Instrumentation in Shoulder Arthroscopy

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Arthroscopy is a reliable and effective minimally invasive technique that has gained popularity in the past 20 years among shoulder surgeons. Arthroscopic surgery requires specific and complex instruments whose evolution has followed that of the surgical procedures. These instruments are expensive, and therefore, proper utilization and maintenance are essential. Furthermore, different surgical procedures, such as rotator cuff repair and capsulorrhaphy, call for different instruments which are specific to the operation being performed. Many surgical instrument companies currently produce tools which are very similar to one another with only minor technical differences; the selection of the most appropriate instrumentation depends on the individual discretion of the surgeon. In fact, each arthroscopic surgeon generally has his own set of instruments.

Systematicity is fundamental to successfully manage the instrumentation. The entire operating room team must be thoroughly trained on the equipment utilized for every type of surgery and informed of the technical preferences of the surgeon. The surgical instruments must always be positioned on the operating table in the same order; proper placement of the surgical equipment is critical and must be established before the operation.

Arthroscopy Tower

The arthroscopy tower consists of a vertical cart with various shelves on which the electronic equipment used for the arthroscopic procedure is placed.

Modern arthroscopy towers have a modular design to conform to any setup need. The power cords of the various units are pre-wired, and cable management is accomplished on either side of the cart. The carts are configured with wheels which allow them to be moved to the optimal position during surgery. The standard equipment to be placed on the tower includes a high-definition (HD) flat-screen monitor with dimensions varying from 25″ to 32″ suspended by a large moveable arm which enables the screen to be appropriately positioned according to the surgeon's needs. The video camera unit is placed on the first shelf of the cart followed by the light source. The cameras are generally equipped with 3 CCD (Interline Transfer Micro-Lens High Sensitivity CCD Image Sensor, 768 × 494 pixels each); these sensors allow for a resolution of 800 horizontal lines and 450 vertical lines to be displayed on the monitor. Adjustment for the brightness is automatic, thanks to an auto shutter with a speed of 1/10,000 s, controlled by the unit or by a control button located on the top of the camera head. With these buttons, it is possible to program the main functions: brightness, white balance, and peripheral illumination correction. The light sources consist of xenon 100–300 W lamps with a color temperature of 5,700–6,000°k and utilization temperature of 5–38°. A fiber-optic cable, approximately 2.5 m long with a diameter of 4 mm, is connected to the unit. It is currently possible to have a single, integrated control unit that combines the HD video camera (1080 p), "xenon bright" LED light source, and image management console with a tablet that is not only able to record videos and/or photos of surgical procedures and memorize the surgeon's preferences regarding setup but that also enables any authorized workstation to follow the surgery in streaming. Next on the arthroscopy cart, there is an irrigation pump, a unit for the motorized instruments that allows two motorized tools to be used at the

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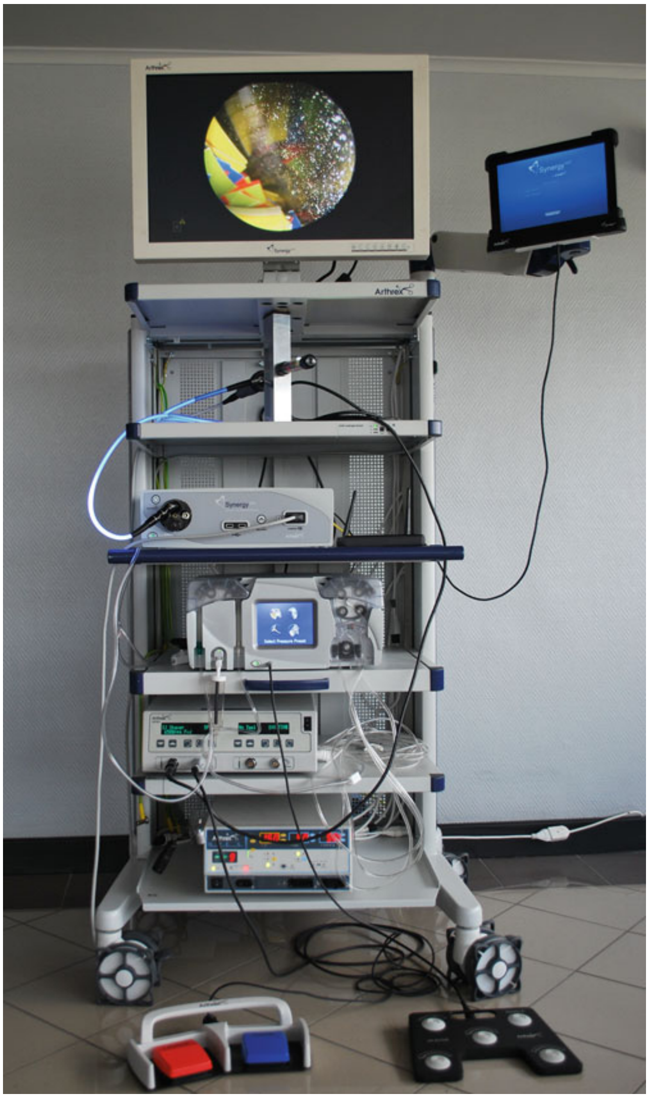

Fig. 7.1 Arthroscopy cart: a high-definition (HD) flat-screen monitor and a tablet suspended by a moveable arm are placed on the top; an integrated control unit that combines the HD video camera, the "xenon bright" LED light source, and the image management console is placed on the second shelf, followed by the irrigation pump, the motorized instruments unit, a radiofrequency generator, and the footswitches

same time, a radiofrequency generator, and a space for the footswitches (Fig. 7.1).

The arthroscopy cart is placed on the operative side of the operating table and in front of the surgeon (see Chap. 8).

Arthroscope

The arthroscope is composed of a rigid external sheath, at the distal end of which there is an optic device (objective end) that is able to reproduce the image of an object placed in front of the instrument. The area being examined is illuminated using a fiber-optic bundle which is placed on the inside of the metal sheath parallel to the axis of the optical system, along with the utilization of a light source. The image is transmitted to the ocular end, located at the proximal end, through an efficient system of lenses strategically positioned on the inside of the sheath.

The ocular end is equipped with wiring which enables it to be attached, using a special adapter, to the video camera; it is also connected to the light source.

The arthroscope is inserted into a metallic sheath, which is characterized by two lateral extensions (one for the inflow and one for the outflow of fluids) and a diameter that is large enough to assure an adequate flow (generally 4.5 mm).

There are different size arthroscopes currently available on the market with diameters ranging from 1.9 to 4.0 mm; those utilized in shoulder surgery generally have a diameter of 4.0 mm.

