FlexiLap: Design concept for Versatile Laparoscopic Operations

Abstract: The laparoscopic forceps is a versatile and innovative medical device designed to address the challenges of longer wait times for surgeries, reduced recovery time, patient anxiety, and high dexterity required for complex procedures. Inspired by advanced research in soft robotic actuators and control models, this device aims to reduce the number of incisions required during surgery while improving overall patient outcomes. The device features a flexible actuated shaft inspired by snake motion, interchangeable forceps heads, and a built-in camera and LED light for better motion-to-display synchronization. The onboard display improves accuracy and control, and the suction and irrigation system eliminate the need for separate tools. This device offers superior accuracy, control, and multi-functionality, making it a unique solution for laparoscopic surgery.

1. Overview: The laparoscopic forceps is a versatile medical device designed to improve patient outcomes during laparoscopic surgery. It is equipped with a flexible actuated shaft, interchangeable forceps heads, and a built-in camera and LED light to provide superior accuracy and control during surgery. Additionally, the device features a suction and irrigation system that eliminates the need for a separate tool, reducing the number of holes required in the patient's body compared to other forceps designs.

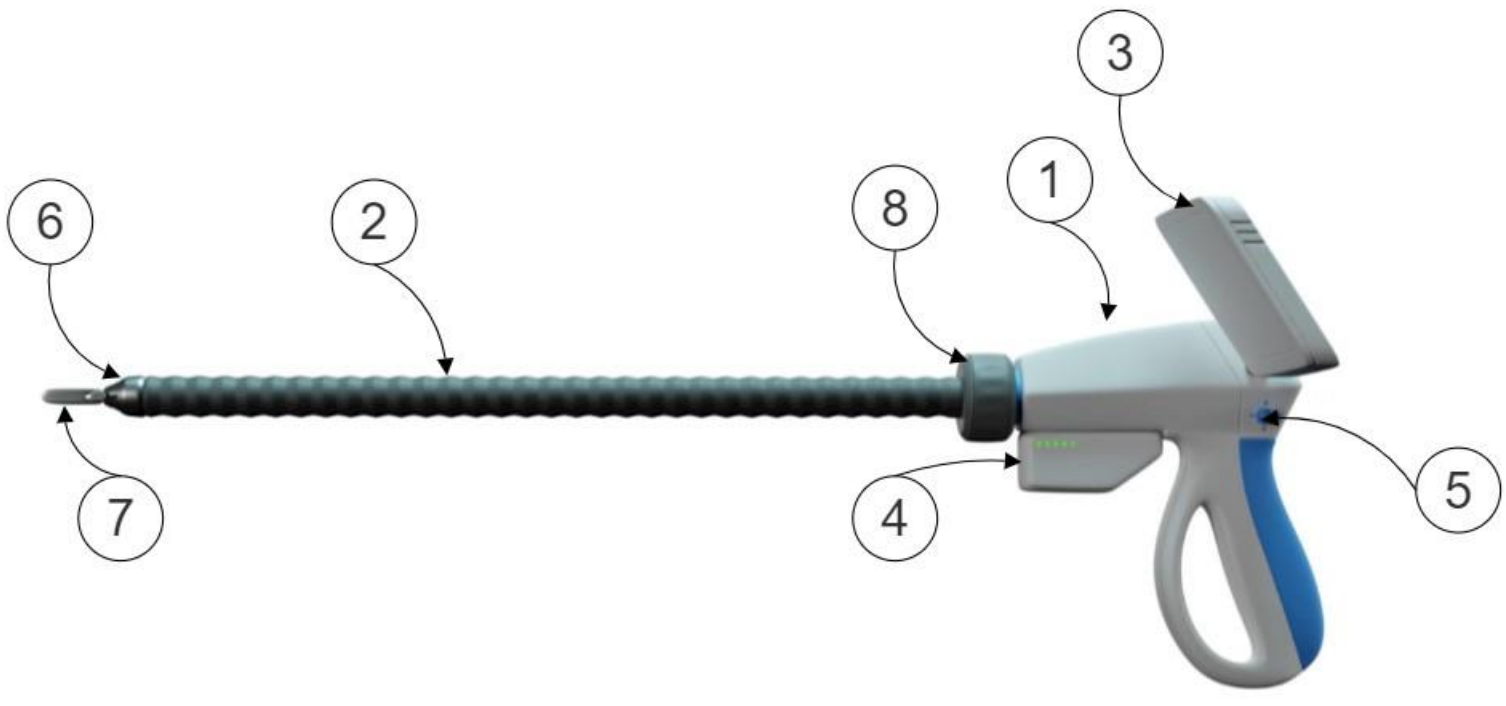
- The onboard display further enhances the device's functionality by allowing for better motion-to-display synchronization, which improves the surgeon's accuracy and control during the procedure. The laparoscopic forceps' portability and ease of use make them a unique and innovative solution for Adrenalectomy to remove one or both adrenal glands, Colectomy to remove parts of a diseased colon, Gallbladder surgery (cholecystectomy) to relieve pain caused by gallstones, and gynaecological problem treatments not just limited to endoscopy.

