



# Application Prospect of Monopolar Low-temperature Plasma Knife in Oral and Maxillofacial Surgery

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**Abstract:** Oral and maxillofacial surgery is primarily responsible for the treatment of oral and maxillofacial tumors, jaw fractures, maxillary sinusitis, and other temporomandibular joint diseases using surgical techniques. With improvements in living conditions and dietary changes, the demand for diagnosis and treatment in oral and maxillofacial surgery has been steadily increasing. Simultaneously, both patients and healthcare providers have higher expectations for intraoperative effectiveness and postoperative recovery. With the advancement of technology, surgical knives in oral and maxillofacial surgery have gradually transitioned from traditional physical blades to high-frequency electric scalpels. However, high-frequency electric scalpels have drawbacks, including substantial tissue damage, the generation of intraoperative smoke, electrode adhesion, imprecise cutting, and reliance on traditional surgical blades. This paper proposes the idea of using a monopolar low-temperature plasma knife in oral and maxillofacial surgery, with a focus on research utilizing the monopolar low-temperature plasma surgical system produced by Jingyi Medical (Host Model: PSG-60A; Electrode Model: PS-01) as an example. This equipment disrupts tissue molecular bonds through the low-temperature plasma layer formed around the knife tip, allowing for tissue cutting and separation. This approach significantly reduces tissue damage compared to traditional surgical blades and high-frequency electric scalpels, while also simplifying surgical procedures, improving cutting precision, and enhancing postoperative recovery. Through this research, it can be observed that the monopolar low-temperature plasma knife has significant potential for widespread application in oral and maxillofacial surgery.

**Keywords:** oral and maxillofacial surgery, monopolar plasma system, low-temperature plasma knife

## 1. Introduction

Oral and maxillofacial surgery is a branch of dentistry and a vital subfield of clinical medicine. This discipline primarily involves the treatment and repair of oral and maxillofacial diseases and injuries using various surgical techniques to achieve specific therapeutic goals. With changes in living standards and habits, oral and maxillofacial surgery is facing increasingly complex and challenging cases. Beyond traditional oral and maxillofacial injury treatments and repairs, oral and maxillofacial surgery also encompasses the treatment of facial tumors, salivary gland diseases, and other temporomandibular joint disorders. Taking Hunan as an example, influenced by local dietary habits and food structures, the incidence of oral cancer in Hunan is significantly higher than in other regions. Consequently, the number of patients undergoing oral and maxillofacial surgery for oral cancer remains consistently high[1]. In this context, while oral and maxillofacial surgery is addressing a substantial workload of surgical procedures, it is also actively seeking methods to improve the quality of surgical procedures and postoperative recovery. Unlike other surgical procedures, oral and maxillofacial surgery often involves the restoration and reconstruction of facial aesthetics. In addition to treating diseases and repairing injuries, it requires special consideration of surgical instruments' impact on tissue during procedures. Traditional surgical instruments commonly used in surgery are metal scalpels, which physically cut through human tissues to achieve the separation and excision of target tissues. However, metal scalpels not only cause significant bleeding but may also pose risks of injury or infection to the operating surgeon. With technological advancements, surgical procedures have gradually transitioned from using solely steel scalpels to a combination of steel scalpels and high-frequency electric scalpels. In this combination, metal scalpels are often used to incise the skin while high-frequency electric scalpels achieve tissue desiccation or even carbonization through high-temperature cauterization, enabling tissue separation and treatment. However, this approach still has some drawbacks, such as the generation of a significant amount of intraoperative smoke, substantial tissue damage, slow postoperative healing, and strong pain sensations, along with suboptimal aesthetic results. In response to the limitations of existing surgical cutting devices, a monopolar low-temperature plasma surgical system (manufactured by Jingyi Medical, Host Model: PSG-60A; Electrode Model: PS-01) has emerged, and it has now been developed into a monopolar low-temperature plasma knife for open surgeries. This paper will analyze the principles and advantages of the monopolar low-temperature plasma knife,

specifically addressing the shortcomings of traditional oral and maxillofacial surgical instruments. It will also provide an analysis and outlook on the application prospects of this product in oral and maxillofacial surgery.

## **2. Classification and Characteristics of Oral and Maxillofacial Surgical Instruments**

Traditional oral and maxillofacial surgical procedures and instruments share certain commonalities with other open surgical procedures. To explore and compare the advantages of the monopolar low-temperature plasma knife (Jingyi Medical, Electrode Model: PS-01), traditional surgical instruments and their drawbacks will be first analyzed.

Surgical cutting devices can be classified into energy-based and non-energy-based instruments based on whether they use energy for cutting. Energy-based surgical devices can further be categorized into mechanical energy-based surgical devices and electrothermal energy-based surgical devices[2].