The arthroscope is characterized by field of view, inclination of view, and movements. There are two fields of view: one apparent and one real.

The apparent field of view is determined by the diameter of the circular image as seen through the ocular end of the arthroscope and displayed on the monitor. This field is influenced by the distance between the object and the arthroscope. The larger the circle, the larger the image will appear. The real field of view is the angle of view produced by the arthroscope and generally varies from 80° to 115°.

The inclination of view is the angle of projection at the objective end of arthroscope. The inclination is calculated by drawing a line along the axis of the arthroscope that intercepts the line drawn from the center of the arthroscopic image on the lens. There are various angles: 30°, 70°, and 90°. These angles allow for a complete inspection of the joint in all its corners because the structures being evaluated are often found on the side of, above, and below the position of the arthroscope. The standard 30° view is the easiest and most widely utilized because rotating the optical system at this angle provides for the best surgical viewing.

Moreover, the arthroscope is designed to perform three movements: pistoning, angulation, and rotation. The forward and backward movement of the arthroscope is called pistoning. The diagnostic arthroscopy begins with a broad overview, and then the arthroscope is moved closer to the specific structures for a better, more in-depth visualization. Angulation is a sweeping motion that allows the inspection of all the structures. Rotation is the most valuable movement in arthroscopy. Once the arthroscope is positioned at an appropriate distance to achieve a broader viewing, rotation of the scope allows the surgeon to inspect the joint without pistoning or angulation (Video 7.1).

The ability to effectively utilize the arthroscope is one of the elements which distinguish a good surgeon from an excellent surgeon because understanding the lesions, choosing the type of repair, and the repair itself depend on good visualization.

Illumination of the operating field is affected by two main factors: the amount of light and the quality of the lens system which transmit the light. Conceptually, the larger the size of the arthroscope, the more space there is for fiber optics which conduct the light beam. The most commonly used lens system is a system of cylindrical lenses (Rod lens system) developed expressly to balance the relationship between the fiber optics and the lenses to ensure a bright and clear viewing of the area being operated.

During the preparatory phase, it is essential to meticulously check all instrumentation relating to the optical system. Potential technical problems that could negatively impact the visualization and that should be investigated prior to surgery include the following:

- Arthroscope: any damage on the surface of the ocular end or the objective end caused by improper use or maintenance of the arthroscopic instruments (i.e., cracks, scratches, burns).
- Light source: any problems stemming from the source or the cable which connects to the arthroscope; both ends of the cable should be inspected for dirt or breakage. Care must be taken not to twist or bend the cable to avoid breakage of the fibers.
- Camera: check the focus and white balance.

Fluid Management

In all surgical procedures, good visualization of the operating field is critical. To obtain good visualization in shoulder arthroscopy, the following conditions must exist: proper functioning of the optical systems, adequate joint distention that allows for thorough inspection of the anatomical structures during the diagnostic phase, and correct utilization of the arthroscopic instruments during surgery. Therefore, the main objectives of fluid management are joint distention and limiting bleeding to ensure a clean operating field and good visibility and increasing the effectiveness of the cutting tools. To achieve these objectives, it is necessary to have constant positive intra-articular pressure in addition to maintaining the correct balance of fluids.

Fluid dynamics are based on four parameters: flow, flow rate, pressure, and resistance. Flow measures the volume of fluids which moves past a cross section of a tube in a given unit of time and is expressed in liters per minute (L/min) or milliliters per minute (mL/min). Flow rate measures the distance that a certain volume of fluids travels in a given unit of time. Pressure (mmHg) refers to the amount of force applied to a specific area or more precisely to the relationship between a mass and the volume in which it is contained. If the volume containing a certain amount of fluids increases because the walls expand, the pressure will decrease. On the other hand, if the walls of the chamber containing the liquid are not able to expand and the amount of fluids is increased, the pressure will increase. Resistance refers to a tubular system's tendency to obstruct the flow of the fluids and is influenced by the diameter of the tube.

Movement of fluids occurs along a pressure gradient; the fluids move from areas characterized by greater pressure to areas of lower pressure. In fact, the flow in a tube is directly proportional to the pressure gradient. This relationship affirms that the greater the pressure gradient, the greater the flow. Furthermore, liquids flow in the direction of least resistance. The flow in a tube is, hence, inversely proportional to the resistance. This inverse relationship confirms that as the resistance increases, the flow will decrease and vice versa. Therefore, flow is determined using the following formula: flow = pressure/resistance. For a liquid which flows in a tube, the resistance is usually impacted by three parameters: the radius of the tube (r), its length (L), and the density of the liquid (η) (eta). The following equation, known as Poiseuille's law, demonstrates the relationship between these factors: $R = 8L\eta/\pi r^4$. If we consider the density of the liquid to be constant, this equation shows that (1) resistance to the flow increases when tube length is increased and (2) resistance to the flow decreases when tube radius is increased.

A complete irrigation system is composed of a pump with a varying number of restrictions which are connected in series (diameter of the inflow tube, arthroscope with sheath, joint, outflow cannula, or suction hose). The pump generates an initial pressure, and flow will vary according to the total number of restrictions in the system. Local pressure will be reduced in every location where there is a restriction, and if there are many restrictions before reaching the joint, the drop in pressure will be substantial, resulting in an intra-articular pressure which is lower than that created by the system. From a practical point of view, the main factor which determines inflow is the resistance encountered at the point of entry (diameter of the entry cannula and/or the sheath of the arthroscope). The inflow tube is generally connected to the sheath of the arthroscope to have a direct flow towards the field of view and to be able to manage modifications in pressure in the event of bleeding. Outflow is typically managed through the cannula in the anterior-superior portal. When inflow is equal to outflow, intra-articular pressure is stable and balanced.

Intra-articular pressure, or subacromial space pressure, is determined by the initial pressure of the system, changes in joint position (abduction and traction reduce the pressure; rotations increase it), and inflow/outflow points controlled by the surgeon.

In general, fluid pressure within the glenohumeral joint is kept close to 30–40 mmHg; it can increase to between 40 and 70 mmHg in the subacromial space to allow for an adequate visualization. Maintaining the mean arterial pressure between 70 and 90 mmHg, or the systolic blood pressure at 100 mmHg, improves the visualization. In a study regarding the relationship between systolic blood pressure and irrigation pressure in the subacromial space, Morrison et al. [1] demonstrated that a difference of more than 49 mmHg between systolic blood pressure and subacromial space pressure, due to an increase in the patient's arterial pressure or a decrease in irrigation pressure, causes bleeding. An inadequate intra-articular irrigation pressure compromises operating visibility because it produces a collapse of the joint and turbulence secondary to bleeding, increasing the risk of inadvertently damaging articular structures. Nevertheless, excessive irrigation pressure can cause an extravasation in the soft tissue, rupture of the synovial membrane, and even compartment syndrome [2–5]. A constant flow of 5–10 mL/min is sufficient for a proper viewing.