- Furthermore, the design of the laparoscopic forceps is inspired by advanced research in soft robotics actuators and control models. The use of soft robotics and advanced control models helped to create a flexible, multi-functional device with superior accuracy and control.

- Overall, the laparoscopic forceps represent a significant advancement in laparoscopic surgery technology, providing surgeons with a more versatile and efficient tool for performing complex procedures with improved patient outcomes.

2. Design and Technical Details:

The design details are discussed as follows:



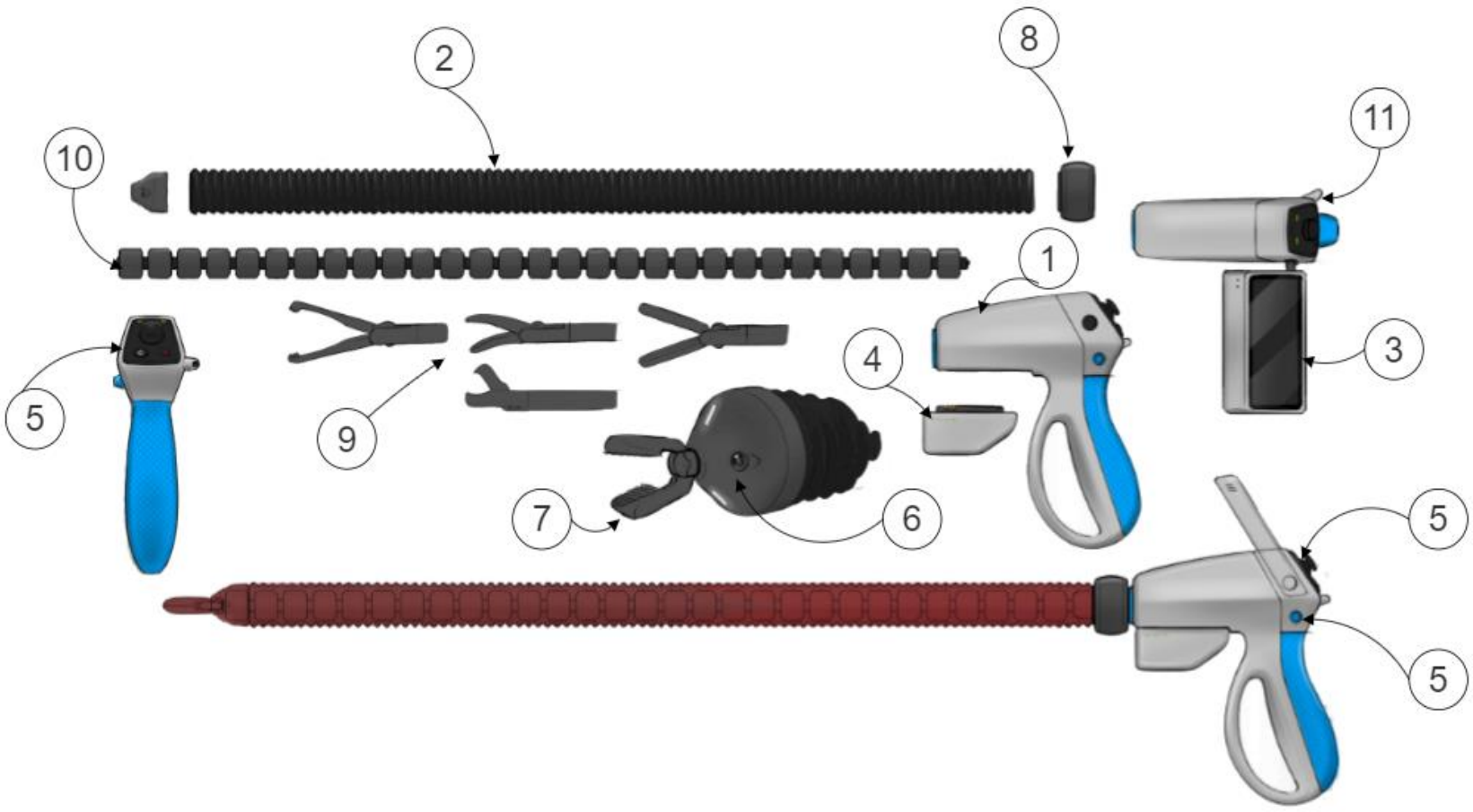
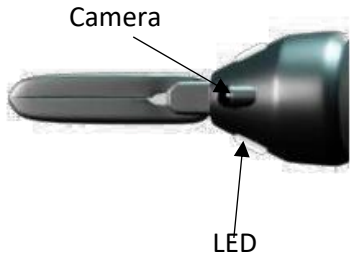


