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Advancements in Minimally Invasive Arthroscopic Surgery: A Boon for Treating Joints

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Abstract: ***With increase in the advancements in the world of surgery's, minimally invasive surgical (MIS) techniques are considered as a boon. In the 20th century, Arthroscopy is one of the greatest advancements witnessed in Orthopedic Surgery. Arthroscopes are used to perform an Arthroscopic Surgery. These powered instruments now have a wide range of blades and burr's options available for the surgeon to choose from. The proper detailed usage of the various types of blades and burr's have been discussed. A complete Arthroscopy system consists of various components. Each component plays an equally important role to develop a seamlessly operable Arthroscopic System. These components and their roles are described and discussed in detail. The hardware and software parts of the prototype system are explained in detail.***

Keywords: Arthroscopy, Arthroscope, Arthroscopy System, MIS, blades& burrs, prototype, orthopedic surgery, surgeon

1. Introduction

The traditional procedures of orthopaedic surgery are difficult to accurately treat micro-traumas, and the recovery period after these treatments are long [1]. Arthroscopic surgery's development is seen as a turning point in orthopaedic surgery. The origin of the term arthroscopy comes from the Greek words arthros and scope in, which mean joint and look, respectively [2].

Arthroscopic surgery is considered to be a minimal invasive surgery that provides a limit need of incisions size, less time of wound healing, and decreases the risk of infection, which allows higher degree of clinical accuracy. This procedure is performed on knee, shoulder, elbow, ankle, hip or waist. It is performed to treat loose bone fragments, inflamed joint linings, scarring within joints, damaged or torn cartilage and torn ligaments.

Powered cutter arthroscopic shaver system plays an important role in arthroscopic surgeries. They are designed for use in different clinical situations and for specific functions to cut massive tissue in a short time. Burs have several spiral curve cutting edges and it is useful for aggressive bony site preparation, intercondylar osteophytes resection, cartilage and osteochondral debridement [3].

The Degree of aggression of blade is determined by the shape and geometry of the edges of inner and outer tips [4].

The currently available shavers have various sizes (in length and diameter) and shapes (straight, curved, flexible) to meet diverse types of joint surgery[5]. The diameters usually range from 1.9 to 6.5 mm, and lengths from 120 to 180 mm [6].

Knee arthroscopy for osteoarthritis offers an alternative pain relief option for patients who are not ready or are unwilling to undergo a major surgical procedure such as knee replacement surgery [7].

2. Shaver System

The entire Arthroscopic shaver system consists of Console, Handpiece, Suction Cannister, Blades and Burrs. There are a wide range of blades and burrs available for treating different types of abnormalities. Blades have an Outer tube, Inner tube and a cutting window.

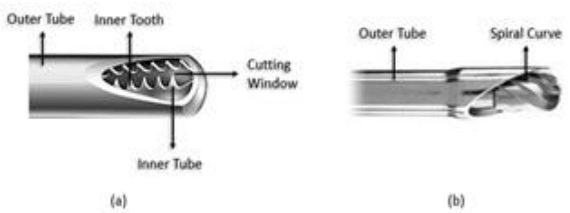


Figure 1: (a) Blade; (b) Burr

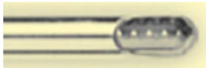
Based on the type of blade, it is determined to have or not have teeth on its inner or outer parts. Burrs have an outer tube and an inner rotary cutting tool. Burrs are used to remove bone, whereas blades are used to cut delicate tissue like ligaments or cartilage.

Table 1: Different Blade Profile Application

Shape	Length (mm)	Diameter	Curve angle	Curve Direction	Area of Application
Any	120	4.2 mm	0°	-	Partial and total synovectomy, removal of regenerative meniscus and removal of detached articular cartilage/cartilage fibrillations, removal of degenerative meniscus, scars strands and adhesion strands
Any	120	4.2 mm	15°	Up	For reaching meniscus and cartilage areas as well synovial areas
Any	120	4.2 mm	15°	Down	For reaching meniscus and cartilage areas as well synovial areas
Round	120	5.5 mm	0°	-	Removal of mechanical distributing projections; planning of bones, moulding of the subchondral bone in subchondral abrasion for induction of fibrocartilage,
Oval	120	5.5 mm	0°	-	For large area removal, such as in subacromial decompression of shoulder and osteophytes /notchplasties

There are different profile types used for various procedures or areas of treatment. Table 1 has a detailed description of the different application areas for various types of blade profiles.

Table 2: Blade Aggressiveness

Inner Tube Type	Outer Tube Type	Level of Aggressiveness	Image
Smooth	Smooth	Lowest	
Toothed	Smooth	Medium	
Toothed	Toothed	Highest	

The Blade can be operated in three modes: Forward (Clockwise), Reverse (Counter-Clockwise) and Oscillation. For cutting soft tissues, the blade is operated in oscillation mode at a speed of 188-1200 rpm. For cutting bony resection, the blade is operated in forward mode at a speed of 5000 rpm.

The curve is given for easier access to areas which cannot be reached with ease in straight blades. The diameter varies when the area of application is big. The Degree of aggression of blade is described in the Table 2.