Fluids

The liquids utilized must have osmotic, ionic, and pH biologically compatible properties to not cause tissue damage. Furthermore, they must not conduct electricity to ensure safe utilization of the radiofrequency tools. We use 3 L bags of sterile saline solution with one vial of noradrenaline added to help control any bleeding. These bags are hung at a fixed height from a pole adjacent to the arthroscopic tower and connected to the irrigation pump through a Y-connector.

Irrigation Systems

It is possible to use two different irrigation systems: a gravity system and an automatic pump system.

Gravity System

The gravity system depends on hydrostatic pressure; the pressure gradient and the flow generated by this system are exclusively due to the difference in height between the irrigation solution bags and the joint (30 cm = 22 mmHg) and the diameter of the sheath of the arthroscope (Poiseuille's law). Keeping the bags at a fixed height, the pressure gradient is not influenced by the volume of the bags. Therefore, the flow is modified by altering the height at which the bags are hung and not by altering their volume (Bernoulli's principle).

Intraoperatory vision can be influenced by fluctuations in inflow, for example, when a bag is emptied, and hence, saline solution bags are generally connected to the system in the following ways:

- One open and one closed
- Both open: one higher that will be emptied first and one lower that will subsequently begin to be emptied, generating less of a pressure gradient but ensuring the ability to change the first bag without interrupting the flow [6–8]

The outflow represents another fundamental point to be considered. When motorized instruments are utilized, outflow increases, and the inflow is not able to sustain an adequate intra-articular pressure, resulting in a negative fluid balance, and consequently, the joint will tend to collapse. To avoid this problem, it is recommended that suction be regulated through the manipulation of the motorized instrument or by manually closing the suction hose at intermittent intervals.

The advantages of a gravity system lie in its simplicity, safety, and low cost.

Automatic Pump Systems

In these systems, the pressure gradient is completely controlled by the pump and, therefore, does not depend on the height of the bags, volume, or gravity. These pumps create a constant and predictable flow and are able to produce greater flows and higher pressures than those produced by a gravity system. The higher pressures enable any bleeding to be stopped by plugging the vascular wall, and greater flows can be generated when using motorized tools.

There are two types of pumps: the peristaltic pump and the centrifugal pump.

The peristaltic pump works by pulsing, closing, and opening the inflow tube, releasing a certain amount of fluids. Pressure and flow are regulated by adjusting the revolutions per minute (RPM) on the pump control unit. The disadvantage of this type of pump is that the flow is pulsed; since the pressure is determined by the flow rate, high flow rates can produce pressure surges.

The centrifugal pump utilizes a rotating pump which continually releases a volume of liquid. In this way, there is a uniform control of the pressure, and surges are avoided. The disadvantage is that a continuous flow in an uncontained space (i.e., subacromial area) can cause an excess fluid extravasation if the outflow is not well balanced.

Pumps with independent control of the flow and pressure are available on the market. We use a pump that has an integrated inflow/outflow fluid management system but that can also be used exclusively as an inflow pump. Using piezoelectric sensors, constant control of the pressure is maintained without producing any pulsing effect while, at the same time, adjusting for changes in pressure and intra-articular flow. It is, therefore, able to achieve an adequate intra-articular distention even when the outflow increases as a result of the use of motorized tools. The setting of the pressure and flow values is adjustable using the control unit, either with a touch screen or a remote control (Fig. 7.2).

Hand Instruments

Hand arthroscopic instruments must be the appropriate size for the joint and have magnetic properties which allow them to be recovered in the event of breakage. The tools used for

Fig. 7.2 Irrigation pump. Touch screen allows to select preset pressure and flow values according to the procedure (shoulder, knee, hip, or ankle arthroscopy) or to adjust values according surgeon's need

evaluation purposes, or for creating arthroscopic access, usually have blunt ends which reduce the risk of lesions on the joint surfaces and/or peripheral vessel and nerve structures. On the other hand, the instruments used for surgical procedures generally have sharp ends to be able to cut effectively.

Permanent Skin Marker

A dermographic pen is utilized to draw landmarks of the underlying bone structures on the patient's skin. These landmarks help the surgeon to identify arthroscopic access points as well as neurovascular structures which could be at risk during the operation (see Chap. 10).

Needles

An 18 gauge spinal needle is used to correctly identify the arthroscopic entry points on the skin and trajectories leading into the joint (see Chap. 10).

Cannulas

Arthroscopic cannulas can be made of plastic or metal; they are all equipped with a blunt trocar that facilitates the penetration through the soft tissue to reach the joint.

We prefer to use a metal cannula to create the arthroscopic portals. We use plastic cannulas with different calibers throughout the remainder of the surgery: 8.0 mm operative cannulas and 5.5 mm outflow cannulas.

Plastic cannulas have the following characteristics (Fig. 7.3):

- They are available in different colors that indicate the different calibers.
- They can be smooth or threaded; the threaded design helps prevent the cannulas from accidentally slipping out during the operation.
- They can be rigid, semirigid, or flexible,
- They are translucent to facilitate viewing and management of the sutures and knots.
- They are equipped with a lateral spigot which allows outflow to be controlled manually and an anti-reflux valve, in either plastic or silicone, which helps to maintain intra-articular pressure, limiting spontaneous outflow of fluids.

In addition to managing outflow and facilitating the passage of sutures and knots, cannulas are used to ensure the passage of arthroscopic instruments in the joint without damaging soft tissue, avoiding the creation of false routes.

Switching Sticks

There are generally two switching sticks per arthroscopic kit. They are metal rods without a head and with blunt ends that serve as a guide in the creation of portals and to facilitate the exchange between portals and cannulas. If it is necessary to invert the position of the arthroscope and the cannula, the two switching sticks are inserted, one in the cannula and the other in the sheath of the arthroscope; in this way, it will be possible to switch the portals, leaving the sticks inserted so the portals are not lost (Fig. 7.4).

Fig. 7.3 Different types of cannulas are available. They can be smooth or threaded, rigid, semirigid, or flexible. Different colors indicate different calibers. They are translucent to easily manage the sutures. Lateral spigot allows outflow control

Fig. 7.4 The two switching sticks are used to switch the anterior and the posterior portals

The switching stick can also be used as probe to evaluate texture, thickness, and mobility of an anatomical structure and the tension of a repair after the operation.