Table-1: Parts details

Part No.	Part Name	Material
1	Handle section	ABS plastic
2	Corrugated main tube	Soft Silicon
3	Display Screen	ABS body
4	Battery	Lithium ion
5	Handle top buttons	Silicon
6	Camera module	Silicon
7	Gripper claws	Stainless steel
8	Clamping Knob	Silicon
9	Interchangeable forcep head	Stainless steel
10	Flexible shaft Actuator holding forcep rail	Silicon/Nitinol
11	Inlet/outlet	ABS plastic/steel

- Camera module: It is tapered, and two cameras mounted onto it protruding giving 180 degrees of a wider vision displaying surgical activity on the screen. The two bright LEDs are also mounted on the tapered profile.

    a) This camera has multiple resolution options including 4K, 2K, 1080P, and 720P with a frame rate of 25. It records in the ASF format and has an angle of 180 degrees. The camera can display and record in low light conditions with a minimum illumination of LLUX. The camera has a recording time of over an hour and uses the H.264 compressed format. The camera can capture video within a range of 5m2 and has a power consumption of 40 ma at 2.8 V. Overall, this camera is a versatile device that can capture high-quality footage in various resolutions, and has a wide-angle lens, making it suitable for a variety of settings. Thermal and moister resistivity.



- Handle section Body:

  Consists of a grip for holding, Knob clamping SMA wire shaft and forcep rail assembly, drive, electrical components, and micropump at the inlet.

- Battery and the screen:

  i. Battery: The laparoscopic forcep is equipped with a rechargeable lithium-ion battery that provides power to the device. The battery has a high capacity and can last for 3.5 hours of continuous use, depending on the settings and usage of the forcep. The battery is easily replaceable and can be charged using a charging dock that comes with the device.

