Phacoemulsification is a dynamic procedure where the operating surgeon as well as the machine at work is doing number of rapid changes to make the procedure smooth and successful. The basic procedure of emulsifying the lens and aspirating out is not as simplified as stated in these words. Lot many things have to be done behind the scenes before a wonderful piece of work can be carved out of cataract surgery.

The whole process of emulsification and aspiration is based on certain physical and biological principles comprising the science of phacodynamics. In this chapter certain basic and few advanced concepts in phacodynamics are described.

**Mechanism of Action of Phaco**

The concept of phacoemulsification involves the use of a probe tip which vibrates rapidly to break up lens material into fragments. Fragments are aspirated from the eye via the center of this probe tip which is hollow. An outer sleeve provides for passage of infusion fluid. Fluid enters the eye via infusion ports in this outer sleeve. The infusion fluid constantly replaces any aspirate removed from the eye to maintain stable intraocular pressure.

Factors involved include:

a. **Cavitation** (Fig. 11.1): At the cessation of the forward stroke, the tip has imparted forward momentum to the fluid and the lens particles in front of it. On the tip being retreated, the fluid cannot follow thereby creating a void in front of the tip. The void is collapsed by the implosion (cavitation) of the tip thereby creating additional shock waves.

b. **Jackhammer effect**: A mechanical impact of the tip against the lens.

c. **An acoustical wave**: transmitted through fluid in front of the tip

d. **There is an impact of fluid and lens** particles being pushed forward in front of the tip.

**Power Settings**

Initially the manufacturer’s recommended settings are used. With experience, the surgeon can select his own settings. Power variables are adjusted intraoperatively depending on density of nucleus where phaco tip is engaged.
PHACODYNAMICS: STEP BY STEP

While too little a power will fail to cut the nucleus instead push the nucleus due to manual force, too much power will cause the nucleus to be thrown away from the ultrasound tip called ‘chatter.’ Too little power pushes nucleus and causes zonular stress while too much can pierce nucleus and may cause rent in posterior capsule.

The ultrasound power is usually preset to 50 to 70 percent. If the lens is soft, it is decreased to about 30 to 40 percent and if it is hard, the power is increased to 80 or 90 percent. Power is reduced if the nucleus chatters and the linear ultrasound mode is changed to pulse mode, which tends to hold the nucleus better against the tip. Ultrasound is inaudible; the buzzing results from harmonic overtones of the handpiece and phaco tip.

Phaco power is changed by changing the stroke length, duration of phaco power and changing the tip design.

**Phaco power**: Phaco power is the ability of the phaco handpiece to cut or emulsify cataract. Phaco power is directly related to stroke length, frequency and efficiency of handpiece. Since the frequency for a machine is usually fixed, it depends mainly on the stroke length.

**Stroke length**: Stroke length is the distance by which the titanium phaco tip moves to and fro. It is the most important factor in deciding the phaco power. The stroke length can be altered by changing the phaco power setting of the machine. Usually the stroke length lies between 2 and 6 mils (thousandth of an inch)

**Frequency**: Frequency is the number of times the tip moves and is fixed for a particular phaco handpiece. It is measured in KHz.

**Constant and pulse phaco power**: (Fig. 11.2) in constant mode, power is delivered continuously and it can be linear or panel controlled. Pulse mode allows phaco power delivery at preset intervals which can be changed. The pulse mode gives relative intervals where there is absence of tip movement. This improves the flow characteristics and helps in evacuating small nucleus particles toward the end of the surgery. The pulse mode is also relatively safer for the epinucleus because a more consistent and predictable flow will provide greater stability in the posterior chamber.

**Burst Phaco**: Use of high phaco power for a few milliseconds when the phaco tip is occluded with nuclear material.

**Maximum phaco power**: Maximum phaco power is preset by the surgeon. It determines the maximum obtainable ultrasonic energy when the foot pedal is fully depressed.

**Actual phaco power**: Actual phaco power in a machine with a linear foot-pedal control is proportional to foot pedal position and denotes the power actually being delivered at a given time.

**Effective phaco time**: Effective phaco time is the total phaco time at 100 percent phaco power. It can be less than the total foot-pedal time. Less EPT indicates proportionately less energy delivered to the eye thereby reducing the side effects of phaco power.