Dilators

Dilators are metal instruments that are utilized to dilate the arthroscopic portals in order to facilitate the passage of the cannulas. They are cannulated so they can easily slide over the switching stick, which acts as the guide (Fig. 7.5).

Wissinger Rod

This metal rod has a head and blunt ends; it is used to create an access portal with an inside-out technique which involves the following steps:

- Place the arthroscope with its sheath on the point where the access portal is to be created
- Remove the arthroscope while keeping the sheath in place
- Insert the Wissinger rod into the sheath of the arthroscope until the tip touches the skin

Fig. 7.5 Dilators. Different colors indicate different calibers. They are cannulated, so they can easily slide over the switching stick and facilitate passage of the cannulas, without losing portals

- Create an incision using a scalpel and place a cannula on the tip of the Wissinger rod
- Remove the Wissinger rod after having placed the cannula in the joint and repositioned the arthroscope

Probe

The probe is an instrument with a curved end which represents the "extension of the surgeon's finger." It is inserted into the joint through an arthroscopic portal. In the diagnostic phase, it allows for palpation of the lesion and assessment of its mobility (Fig. 7.6). Some probes are graduated and, hence, are able to estimate the size of the lesion.

Chisel Dissector

Available in various sizes, the chisel dissector is characterized by a flat and sharp end. It is primarily used in instability surgery and enables the surgeon to loosen scar adhesions and to adequately mobilize the capsulolabral complex from the glenoid neck (Fig. 7.7).

Rasp

An instrument utilized to abrade bone surfaces and/or capsular tissue to create bleeding (Fig. 7.8). This same procedure can be performed using a motorized instrument.

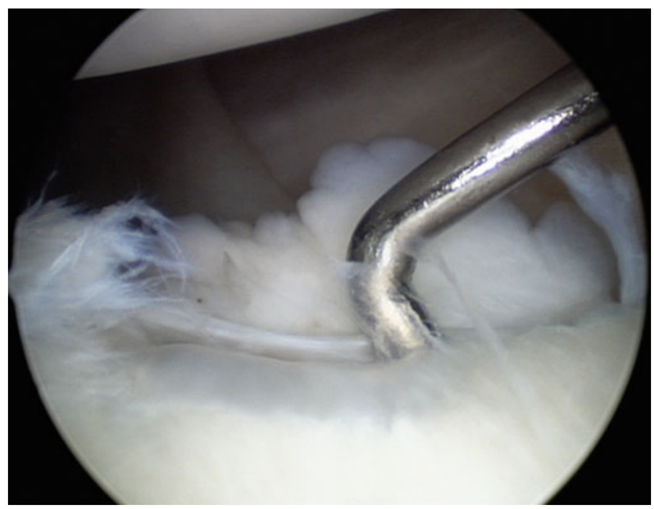

Fig. 7.6 Probe is used for palpation of a lesion of the anterior glenoid labrum

Cutting Instruments

Various cutting instruments are currently available on the market, and they each perform different functions.

Punches

Punches are a particular type of basket scissors; they can be straight, curved, or angled (upturned, right, left) with antegrade or retrograde bite (Fig. 7.9). Because of their shape, they enable the surgeon to reach areas which are typically

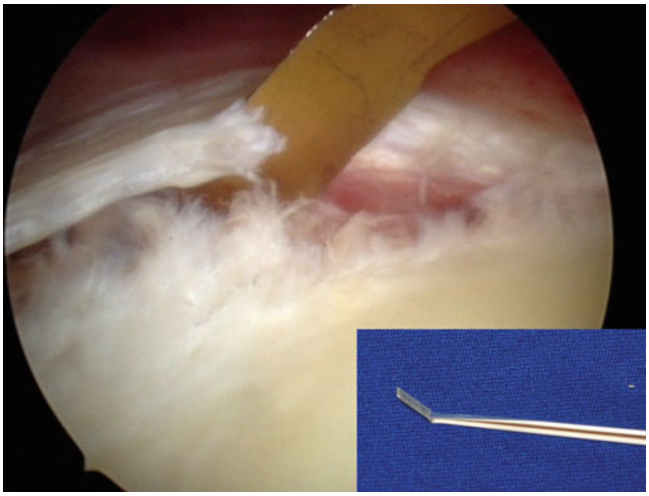

Fig. 7.7 Chisel dissector is characterized by a flat and sharp end. It is used to elevate and mobilize scarred tissue to be repaired

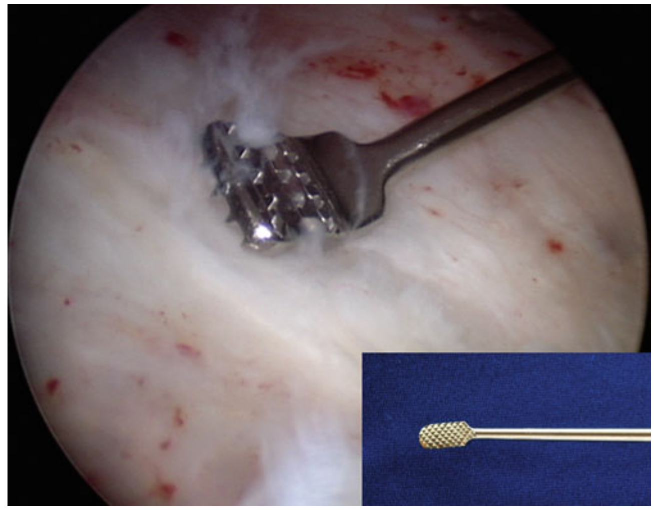

Fig. 7.8 Arthroscopic rasp. It is used to abrade bone surfaces and/or capsular tissue

Fig. 7.9 Different types of basket scissors: right angled, straight, and upturned with anterograde bite

difficult to access. The use of basket punches in shoulder surgery is currently limited because of the widespread utilization of motorized or radiofrequency tools. Nevertheless, punches are generally used for the removal of capsular (i.e., arthroscopic capsular release) or tendon (i.e., atrophic edge of a rotator cuff lesion) tissue.

Scissors and Suture Cutters

The scissors can be straight or curved. They are frequently utilized to cut soft tissue, such as the rotator cuff (i.e., during an interval slide procedure), the capsule (i.e., during an arthroscopic capsular release), or the long head of the biceps (tenotomy), as an alternative to radiofrequency instruments. They can also be used to cut the suture strands after a knot has been tied. Suture cutters were designed to facilitate arthroscopic cutting of high-resistance braided sutures, such as FiberWire, and are available in a closed and open end. The suture strands are carried by the instrument to the outside of the joint; the instrument then slides through the cannula to the point where cutting is needed (Fig. 7.10).