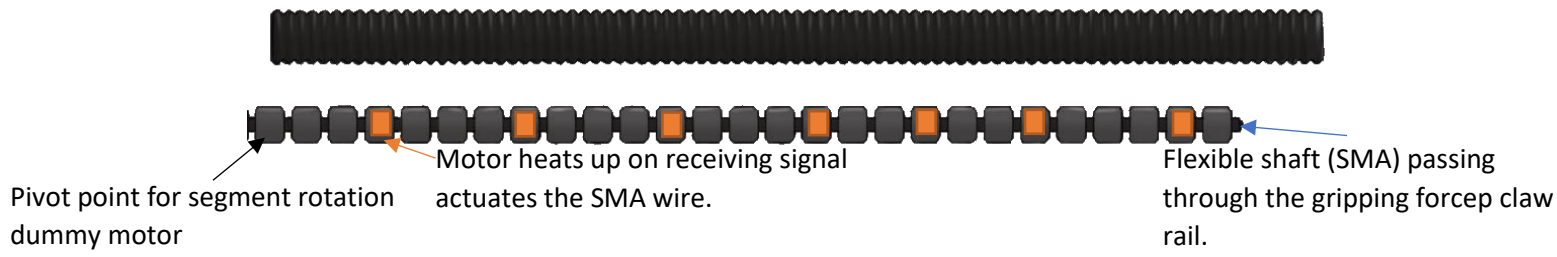
  ii. Display Screen: The laparoscopic forcep features a high-resolution display screen with a graphical user interface that provides a clear view of the surgical site. The display screen is integrated with an inbuilt battery that can last for several hours, depending on the brightness and usage of the screen(4.4v approx). The display screen can be adjusted to different angles for easy viewing and can be detached from the forcep for convenience. The display screen also features touch controls that enable the surgeon to control the settings of the forcep and adjust them as needed.

- Corrugated tube and Flexible shaft actuator:

a) The flexible shaft actuator for the laparoscopic forcep consists of a flexible shaft made of a high-strength, biocompatible material that allows for precise control of the instrument's movements. The actuator is designed to be compatible with a range of laparoscopic forceps and features a small profile for easy insertion into the surgical site.

b) The flexible shaft actuator is powered by a heat motor that provides high torque, force enabling the laparoscopic forcep to perform delicate and precise movements with ease. The motor is controlled by a user-friendly Nintendo joystick-style button that allows for intuitive operation and adjustment of the forceps' movements.

c) The actuator also features a feedback system that provides real-time data on the position and orientation of the laparoscopic forcep, allowing for increased precision and accuracy during surgical procedures. The system is designed to be durable and reliable, with a long lifespan and minimal maintenance requirements. Overall, the flexible shaft actuator is an essential component of the laparoscopic force, providing the high degree of precision and control necessary for safe and effective surgical procedures.