(1) Non-energy-based Surgical Instruments. Non-energy-based surgical instruments are the most traditional devices, primarily employing sharp materials for physical tissue cutting. The most typical non-energy-based surgical instrument is the steel blade. In contemporary open surgeries, steel surgical blades are the primary tools responsible for cutting the skin or tissue. When these surgical devices are used to cut tissue, they often result in bleeding, necessitating various methods for hemostasis during surgery, which increases the workload of the procedure. Additionally, due to the extreme sharpness of steel surgical blades, using them in surgery poses certain risks to the operating surgeon.

(2) Mechanical Energy-based Surgical Instruments. Mechanical energy-based surgical instruments use physical energy transfer mechanisms, such as high-energy ultrasound, to penetrate tissues. When tissue cells are exposed to high-energy ultrasound, the ultrasonic cavitation causes cell rupture, achieving tissue cutting. Simultaneously, high-frequency energy generates high temperatures during tissue penetration, leading to a rapid increase in temperature at the focal point, serving therapeutic or coagulation purposes. These devices are often used in endoscopic surgery and have particularly good results in cancer treatment but are less commonly used in oral and maxillofacial surgery.

(3) Electrothermal Energy-based Surgical Instruments. Electrothermal energy-based surgical instruments primarily include high-frequency electric scalpels, radiofrequency knives, nano-knives, and laser scalpels. Among these, high-frequency electric scalpels can be classified into monopolar and bipolar types. Monopolar scalpels are mainly used in open surgery and achieve tissue cutting through high-temperature tissue destruction, while bipolar scalpels are primarily employed for coagulation and closure, using high temperatures to induce tissue deactivation for closure purposes. However, both types of scalpels can cause significant tissue damage and may be challenging to precisely target fine structures. Radiofrequency knives, similar to laser and nano-knives, can be classified into monopolar and bipolar types as well. They are mainly used for tissue ablation, which involves using electrical and thermal energy to rupture and evaporate target tissue cells, achieving cutting or damage.

## **3. Monopolar Low-Temperature Plasma Surgical System Overview (Produced by Jingyi Medical, Main Unit Model: PSG-60A; Electrode Model: PS-01)**

In the preceding sections, various common traditional surgical cutting devices used in oral and maxillofacial surgery were discussed. However, these devices have certain disadvantages in terms of safety, surgical efficacy, and cost-effectiveness. With the advancement of plasma technology, plasma knives based on non-equilibrium plasma have emerged and have gradually found applications in oral and maxillofacial surgery and other fields. This section will introduce the monopolar low-temperature plasma surgical system.

### **3.1 Overview of Plasma Technology**

Plasma is a state of matter that exists at higher energy levels than solid, liquid, and gas, with energy levels significantly exceeding those of gases. Plasma can generally be categorized into two types: high-temperature plasma, typified by stars and rarely encountered in daily life, and low-temperature plasma. Non-equilibrium plasma, a subset of low-temperature plasma, finds applications not only in agriculture and industry but also in the field of medicine. One of its notable applications is in monopolar or bipolar plasma knives. Bipolar plasma knives have been used earlier and are mainly employed for tissue ablation or hemostasis. They work by creating plasma between two electrodes in the target tissue, leading to tissue ablation or hemostasis. In contrast, monopolar plasma knives are more precise and do not require physiological saline assistance[3].

### **3.2 Working Principle of Monopolar Low-Temperature Plasma Surgical System**

As previously mentioned, bipolar plasma is generated with the assistance of positive and negative poles in physiological saline to achieve tissue coagulation or ablation. To further enhance the precision of plasma effects and achieve precise tissue cutting and separation, the monopolar low-temperature plasma surgical system was introduced. Different from bipolar

plasma, the monopolar low-temperature plasma surgical system, produced by Jingyi Medical, features a precise active electrode (referred to as the "plasma pen"). It establishes a complete electrical circuit by closely contacting the body surface with a negative electrode plate. When the electrode comes into contact with the body, it continuously releases pulses, exciting the sodium chloride in the body tissue fluid into a plasma state near the tip. Under the influence of the electric field, charged particles continuously gain energy until they have enough energy to break the molecular bonds in the body tissues. This process leads to tissue disintegration. During this process, the body tissue is decomposed into gases such as carbon dioxide, hydrogen, and oxygen, achieving tissue vaporization and serving purposes such as cutting and coagulation.