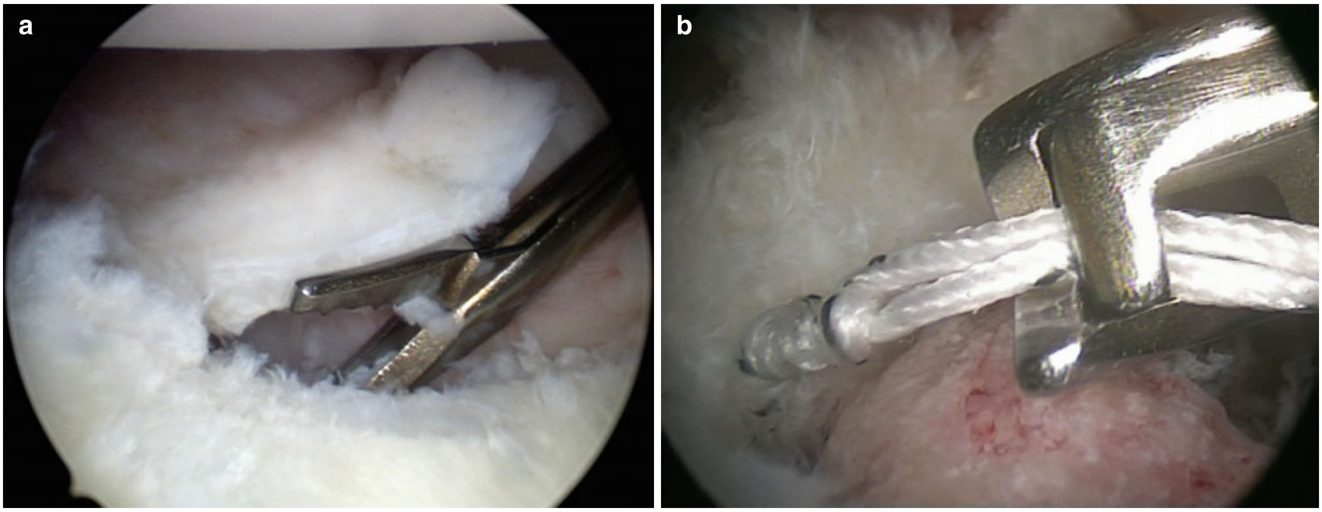

Fig. 7.10 (**a**) The basket scissors are used to perform capsular release. (**b**) Suture cutter is used to cut high-resistance braided suture

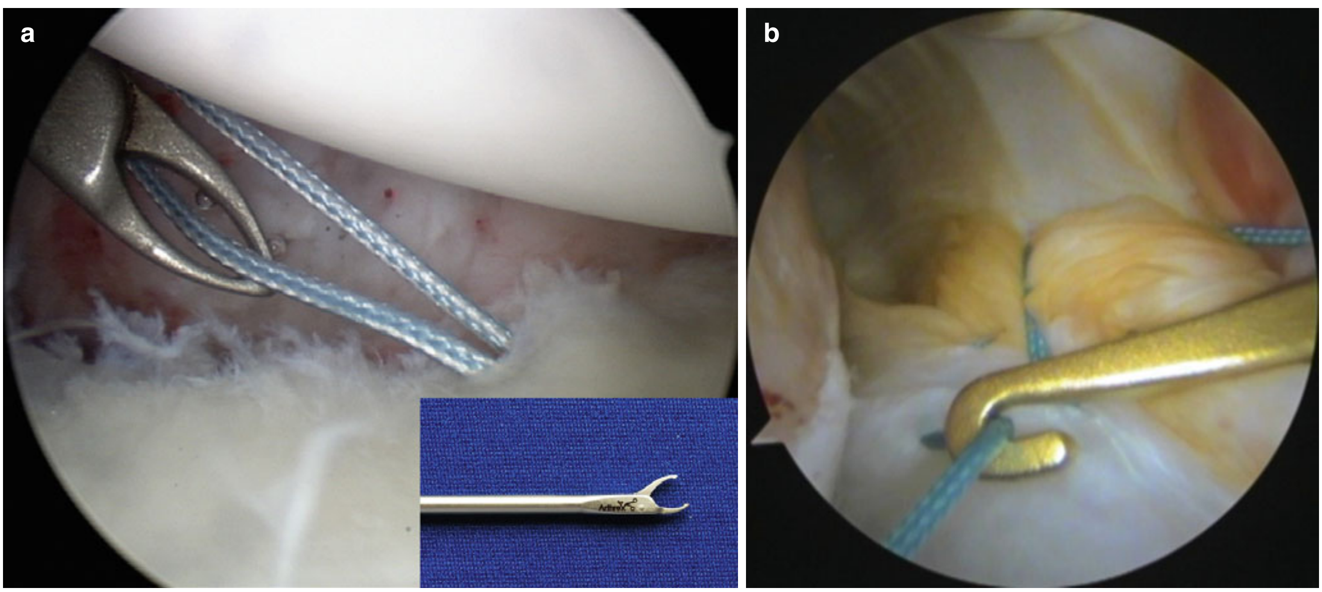

Fig. 7.11 (**a**) Suture retriever. The jaw creates a closed loop (*see* inset). (**b**) The crochet hook is used to recover a suture strand

Grasping Instruments

A wide variety of grasping forceps are available in various sizes and with different bites; they are made out of metal and have either straight or slightly curved tips. They can be locking, non-locking, or with self-releasing locking mechanism.

Suture Retrievers

Suture retrievers are used to recover and manage the suture strands. The jaw creates a closed loop which allows the suture to slide freely during suture extraction.

The crochet hook is another simple tool that performs well in tight spaces to retrieve suture loops during any suturing procedure. The smooth tip prevents abrasion of suture strands, and the ergonomic handle facilitates instrument manipulation in the wet arthroscopic environment (Fig. 7.11).

Graspers

Graspers can be blunt, serrated, or hook shaped. A fundamental requirement of these forceps is the ability to provide an atraumatic grasp that does not compromise the integrity of the structure. They can be used for tissue grasping and/or reduction, foreign and loose body removal, minor arthroscopic biopsies, and suture retrieval and management (Fig. 7.12).

Suture Passers

The role of suture passers is to allow for the passage of suture strands through the soft tissue (tendons or capsulolabral tissue). They are divided into two types: direct and indirect. Direct suture passers enable the passage of the suture directly through the tissues without using suture shuttles. Passers can be further classified as antegrade or retrograde based on the way in which they are utilized. The type of lesion and quality of the tissue determine which instruments will be used. The technique of passing the sutures through the soft tissue will be discussed in Chap. 13.

Direct Suture Passers

Direct passages are frequently used in rotator cuff repair surgeries. All suture passers are equipped with a safety-lock feature which prevents accidental opening of the forceps during the introduction or extraction of the suture.

