested from the same-sized donor area than are obtained with performance of the same dissection using either the naked eye alone or simpler, more conventional methods of magnification such as with loupes and backlighting. In addition to providing increased magnification, the stereoscope is accompanied by an extremely bright light-beam focused on the minute area that is viewed through the microscope eyepieces (Fig. 11B-1). This combination of greater magnification and extremely powerful illumination makes the donor-area tissue appear translucent. The hair shafts and other components of the pilosebaceous units