## **4. Characteristics of Oral and Maxillofacial Surgery and Prospect Analysis of Monopolar Low-temperature Plasma Knife (Made by Jingyi Medical Institute, PS-01 Electrode)**

### **4.1 Characteristics of Oral and Maxillofacial Surgery**

To analyze the potential application of the Monopolar Low-Temperature Plasma Surgical System (manufactured by Jingyi Medical, electrode model PS-01) in oral and maxillofacial surgery, it is essential to understand the specific characteristics of this surgical field.

(1) Abundance of Intraoperative Bleeding Sites. The oral and maxillofacial region has a rich blood supply, leading to numerous bleeding points during conventional surgeries. Therefore, it is crucial to manage intraoperative bleeding by preparing appropriate hemostatic measures, such as monopolar low-temperature plasma surgical systems and electrocautery devices [4].

(2) High Incidence of Postoperative Complications. Due to the abundant facial nerves in the oral and maxillofacial region, surgical procedures in this area often result in a higher risk of postoperative complications. This highlights the importance of precise tissue cutting and handling during oral and maxillofacial surgery to minimize the occurrence of severe complications.

(3) Impact on Maxillofacial Morphology. Oral and maxillofacial surgeries, unlike procedures in other anatomical regions, frequently require the restoration of facial morphology as one of their surgical objectives, whether for treatment or aesthetic reasons. These surgeries often leave scars, making it imperative to minimize scarring and reduce tissue damage at the incision site [5].

Considering these characteristics, the Monopolar Low-Temperature Plasma Surgical System (manufactured by Jingyi Medical, electrode model PS-01) offers advantages such as precise tissue cutting, minimal incision damage, reduced scarring, and reliable hemostatic capabilities. This positions it as an excellent tool for oral and maxillofacial surgery.

### **4.2 Analysis of the Prospects for Monopolar Low-Temperature Plasma Surgical System (Made by Jingyi Medical Institute, PS-01 Electrode) in Oral and Maxillofacial Surgery**

Based on the characteristics of oral and maxillofacial surgery mentioned earlier, the Monopolar Low-Temperature Plasma Surgical System (manufactured by Jingyi Medical, electrode model PS-01) offers significant potential due to its enhanced safety, improved surgical outcomes, superior hemostatic capabilities, and cost-effectiveness.

(1) Enhanced Safety. The safety of the Monopolar Low-Temperature Plasma Surgical System is evident in several aspects. Firstly, it completely replaces steel blades, eliminating the risk of accidental injuries during surgery. Secondly, its extremely small plasma generation range (only within approximately 1mm of the blade) minimizes the risk of electrical shock due to extended arcs. Additionally, its operating frequency reduces muscle twitching, enhancing surgical safety. Lastly, this system produces minimal smoke during surgery, making it safer compared to high-frequency electric knives.

(2) Improved Surgical Outcomes. The Monopolar Low-Temperature Plasma Surgical System (manufactured by Jingyi Medical, electrode model PS-01) delivers superior surgical outcomes in various ways. Firstly, it enables precise tissue cutting with a minimal plasma action range, preventing unnecessary damage. Secondly, its low operating temperature significantly reduces thermal damage to surrounding tissues, facilitating faster postoperative healing. Thirdly, because of the small damage to the surrounding tissues, it is not easy to form scars after surgery.

(3) Superior Hemostatic Capabilities. As mentioned earlier, surgeries in the maxillofacial region often involve numerous bleeding points, making hemostasis a critical evaluation criterion. The Monopolar Low-Temperature Plasma Surgical System excels in hemostasis, utilizing an appropriate operating temperature range (50°C-100°C) to deactivate tissues, causing gradual evaporation, shrinkage, and coagulation of cell fluid. This effectively seals blood vessels, achieving excellent hemostatic results while ensuring precise cutting and minimal tissue damage.

(4) Cost-Effectiveness. The cost-effectiveness of this system is evident in terms of reduced consumables and postoperative recovery expenses. Since the Monopolar Low-Temperature Plasma Surgical System does not require steel blades for assistance, it saves on consumable costs. Additionally, precise control of energy input leads to manageable energy consumption, reducing operating costs. For patients, precise incisions and minimal tissue damage contribute to faster postoperative recovery, resulting in reduced recovery expenses. Moreover, the system's broad application scope increases overall efficiency.

## 5. Conclusion

Based on the comparative analysis presented in this article, the Monopolar Low-Temperature Plasma Surgical System (manufactured by Jingyi Medical, mainframe model PSG-60A, electrode model PS-01) emerges as a promising tool for open surgical procedures. It combines the advantages of electric knives while offering superior safety, improved surgical outcomes, excellent hemostatic capabilities, and cost-effectiveness. Therefore, it can be considered to have a bright future in the field of oral and maxillofacial surgery, deserving practical implementation and wider adoption.

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