For direct antegrade passages, we use suture passers preloaded with a single-use needle, which can be used for all the sutures of a single operation. Before introducing it into the joint, the suture is loaded on the passer's bite. Once in the joint, the passer's bite enables adequate grasping of the free end of the rotator cuff (up to 16 mm), and the preloaded needle pushes (with a direct antegrade approach) the suture through the tissue. Most modern passers have a suture capture trap which allows for suture retrieval during the extraction of the passer; alternatively, a grasper can be used to retrieve the sutures (Fig. 7.13).

For direct retrograde passages, instruments with a sharp end and an open loop, dorsal or ventral, are utilized. They are available with different angles of curvature. The sharp end facilitates the passage of the instrument through the tissue, and the loop aids in the retrieval of the sutures (Fig. 7.14).

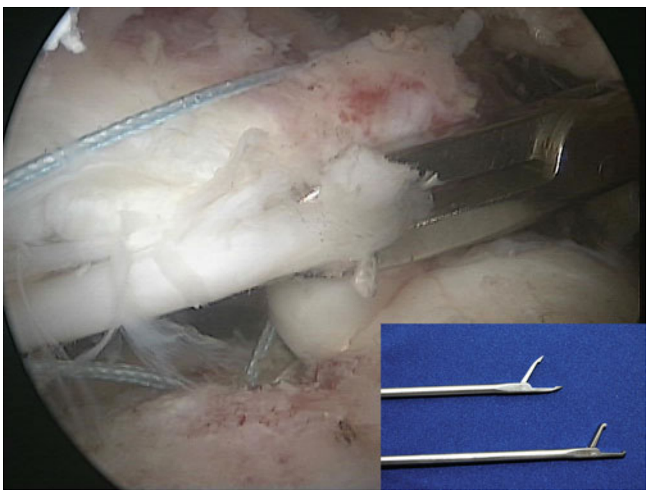

Fig. 7.12 Graspers can be blunt, serrated, or hook shaped (*see* inset). They can be used for tissue grasping, loose body removal, and suture retrieval

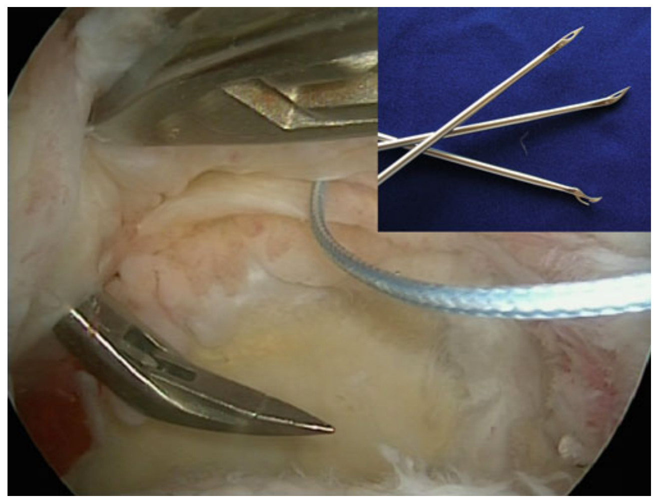

Fig. 7.14 Direct suture passers for retrograde passages. They can be straight or angled and are characterized by a sharp end and an open loop, dorsal or ventral (*see* inset)

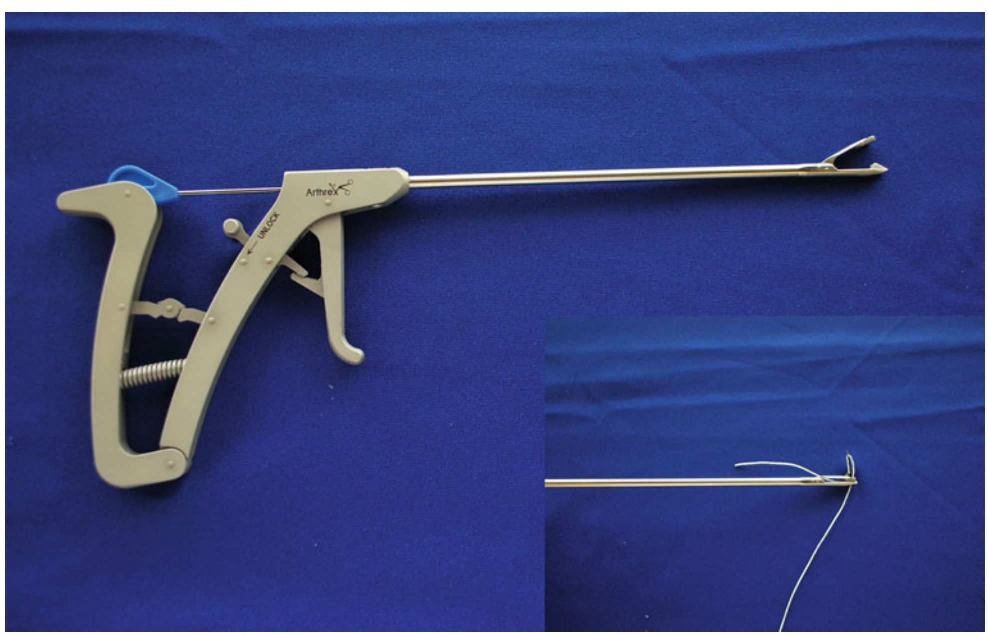

Fig. 7.13 New generation direct antegrade suture passers have a suture capture trap (*see* inset) which allows for suture retrieval during the extraction of the passer

Indirect Suture Passers

Indirect suture passers rely on a suture shuttle to pass the suture through the tissue using a retrograde approach. They are hook-shaped instruments with different inclinations, curvatures, and sizes which allow them to be used effectively into the joint. They are primarily used in the repair of the capsulolabral complex for the treatment of shoulder instability or for certain techniques in rotator cuff repair (i.e., margin convergence). The distal end of the suture passer is cannulated to enable passage of the suture shuttle on which the suture is loaded. This suture shuttle can be manually loaded or preloaded in the instrument and consists of either a monofilament suture or a metal wire coated in a plastic film to make it atraumatic, with an eyelet along its length or at the distal end in which the suture is loaded (Fig. 7.15).

Knot Pusher

The knot pusher allows the knot to be pushed through the cannula into the joint. There are various configurations of knot pushers available on the market: standard single hole, cannulated double-diameter single hole, standard two hole, and modified two hole that, pulling the knot, opens mechanically (Fig. 7.16).