**Linear and panel control**: In linear control, pressing the foot-pedal leads to gradual rise of the parameters from 0 to preset with a linear relation to the foot-pedal control. In panel mode, the parameter reaches the preset panel maximum on pressing the foot switch without any linear foot pedal control. Linear mode is more commonly used since it gives the surgeon more control.

So as the phaco tip delivers energy to the lens matter it gets emulsified and gets replaced by BSS as aspiration is done. As it is now well understood that the energy dispersed in anterior chamber is deleterious to ocular tissue, most important is endothelium. Hence attempts are now made to reduce the dispersion of phaco power towards endothelium it is achieved by

1. Modulation in power delivery such as pulse, burst.
2. High vacuum settings.
3. Surgical maneuver like chopping and phaco in the bag.

The first two ways are now possible with newer machines at work. First we shall discuss about various new power delivery modifications.

**Pulse- Burst- Hyperpulse (Figs 11.2 and 11.3)**

The traditional phaco consisted of continuous phaco delivery. Which was followed by traditional pulse then burst mode and the latest in line is hyperpulse.

First introduced by Advanced Medical Optics, Inc. (Santa Ana, CA), on its Sovereign cataract extraction
system with Whitestar Technology in 2001, advanced power modulations such as hyperpulse technology have recently been adapted by both Alcon Laboratories, Inc. (Fort Worth, TX), in its new Infiniti system and by Bausch and Lomb (Rochester, NY) for the Millennium microsurgical system’s Custom Control Software (CCS) upgrade.

By rapidly cycling micropulses of phaco energy with variable duty cycles, the surgeon gains three advantages:
1. Better phaco efficiency (same work less power)
2. A decreased heat buildup and risk of thermal injury
3. Enhanced followability with less chatter due to the better balance between phaco repelling forces and the flow/vacuum attractive forces.

**Pulse**

With traditional pulse (which in the original software of all three platforms was limited to a maximum of 10 to 20 pulses per second), the duty cycle was fixed at 50 percent. A setting of four pulses per second therefore meant that each pulse interval was 250 milliseconds long, comprising a 125 milliseconds phaco-on and 125 milli-
seconds phaco-off period. Increasing the pulse rate to 10 would decrease the pulse interval to 100 milliseconds (50 milliseconds phaco-on and 50 milliseconds phaco-off). No matter the pulse setting (from two to the previous limit of 20), the phaco power was always on 50 percent of the time (a 50% duty cycle). With pulse mode chosen, foot position three on the footswitch controlled linear power with a fixed phaco-on and phaco-off interval.

**BURST MODE (FIG. 11.2)**

Burst mode was the first power modulation to indirectly allow variation of the duty cycle. In traditional burst mode, the phaco-on time is preset, and the phaco-off time was linearly controlled or decreased with foot position three. Phaco power remained constant in all positions of foot position three. For example, the Millennium’s CCS software allows the surgeon to set a phaco-on period of between 4 and 600 milliseconds. The phaco-off time is variably controlled with foot position three. Starting at the beginning of foot position three, the cycle interval becomes progressively shorter than 1,200 milliseconds as the pedal is depressed. At full pedal excursion, the phaco off period goes to zero, and the equivalent of continuous phacoemulsification is achieved. Burst mode fixes the phaco power and phaco-on time but effectively allows the surgeon to vary the duty cycle. If, for example, the burst-mode phaco-on time is preset to 300 milliseconds, then the duty cycle goes from 25 percent (300 milliseconds phaco-on with 900 milliseconds phaco-off) at the top of foot position three all the way to 100 percent at full foot pedal depression.

**NEW POWER MODES**

On all three companies’ systems, the newest hyperpulse power modulations allow surgeons to choose variable duty cycles as well as newer pulse settings of 100 pulses per second and beyond. By preprogramming different combinations of settings, ophthalmologists can employ unique power modulations for different lens densities or disassembly techniques. For example, one may approach soft nuclei with lower overall phaco energy settings such as a power of 30 percent, a frequency of 60 pulses per second, and a low duty cycle of 10 to 40 percent. Hard nuclei can be approached with 40 percent power, 30 pulses per second, and a duty cycle of 40 to 50 percent. Similarly, different power modulations are advantageous for different stages of the procedure. Continuous mode works best for sculpting, in which low vacuum settings and a stationary in-the-bag lens are present. By contrast, short, higher-powered microbursts (Fig. 11.3) of energy coupled with longer phaco-off periods avoid repulsion and achieve good impaling ability during quick chopping, which employs high vacuum and requires rapid, strong occlusion. For quadrant removal or other supracapsular techniques, followability is critical and can be enhanced by using a hyperpulse setting in the 50 to 100 pulses per second range, with a 25 to 40 percent duty cycle. Minimizing the percentage of ultrasound and allowing more rapid cycling between the phaco-on and phaco-off periods decreases the repulsive forces and allows the forces of fluidic attraction to predominate. This type of setting creates so-called “magnetic followability,” which minimizes chatter and wasted phaco energy. Many surgeons feel that hyperpulse mode enhances the efficiency of cavitation by preventing the wasteful buildup of cavitation bubbles on top of each other as occurs in continuous mode.