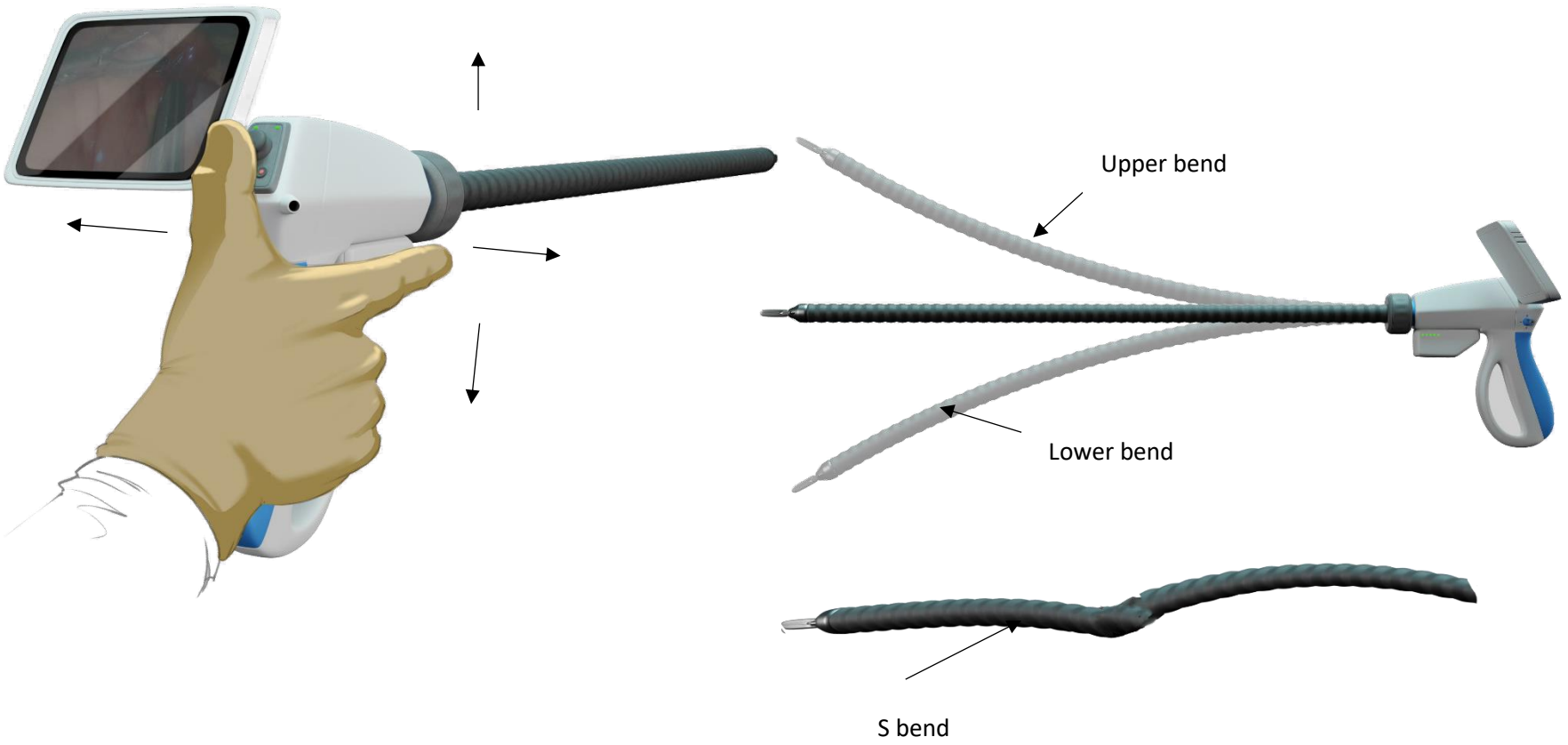


3. Functionality:

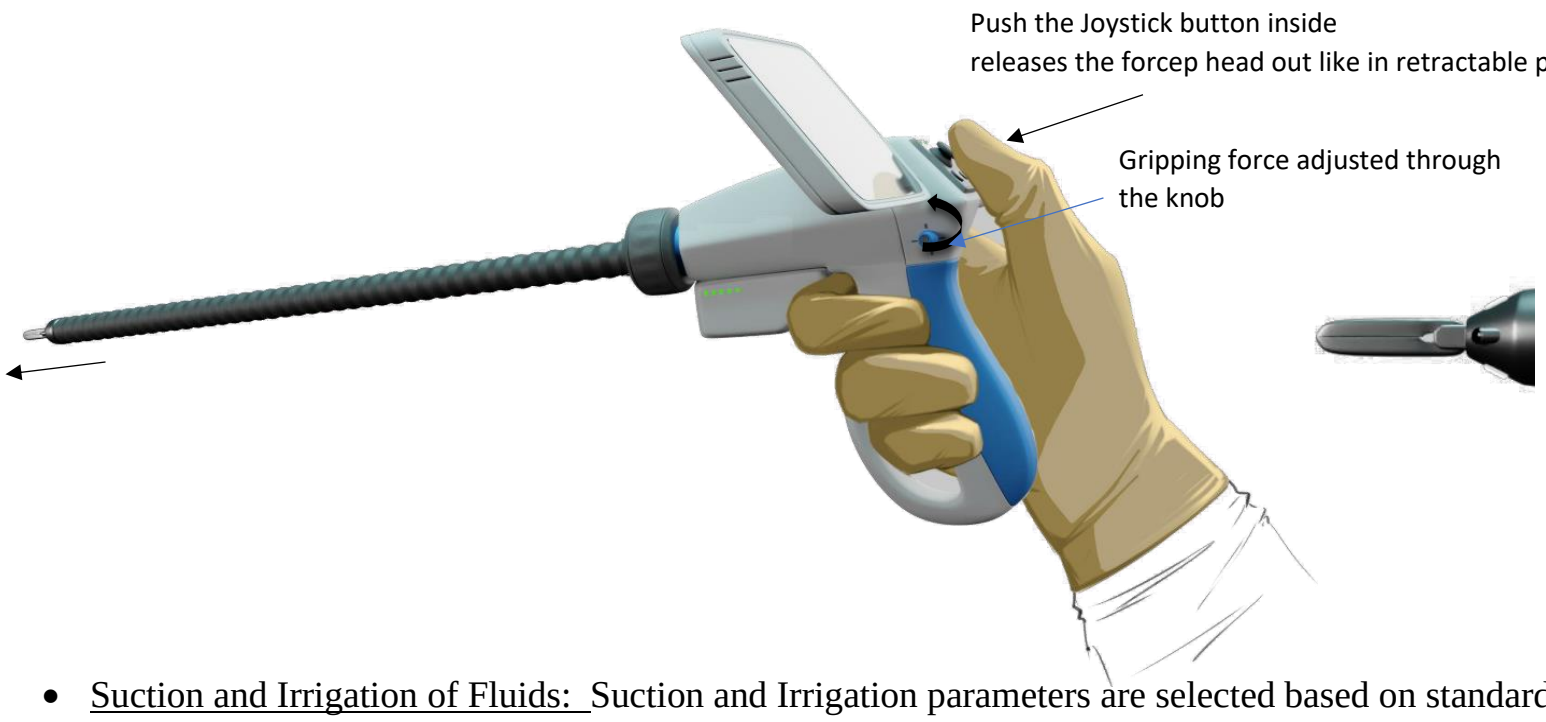
- The laparoscopic forceps are designed to provide superior accuracy and control during surgical procedures. The forceps feature a flexible, multi-functional design that can be used for a variety of tasks, including grasping, and manipulating tissue, coagulating blood vessels, and cutting tissue. The device is equipped with advanced soft robotic actuators and control models, which allow for precise and smooth movements. The forceps can be operated using a foot pedal, allowing the surgeon to control the device without needing an assistant. Additionally, the forceps are designed to reduce the number of incisions required during surgery, which can lead to faster recovery times and improved patient outcomes. Overall, laparoscopic forceps are a versatile and efficient tool that can help surgeons perform complex procedures with greater ease and