Golden Retriever

The golden retriever is a metal tube (4.2 mm diameter) with a magnet at one end. It is used to recover any metal pieces which have dropped in the joint due to instrument breakage. For this reason, it is fundamental that all the arthroscopic instruments have magnetic properties. The golden retriever functions with

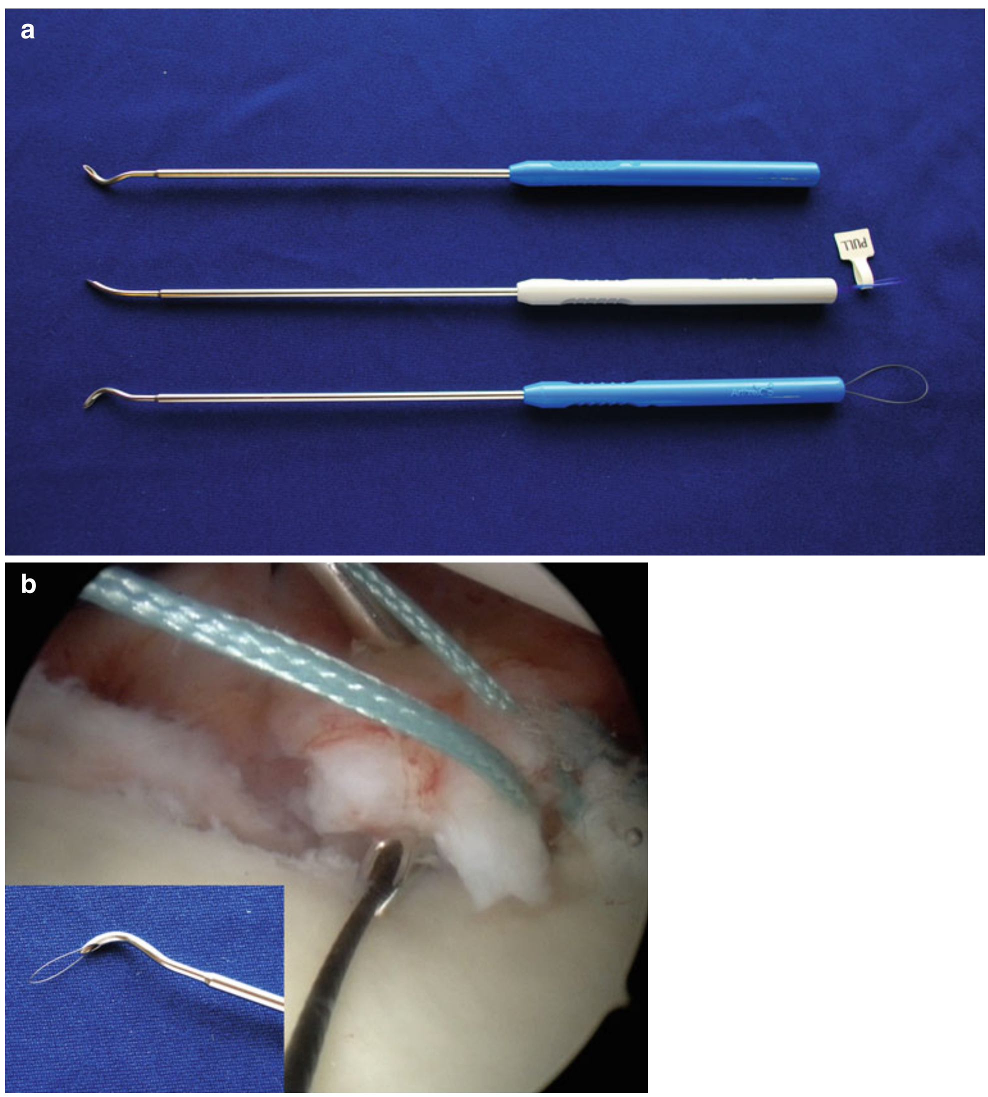

Fig. 7.15 (**a**) Indirect suture passer can be straight or angled (*right*, *left*). (**b**) The distal end of the suture passer (*see* inset) is cannulated to enable passage of the suture shuttle on which the suture will be loaded

both applied suction forces and magnetic power. The suction serves to mobilize the fragment guiding it towards the magnetic field. It was by design that the golden retriever cannot deliver suction as powerful as it would seem to be able to. Therefore, the suction should be removed as soon as the metal piece approaches the magnet, ensuring solid contact between the two surfaces without soft tissue interposition.

The golden retriever cannot be utilized without a cannula. The cannula has the dual function of allowing for the visualization of the retrieved fragment and facilitating its extraction by preventing it from getting lost again in the extra-articular soft tissue. The cannula is removed while it still contains the golden retriever and the recovered fragment.

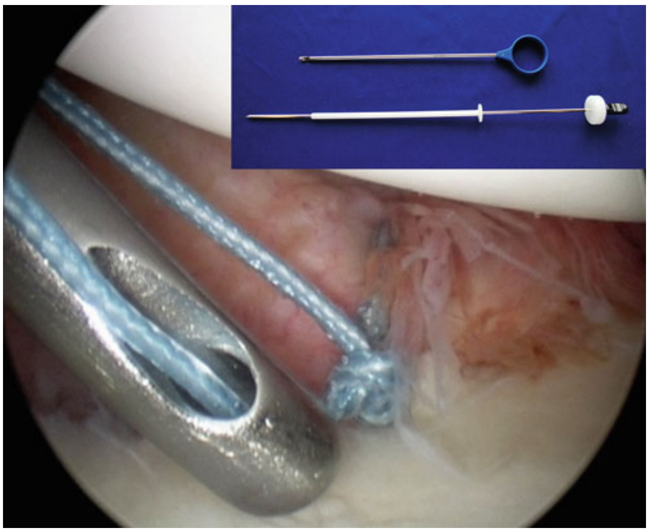

Fig. 7.16 The knot pusher is used to tie the arthroscopic knots. Different types of knot pusher (*see* inset) can be used

Powered Instruments

The shaver is an instrument equipped with a handpiece in which single-use blades, with different shapes and functions, can be inserted. The control unit is inserted in the arthroscopic tower, and it is controlled by footswitch placed near the surgeon's feet or by buttons on the handpiece. The shaver has a suction tube; the suction is managed either directly by the surgeon with a control on the handpiece or by an assistant who adjusts the suction by manually clamping the tube. The suction serves to remove loose tissue or bone fragments in the joint which were generated by the shaver. The rotation speed of the blades is automatically set by the control unit which is able to recognize the type of blade and then adjust the speed from a minimum of 100 to a maximum of 8,000 revolutions per minute. Nevertheless, it is possible to manually modify the setting based on the preferences and needs of the surgeon. The footswitch is used to control the direction of blade rotation: forward, oscillating, or reverse. The blades can be grouped into two major categories: those used for soft tissues and those used for bone. Blades used for soft tissues can have a single or double cutting edge, smooth or toothed. Among the blades used for bone, we can distinguish between those used for cortical abrasion before positioning the anchors (round burr) and those used for