**Variable Phaco Rise Time**

When using phaco power in pulse or burst mode, total phaco energy decreases, and the efficiency of nuclear removal increases. Traditional pulses or bursts are delivered in square waves, but, with recent advances in software, surgeons now have the option of gradually ramping up pulses and bursts as well as of delivering waveform-modulated packets of energy. This gradual ramping up of power achieves a “pulsed pulses” effect. The waveform modulation reaches the same peak power as the conventional square wave pulse, but with less total energy expended (Fig. 11.2C).

Another major advantage of variable rise time is it increases the followability of nuclear fragments during surgery. Phaco power is a repulsive force like a jackhammer; attacking a nuclear fragment with high-powered phacoemulsification pushes the fragment away from and causes chatter at the phaco tip. By ramping up the power
via the variable rise time, a surgeon can grasp nuclear pieces with lower power. Once he gains purchase, delivering higher power will emulsify the nucleus. This process results in an almost magnetic followability of the nuclear pieces and increases the surgical efficiency.

**Occlusion mode** is currently available only with the peristaltic pump, allows the application of different phaco settings before and after tip occlusion.

On the Sovereign, an occlusion threshold vacuum setting can be programmed that will automatically switch phaco parameters. For example, if the vacuum level is 325 mm Hg, the surgeon can set a threshold vacuum level of 250 mm Hg, which when reached would automatically change to new settings. Typically, post-occlusion settings should have a higher Whitestar duty cycle, a higher maximum power, and a lower aspiration flow rate. When power increases from 35 to 45 percent, the Whitestar duty cycle increases from CL (20%) to CD (43%) (The two-letter nomenclature: the alphabets are given numbers according to order. First letter suggests half the ‘On’ period and second on e half the ‘Off’ period in milliseconds), and aspiration flow is decreased from 30 to 24 ml/min. Once a nuclear fragment occludes the port, thus causing the vacuum to rise and exceed the predetermined threshold, the machine switches to more phaco power for greater cutting efficacy and decreases the flow rate to avoid a post-occlusion surge. After the occlusion is cleared, the vacuum level drops, and the settings return to their original lower level. Care must be taken not to increase the power and duty cycle too high in post-occlusion mode. Because the tip is occluded and flow is minimal or zero, the tip can heat up very rapidly, potentially causing tissue damage. The Infiniti system’s occlusion mode differs somewhat. Instead of just relying on a threshold vacuum level, it uses a sophisticated algorithm based on irrigation pressure and aspiration vacuum to determine occlusion onset and full occlusion. The Infiniti’s post-occlusion settings, however, are limited—only allowing for a reduction of power, not the more logical increase in power or duty cycle.

**Irrigation System**

The irrigation in phaco machines is primarily gravity driven with modulations made through various devises in the irrigation and aspiration line. Thus the amount of irrigation is determined by the bottle height relative to the patient’s eye, by the sleeve diameter, and most importantly by the loss of fluid from the eye. Balanced anterior chamber dynamics: Irrigation = aspiration + leakage from the wound.

Rigid sleeves may be preferred over flexible sleeves because the irrigation does not get compromised while manipulating the handpiece in the incision. The eye should be at the same level above the floor as the pump (cassette) of the phaco machine.

Under hydrostatic conditions—when there is no aspiration or leakage present, the pressure inside the system entirely depends on the bottle height. The relation of bottle height and pressure is given in Table 11.1.