precision.

- Maneuverability: Pushing the joystick button left, right, up, and down oscillates the front section depending on the intensity of the moment of the button movement the front tube section takes a specific trajectory providing multiple degrees of freedom in the human body. Flexible shaft actuator bends three forms upper bend, lower bend and S- shaped bend in total providing 8 -degrees of freedom.



- Cauterizing: The surgeon operates the forcep using the joystick-style button shown below. Pressing the inside pushes the gripping cauterizing claws outside the main corrugated flow tube for cauterizing and gripping operations on tissues.



- Suction and Irrigation of Fluids: Suction and Irrigation parameters are selected based on standards for laparoscopy

a) The suction irrigation functionality of the above-discussed laparoscopic forcep is a key feature that allows for efficient and effective management of fluids and debris during surgical procedures. The forcep head is designed to fit inside the corrugated main tube, which allows for precise control and maneuverability during the procedure. This enables the surgeon to easily reach the target area and perform the required suction or irrigation with minimal effort.

b) The front tapered camera module is specifically designed to facilitate the suction irrigation process. Fluid can be easily suctioned from the target area and removed through the tube, ensuring that the surgical field

remains clear and visible throughout the procedure. Additionally, the irrigation function enables the surgeon to deliver a controlled and precise flow of fluid to the target area, allowing for enhanced visualization and better surgical outcomes.

c) The benefits of the suction irrigation functionality of the laparoscopic forcep are significant. By reducing the amount of debris and fluid in the surgical field, the forcep allows for better visualization and greater precision during the procedure. This results in improved patient outcomes and reduced risk of complications.