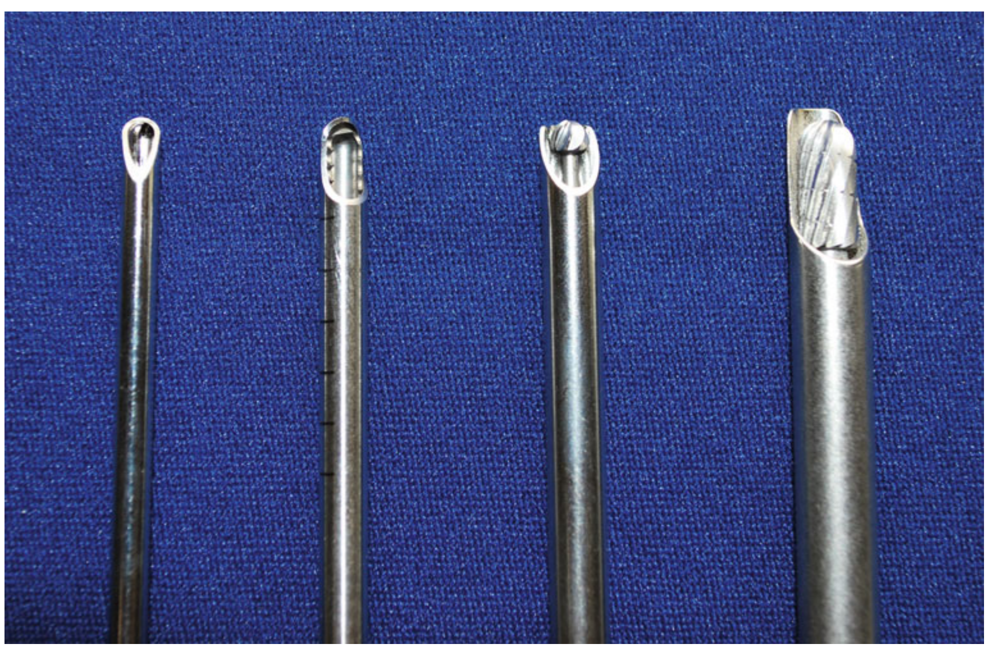

Fig. 7.17 Motorized shaver blades (*from left to right*): smooth for soft tissue, toothed for soft tissue or gentle cortical abrasion, round burr for cortical abrasion, and oval burr for acromioplasty

acromioplasty (oval burr), which are more aggressive (Fig. 7.17). The diameter of the blades can vary according to the model and manufacturer and is selected based on the surgical procedure. The blades most commonly used are medium sized (between 3 and 5 mm). The blade's ability to cut or abrade does not depend exclusively on rotation speed or type of blade employed, but also on the surgeon's ability to manage the instrument. Generally, the harder the tissue, the fewer revolutions per minute are necessary, but greater pressure must be applied on the instrument. The opposite is true for the soft tissues. The hand that guides the instrument is the main determinant of its effectiveness.

Electrosurgery

The use of radiofrequency equipment helps to effectively control bleeding which, together with the irrigation pump, contributes to optimizing the arthroscopic view. The system consists of a radiofrequency generator placed on the arthroscopic tower, a single-use handpiece with integrated electrode, and footswitch control. Reusable handpieces, in which single-use electrodes are inserted, and systems equipped with hand control are also available. The electrodes used vary in terms of shape, size, and angle of curvature. They are selected by the surgeon based on the surgical procedure to be performed. Inside each electrode, there is a code that generates a signal which is transmitted to the generator for the setting of the instrument. There are two basic types of thermal instruments: monopolar and bipolar. Monopolar instruments utilize an "active" electrode placed at the end of the handpiece and a "return" electrode applied to the patient. Bipolar instruments have the active electrode and the return electrode located in the surgical instrument, thereby minimizing the amount of tissue involved in the electrical circuit. Harnessing thermal energy, these instruments allow for effective management not only of coagulation but also of tissue cutting and ablation procedures. The greatest risk associated with the use of these instruments is necrosis induced by high temperatures [9–12].

The thermal effects of radiofrequency waves on the tissue are determined by the following factors: level of energy (power and impedance), duration of the treatment, characteristics of the tissue, type (mono or bipolar), and shape and size of the electrode. Some systems are able to monitor the temperature of the active electrode.

A new method of high-frequency electrosurgery, coblation or "cold ablation" technology, utilizes radiofrequency energy but generates much less heat. This method induces molecular dissociation. Saline solution, typically used in arthroscopy, is introduced in the space between the tissue and the electrode. When the electric current is applied, it creates a layer of charged particles which is referred to as a "plasma" layer. The particles in the plasma layer have enough energy to break the molecular bonds, which results in volumetric removal of target tissue at relatively low temperatures, therefore, minimizing damage to surrounding healthy tissues. The majority of the thermal energy is consumed in the plasma layer due to ionization.

From a practical point of view, the radiofrequency device helps to achieve pinpoint control of any bleeding; it is indispensable in bursectomy and synovectomy because these procedures involve highly vascularized structures. Radiofrequencies allow for a volumetric reduction of tissues while controlling bleeding and maintaining a clear vision of the operating field (Fig. 7.18).

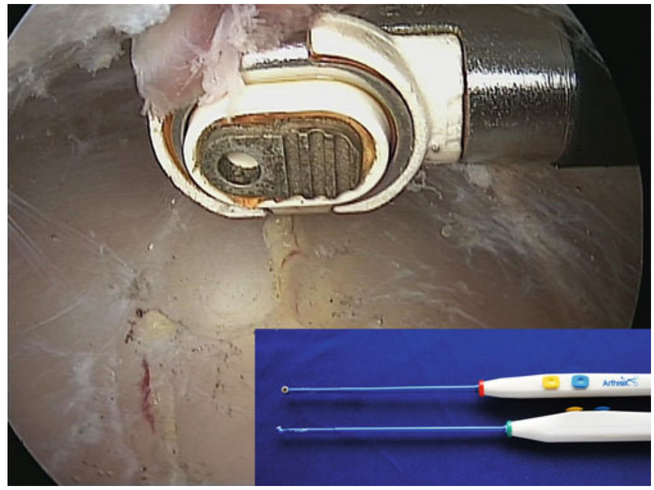

Fig. 7.18 Radiofrequency instrument used to perform subacromial bursectomy. The electrodes vary in shape, size, and angle of curvature (*see* inset)

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