**Aspiration System**

Aspiration is defined as the evacuation of fluid through a closed system. Two important concepts concerning aspiration are flow rate and vacuum level.
Aspiration flow rate: (Fig. 11.5) Flow rate is the quantity of the fluid pulled from the eye per minute through the instrument tip and irrigation tubing. Flow rate therefore helps in bringing the material towards the tip. Flow rate is measured in cc/min and is dependent on the level of vacuum created in the aspiration tubing by the aspiration pump and surface area of the port of irrigation tip. Flow rate determines the rate of rise of the aspiration vacuum when the aspiration port is occluded.

Vacuum: Vacuum level is the difference in pressure between atmospheric pressure and the pressure inside the aspiration tubing. This is a negative suction pressure that is created by the pump.

Port vacuum of (mm Hg/mm²) = Vacuum created (mm of Hg) / Port area (mm²)

The vacuum level created at the port therefore varies inversely with the diameter of the tip. The vacuum or negative suction force created helps in holding the material to the tip and its final aspiration.

Aspiration Pumps

Depending on the machine, three kinds of pumps are used to control aspiration and produce the negative suction pressure, i.e. the vacuum. They are:

1. Peristaltic pump.
2. Venturi pump.
3. Diaphragmatic pump.

The peristaltic pump is also known as a ‘constant flow’ pump while the venturi and the diaphragmatic pumps are of the ‘constant vacuum’ variety.

Peristaltic Pump

Peristaltic pump was popularized by the heart lung machine. In these pumps, a pressure differential is created by compression of the aspiration tubing in a rotatory motion (Fig. 11.6). When the rotational speed is low, vacuum develops only when the aspiration port is occluded. On occlusion, vacuum builds up to preset value in a stair-stepped pattern. By increasing the rotational speed, as in the newer generation machines, a linear build up of vacuum occurs even without occlusion of the tip. It can thus be made to simulate a venturi or a diaphragmatic pump.

Systems with peristaltic pumps have two aspiration controls: aspiration flow and vacuum limit. The aspiration flow control determines the speed at which the pump turns; the faster the pump turns, the greater the resulting flow rate. By comparison, the vacuum limit is simply a safety setting that stops the pump when the vacuum reaches the set limit. Peristaltic systems can have either linear flow or linear vacuum (vacuum limit) modes. (The availability of these modes for each machine function [e.g. phacoemulsification, irrigation/aspiration, and vitrectomy] depends on the device manufacturer and model). In the linear flow mode, the flow rate is controlled by the foot pedal, and the vacuum limit is constant. This allows the surgeon to adjust the speed with which fluid and objects move toward the tip. In the linear vacuum mode (sometimes called the variable vacuum mode), the pump speed remains constant, but the vacuum level at which the pump shuts off varies depending on the depth to which the foot pedal is depressed (i.e. as the
pedal is depressed further, the vacuum limit allowed before pump shutoff increases).

Advantages of a peristaltic pump are that vacuum build up occurs only on occlusion of the aspiration port and also the fluidics of the peristaltic pump are more controlled with little or no deflation of the anterior chamber on sudden removal of occlusion. Vacuum level and flow rate may be controlled independent of each other.

There is a large safety margin in this pump as it is slower in building up vacuum. The peristaltic system is a more forgiving system as there is no inadvertent pull on the ocular structure since vacuum builds up only on occlusion. Peristaltic pump allows both zero and high vacuum phaco.

But the vacuum build up is in a stair-stepped pattern and true linear aspiration is not seen, however newer pumps do simulate a linear build up of vacuum. Because of the stair-stepped pattern of the vacuum build up, there could be more pulsations in the anterior chamber. The vacuum build up is directly related to the density of occlusion which in turn would depend upon the bevel angle of the titanium tip and the tissue density.

The surgeon has to mechanically approach the nuclear or cortical matter to first achieve occlusion for vacuum to build up in order to aspirate the tissue. However, the pulse mode has significantly improved the followability of the tissue, even in the peristaltic pump.

Venturi Pump

A venturi pump uses compressed gas to create inverse pressure. Vacuum generated is related to gas flow which in turn is regulated by a valve (Fig. 11.7). Vacuum build up occurs linearly in a consistent manner from zero to a preset value. The build up is almost instantaneous on pressing the foot-pedal. Due to this there is an increased risk of iris trauma and posterior capsular rents which makes these pumps unsafe, particularly so for beginners. But there is a good followability of the tissue. Nuclear and cortical material can be attracted toward the probe on depressing the foot-pedal.