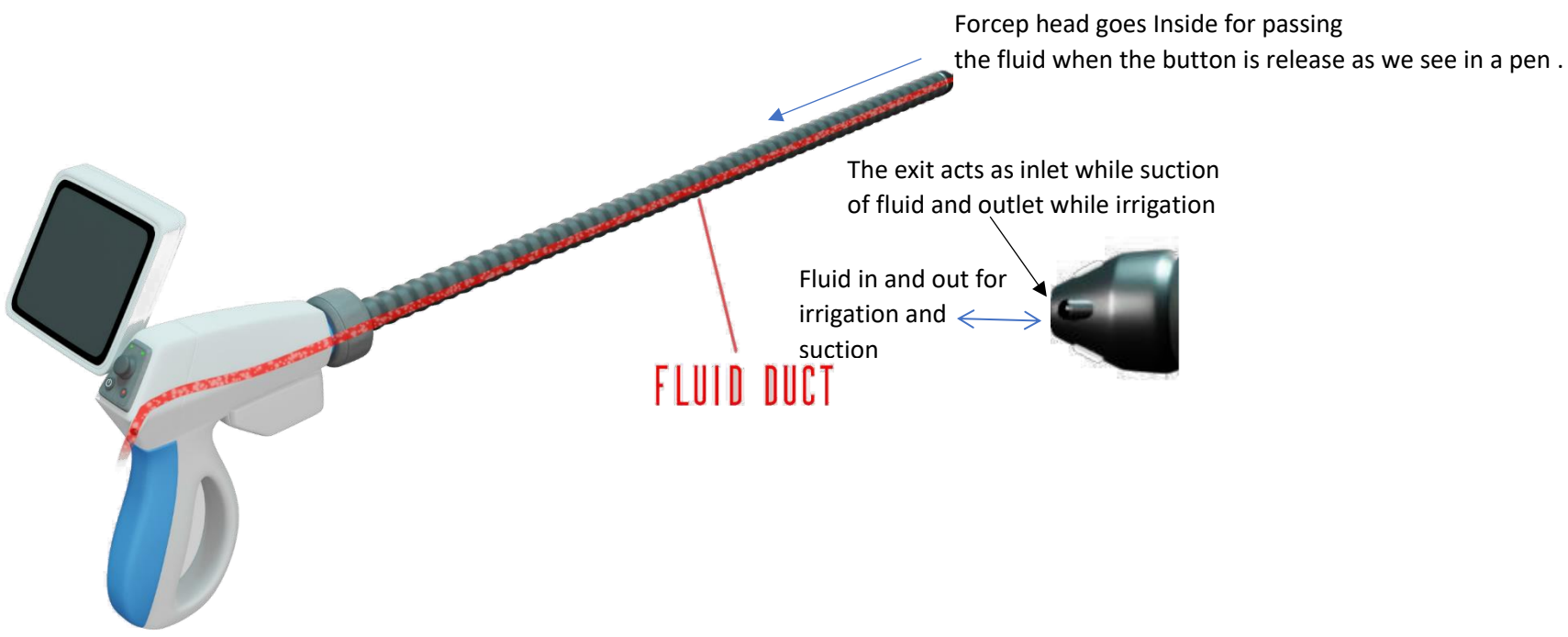
d) Overall, the suction irrigation functionality of the laparoscopic forcep is a crucial component of the device's design. Its ability to manage fluids and debris efficiently and effectively during surgical procedures ensures that the surgeon can work with confidence and precision, leading to improved patient outcomes and greater success rates.

e) Suction pressure: The suction pressure should be enough to effectively remove fluids and debris from the surgical site without causing damage to the surrounding tissue. The recommended suction pressure range is typically between -50 to -200 mmHg.

f) Irrigation pressure: The irrigation pressure should be enough to ensure adequate flow of the fluid through the laparoscopic instrument and the surgical site without causing trauma to the tissue. The recommended irrigation pressure range is typically between 50 to 100 mmHg.

g) Suction velocity: The suction velocity should be high enough to efficiently remove fluids and debris from the surgical site, but not too high to cause trauma to the surrounding tissue. The recommended suction velocity range is typically between 0.5 to 1.5 liters per minute.

h) Irrigation velocity: The irrigation velocity should be high enough to ensure adequate flow of the fluid through the laparoscopic instrument and the surgical site. The recommended irrigation velocity range is typically between 0.5 to 1.5 liters per minute



Forcep high delivery:

the laparoscopic forcep described above can also be used for high delivery of the baby. During the procedure, the forcep is inserted through a small incision or path way in the mother's abdomen and is carefully guided to the baby's head. Once the forcep is positioned correctly, the flexible shaft actuator allows the surgeon to grasp the baby's head securely and apply the necessary traction to facilitate delivery.