3. Flowchart

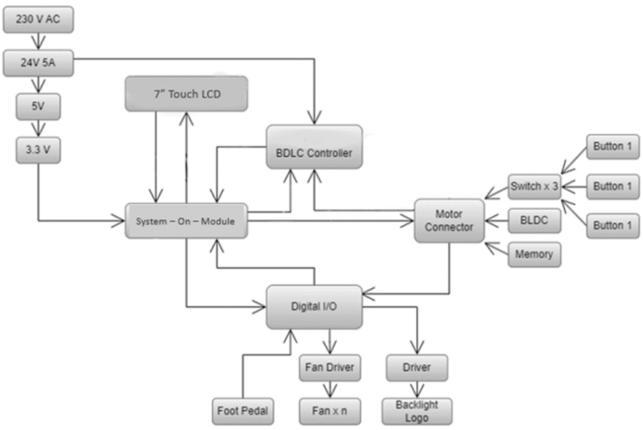


Figure 2: Block diagram of proposed system

The main microcontroller is present inside the console body which is powered by the main's supply. In front of the console, aLCD touch display is present which is connected to the microcontroller. The LCD will display all the user interface available for the operator to use during the procedures. In the handpiece, a Brushless DC motor (BDLC Motor) is present which is connected to the controller for controlling the motor operation.

There are three buttons present on top of the handpiece which have different functions such as mode selection for forward, reverse and oscillation mode. These buttons are also connected to the motor controller so as to assign the mode of rotation to the motor via the controller.

The mode of operation can also be controlled via the foot pedal which sends the instructions to the microcontroller which further transfers the instructions to the controller for assigning the mode of operation to the motor.

4. Mechanical Design

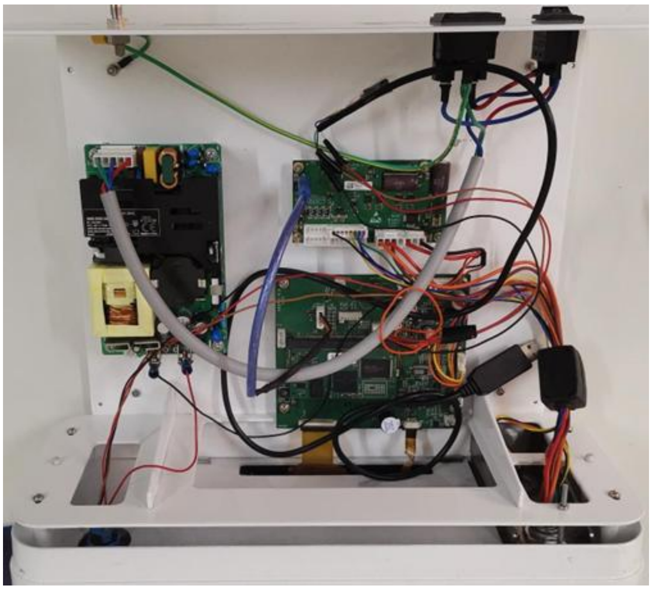


Figure 3: Complete Mechanical Setup

The complete circuitry is placed inside the chassis. Above is the image of the assembled unit where we require just three circuitries to operate the system – Power Supply, Mother board and Motor Controller. All the boards are fixed onto the base plate in order to prevent any foreseen damages during operation or transportation. The form factor of the console was designed after studying the dimensions of the board which would be present inside each unit in order to run the system.

A 24 V standard power supply is used to power up the system from the main supply. The BLDC Motor controller is directly supplied 24V to start the motor. However, the main motherboard is given a supply of 3.3V as shown in Figure 2.

The LCD and Touch panel is connected to the Motherboard. The main board will process the commands given by the user through the Touch Display and accordingly send the required data to the Motor controller to either switch modes or control the rotation speed of the blade.

The Motor controller helps to control the working of the motor as commanded by the user. The three operating modes - Clockwise, Counter Clockwise, Oscillation; are controlled by the motor controller which sends out the signal to the motor head as requested by the user.

5. Result and Analysis

The trial was performed after the complete assembly was done in order to develop the first prototype. Pieces of meat chunks were used for evaluating the efficiency of the shaver system and its functions. The Modes were evaluated in the testing process.

First, the whole system was connected to the mains and the handpiece and footswitch were connected to the system. Saline water was collected in a container and the blade was evaluated inside the saline water.

Figure 4: Performance of Trial

The evaluation of blade should always be done inside the normal water or saline water as it prevents the wear and tear of the blade and preserves its efficiency. Once the blade evaluation is completed, meat pieces are immersed in the same saline water and cutting of the same is performed.

The Modes; CW, CCW and OSC, are evaluated one by one. We got the required outcome after the trial was completed.

6. Conclusion

Several major companies are vying for market share in the fiercely competitive arthroscopic shaver system industry. Due to the rising incidence of joint diseases, the ageing population, and improvements in minimally invasive surgical methods, the market is predicted to keep expanding. The significance of technological developments in the creation of more effective and user-friendly arthroscopic shaver systems may also be emphasized in the report.

The Asia pacific region is expected to witness significant growth in the coming years due to increasing healthcare spending and improving healthcare infrastructure. In the upcoming years, the market is expected to expand steadily due to factors like rising interest in minimally invasive surgery and the creation of more sophisticated and effective arthroscopic shaver systems.

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