On systems using either a venturi or diaphragm pump, the only aspiration control is vacuum. This vacuum setting is the actual negative pressure applied to the collection container and aspiration tubing. For a given vacuum setting, the flow rate is determined by the dimensions of the tubing, fluid viscosity, and the degree of occlusion (i.e. typically, the flow rate will be proportional to the applied vacuum). These systems have only a linear (or variable) vacuum mode. In this mode, the applied vacuum is controlled by the foot pedal. With this type of pumping mechanism, adjusting the vacuum directly affects the flow rate.

Many surgeons prefer venturi pumps as the vacuum build up is linear and there is a good followability of the tissue. Nuclear and cortical material can be attracted towards the probe on depressing the foot-pedal.

But this pump has the least safety margin and is not forgiving to the surgeon. The rise time is too fast. Incidence of ocular tissue damage has been reported to be much higher with this pump as compared to the peristaltic pump.

**Flow Pump**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Occlusion</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate</td>
<td>Present</td>
<td>Changes rise time. More flow rate quicker rise.</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>Followability</td>
</tr>
<tr>
<td>Vacuum</td>
<td>Present</td>
<td>Holding lens material</td>
</tr>
<tr>
<td></td>
<td>absent</td>
<td>No effect directly. But preset vacuum determines maximum flow rate achieved. Higher vacuum preset more flow rate achievable</td>
</tr>
</tbody>
</table>

**FIGURE 11.7: Venturi machine**
Vacuum Pump

<table>
<thead>
<tr>
<th>Vacuum</th>
<th>present</th>
<th>absent</th>
<th>Holds material followability</th>
</tr>
</thead>
</table>

Hybrid Pump

The primary example of the hybrid pump is the Sovereign peristaltic pump or the Concentrix pump (Bausch and Lomb Surgical). These pumps are interesting in that they are able to act as either a vacuum or flow pump dependent upon programming. They are the most recent supplement to pump types and are generally controlled by digital inputs, creating incredible flexibility and responsiveness. Different new pumps are shown in Figure 11.8.

Diaphragm Pump (Fig. 11.9)

A diaphragm pump uses a flexible membrane within a cassette to generate vacuum. Build up of vacuum is more linear and reaches the preset level even without occlusion. This makes it unsafe; however, lens material can be aspirated without having to mechanically approach it. Advantages and disadvantages are similar to venturi pumps.

Rotary Vane Pump

It consists of a rotor fitted eccentrically inside a cylinder. It has multiple lamellae which rotate and push the air out. It creates negative pressure.

Foot Pedal (Fig. 11.10)

Conventional foot pedal of phaco machine consists of 3 positions achieved by depressing the pedal in graduation. Position 1—irrigation; Position 2—aspiration; Position 3—phaco. It has a disadvantage that vacuum cannot be varied when the pedal is depressed to position 3. Some machines have a linear vacuum increase programmed to position 3. An even better solution to this issue is the Dual Linear foot control of the Millennium; this separates simultaneous linear control of vacuum and ultrasound into two planes of pedal movement (pitch and yaw). With linear control of vacuum in phaco mode, the surgeon can approach material with safer lower vacuum levels and increase it only after desired material is positively engaged.

Aspiration pressure: It is inversely proportional to the diameter of the aspirating port. The ultrasonic tip has a port diameter of 1 mm with which the maximum vacuum achievable is 70 to 100 mm of Hg. However, in new phaco...
machines the vacuum can be raised to 500+ mm of Hg in the phaco mode. The I-A tip has a diameter of 0.3 mm and the aspiration pressure may be increased to 500 mm Hg. Aspiration also depends on the tubings and the pump used. Aspiration is an important parameter in different surgical steps and techniques.

**Rise Time and Pump Flow**

**Rise time:** Rise time is a measure of how rapidly vacuum builds up after the aspiration port is occluded.

**Pump flow:** Pump flow is a measure of the rotational speed of the peristaltic pump head which in turn determines flow rate and aspiration.

**Relationship of rise time and pump flow:** (Fig. 11.11)

As the pump flow increases, vacuum builds rapidly as the tip is occluded and therefore the rise time decreases.

Pump flow is usually preset by the surgeon and is measured as a percentage. Normally 100 percent is equal to flow rate of 35 cc/minute. It is an overall measurement of fluid turnover in the eye. Pump flow determines rise time and event time.