In addition, the forcep's suction-irrigation functionality can be used to clear the baby's airway and ensure that they are receiving adequate oxygen during the delivery process. The interchangeable forcep head also allows for customization based on the specific needs of the delivery.

Overall, the laparoscopic forcep provides a minimally invasive option for high delivery of the baby with precise control and flexibility, potentially reducing the risks associated with traditional delivery methods.

Interchangeability:

The interchangeable forcep head is a key feature of the laparoscopic forcep, allowing for flexibility in its application. The forcep head can be easily detached and replaced with different heads to suit the specific needs of the surgery. This feature eliminates the need to use multiple forceps for different purposes, reducing the number of instruments required and streamlining the surgical process.

The forcep head is made of high-quality materials such as stainless steel or titanium, ensuring durability and reliability during surgery. It is designed to provide a secure grip on tissues or organs, with serrated jaws or teeth on the inner surface to prevent slippage. The jaws are available in various sizes and shapes to accommodate different surgical procedures, such as grasping, cutting, or dissecting tissues.

The forcep head can be easily connected to the flexible shaft actuator using a simple locking mechanism, ensuring a secure and stable attachment during surgery. The interchangeable design also makes it easy to clean and sterilize the forcep head after each use, reducing the risk of infection and ensuring patient safety.

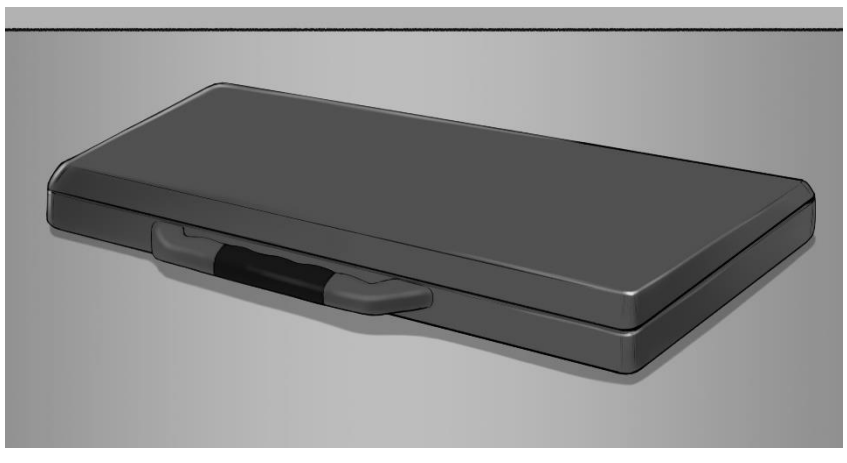
Advantages and Benefits:

The laparoscopic forceps design provides several advantages and benefits compared to traditional forceps:

- It reduces the number of incisions required during surgery, resulting in less scarring, faster recovery time, and reduced risk of infection.

- It improves the precision and dexterity of the surgeon during the procedure, leading to better outcomes for the patient. Thirdly, the use of soft robotics and advanced control models allows for greater flexibility and multi-functionality of the device, reducing the need for additional instruments and simplifying the surgical process.

- Portability and easy to carry the full setup of the forcep is stored in a box for easy carry and operation.



- Rechargeable and Works on DC and AC can be switchable depending on power cut or low battery power.

- Easy sterilization: The forcep parts are antibacterial coated and the sterile solution can pass through the inlet for forcep sterilization eliminating separate cleaning of parts.

- The silicon corrugated outer main tube helps in easy fluid transportation and gives sensation of less pain when passes through the internal organs because of soft nature.

- Finally, on board camera visual helps surgeon to avoid looking at the screen at a certain distance and helps in visual an hand motion synchronization due to on board camera integration

Conclusion:

In conclusion, the laparoscopic forceps design is a promising development in the field of minimally invasive surgery. By leveraging advanced soft robotics and control models, this device offers improved precision, dexterity, and flexibility compared to traditional forceps, leading to better outcomes for patients. With further development, testing, and implementation of artificial intelligence-enabled, sensor fusion model algorithms for trajectory optimization and full autonomy this device have the potential to revolutionize the field of laparoscopic surgery and benefit patients worldwide.