**Maximum vacuum:** Maximum vacuum is preset by the surgeon and is measured in mm of Hg. This determines the maximum obtainable vacuum when the aspiration port is fully occluded. The speed at which this vacuum is achieved is determined by the pump flow setting.

**Actual vacuum:** Actual vacuum indicates pressure at the aspirating port at a given time. This depends on the maximum preset, pump flow, degree of tip occlusion and position of the foot pedal when linear control is used.

**What is Venting?** (Fig. 11.12)

Venting is the process whereby vacuum is equalized to atmospheric levels. There are two methods used to vent vacuum; air and fluid. Vacuum is equalized by opening
the aspiration tubing to atmospheric pressure. But air can be expanded or contracted. Thus the air is stretched as vacuum is building and when the vacuum is vented the expanded air will contract, releasing its stored energy. This can lead to surge. Vacuum can be equalized by opening the aspiration tubing to the irrigation tubing.

\[
\text{Maneuver} & \quad \text{Vacuum} & \quad \text{Power mode/ amount} & \quad \text{Remark} \\
\hline
\text{Sculpting/trenching} & \text{Low vacuum} & \text{Power adjusted according to hardness of nucleus in continuous mode} & \text{Low aspiration needed to just remove the emulsate. Due to lack of space at this stage the nucleus does no get repelled} \\
\text{Rotation of nucleus} & \text{Irrespective of settings it should be done on irrigation mode that is foot pedal position 1} & \text{Do not give unnecessary aspiration which can put stress on zonules} \\
\text{Chopping} & \text{Higher vacuum may be used to hold the nucleus and displace it so that chopper can be used more centrally} & \text{Chopping can be performed at low vacuum or no vacuum by using mechanical forces between chopper and the phaco tip. While using high vacuum to chop, vacuum can be reduced manually as the chop is about to complete} \\
\text{Fragment emulsification} & \text{High vacuum levels can be used depending on chamber stability offered by fluidics of machine} & \text{Occlusion mode helps to prevent surge. Manually flow rate can be reduced , bottle raised or vacuum can be reduced just before complete aspiration of material. Other hardware modifications are also discussed.} \\
\text{Epinucleus removal} & \text{Moderate vacuum levels are effective with greater safety margin.} & \text{Avoid inappropriately high flow rate to prevent abrupt aspiration. Use blunt tipped instrument to feed.} \\
\text{Cortex removal} & \text{I-A tip should be used with higher flow rate.} \\
\text{Viscoelastics removal} & \text{High vacuum with high flow rate.} \\
\]
lens matter or slip of matter from occlusion. The mechanism is shown in figure. During occlusion maximum preset vacuum is achieved as pedal is depressed fully. Due to occlusion there is no active flow in the aspiration line. The pump keeps on trying to move fluid from system. Due to compliance of the vacuum tubes, there is partial collapse of these tubes with reduction in volume of fluid in tube. When the occlusion is broken there will be sudden aspiration of fluid from anterior which may not be compensable by irrigation channel leading due volume deficit in anterior chamber and collapse (Fig. 11.13). Additionally there may be expansion of tubing if it is not properly reinforced which adds to the insult. This collapse can lead to damage to endothelium as well as posterior capsule making it most dreaded complication in fluidics.

Principles of avoiding surge are given as below:

1. Prevent rapid vacuum rise by decreasing flow rate and decreasing preset vacuum level. It gives extra protection against surge by increasing time to achieve maximum vacuum and more safety margin of irrigation.
2. Improve irrigation by increasing bottle height, using pressure irrigation or using sleeve with larger irrigation ports.
3. Prevent compromise of irrigation by tight wounds by proper wound size and use of microflow tips which have alternate grooves for the irrigation despite compression.
4. Avoid leaky wound which adds to the irrigation requirement.
5. Alternate flow during occlusion as in ABS (Aspiration bypass system) of Alcon which avoids a ‘No Flow’ situation even in maximum occlusion due to a small 0.18 mm opening on the side of tip (Fig. 11.14).
6. Tubings with lesser compliance avoids collapse during high vacuum (Fig. 11.15).
7. Reducing vacuum just before occlusion breaks or immediately after it breaks. This can be done manually as experienced surgeon can judge the stage of occlusion break. Now newer software based microprocessor controlled fluidic systems can achieve the same by sampling the pressures of system rapidly.
and reducing the vacuum as the occlusion breaks and flow starts.

**SUGGESTED READING**


