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A Review of Evolution and Innovation of Rubber Tip Dropper in Medical Field

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Abstract: *A comprehensive study of the evolution and innovations in colloidal droppers in the medical field. The study finds that, starting from its early simple form and basic applications, "Glue Tip Droppers" provides a detailed account of the gradual changes in material science, manufacturing processes, and precision measurement needs of glue tip droppers, driven by a variety of factors, including design, materials, and function. While looking forward to the potential future direction of the further development of the collet dropper in the medical field, we discuss its new applications and innovations in the key aspects of modern medical diagnosis, treatment, and drug discovery and development, as well as the significance of these innovations for the enhancement of the quality, efficiency, and safety of medical care.*

Keywords: *rubber tip dropper, medical field, evolution, innovation, materials science*

1. Background

With the rapid development and application of medical technology, gel tip pipette plays an increasingly important role in medical testing industry and medical research field. In terms of accurate drug delivery and micro-sample processing, the requirements of modern medicine are constantly improving, and the innovative research and development of gel tip pipette are constantly receiving attention. Therefore, it is of practical significance to investigate and study the rubber-tip pipette applied in medical sampling, and it will be helpful to innovate and develop it in the future by combing the evolution process of rubber-tip pipette and summarizing its innovative achievements.

2. Early rubber tip dropper

2.1 Early design and materials

In the early days, the design of the rubber tip dropper was relatively simple, consisting of glass and natural rubber. The main body of the rubber tip dropper was made of glass material, and the top rubber tip of the glass tube was made of natural rubber. The rubber tip dropper used air pressure to absorb liquid. The early rubber tip dropper had simple and easy operation characteristics, but there were also many problems. For example, natural rubber is prone to aging and difficult to control elasticity, resulting in excessive reagent extraction and liquid residue after dropping. Over time, the rubber tip can be denatured by corrosion of the reagent, resulting in inaccurate experiments. In addition, glass tubes have fragile and smooth characteristics, affecting the safety of medical procedures. This early rubber tip pipette is difficult to meet the requirements for handling some experiments requiring high precision operation.

2.2 Medical applications

In the medical field, some basic liquid drug preparation and simple chemical reagent addition, mainly using the early rubber tip pipette. For example, in drug preparation, pharmacists use the rubber tip pipette to add the liquid drug to other pharmaceutical ingredients or solvents according to the approximate dose. Although this method can meet the basic preparation needs, the accuracy of drug dosage is difficult to ensure because of insufficient accuracy. The early rubber-tipped pipettes were also used in the laboratory for the transfer and addition of small amounts of reagent, but only for experiments where the dosage requirements were not high. For example, in qualitative experiments, such pipettes could be used by the operator to add reagent, but in quantitative experiments they were difficult to meet the experimental requirements because of their lack of accuracy. In addition, when the early rubber head dropper was

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dealing with some corrosive chemical reagents, due to the poor chemical stability of natural rubber, it was easy to produce chemical reactions, which affected the accuracy of experimental results.

3. Evolution driven by material innovation

3.1 Application of synthetic rubber

Butyl rubber, silicone rubber and other synthetic rubber materials used in the manufacture of rubber head dropper have been successfully developed. These synthetic rubber have good chemical corrosion resistance, high temperature resistance and good elastic stability. Therefore, in medical diagnostic experiments, when some corrosive biological samples or reagents are treated with butyl rubber pipette, the accuracy of sample collection and the reliability of test results can be avoided due to the destruction of the rubber tip. For example, butyl rubber pipette has significantly improved chemical corrosion resistance compared with natural rubber in the treatment of acidic or alkaline solutions. [1]

3.2 Exploration of new polymer materials

In addition to synthetic rubber, some chemical-resistant polymer materials have also been used in the manufacture of rubber dropper. These polymer materials not only have good chemical stability, but also have finer pipe diameter control and smoother inner wall treatment, which can be realized through optimization of processing technology. For example, some high-performance plastic materials made of drip tube body, its inner wall after special treatment, in the process of dripping can reduce the residual amount of liquid, so that the accuracy and integrity of the transfer of liquid have been improved. For example, in biochemical experiments, the use of polypropylene (PP) or polyethylene (PE) materials can effectively avoid liquid residues and reduce errors in experiments[1][2].

4. Innovation under design optimization and precision measurement requirements

4.1 Progress in flow control technology

In order to meet the needs of accurate measurement and control of liquids in the medical field, the flow control technology of the rubber tip dropper is constantly innovating. Early rubber tip dropper mainly relies on the operator's experience and feel to control the speed and amount of liquid dripping, and the error is large. This way of relying on manual control is not only inefficient, but also easy to cause inaccurate results when dealing with some experimental and clinical operations with extremely high dosage requirements. For example, in drug development, small dosage differences can significantly affect the results of experiments, thus affecting the safety and effectiveness of drug evaluations. Some of today's rubber tip pipettes are equipped with micro-knob flow valves or flow regulators that adjust the accuracy of the nozzle design. The precise mechanical structure allows the operator to precisely control the rate of liquid addition and the amount of liquid added per drop according to actual needs. For example, during clinical infusion, the use of a rubber-tipped dropper with flow control can accurately control the input speed of drugs. This is especially important for some treatment scenarios that require strict control of drug dosage, such as chemotherapy drug administration. Through accurate control of drug input speed, adverse reactions caused by too fast or too slow drug input can be avoided, thus improving the safety and effectiveness of infusion therapy. In addition, dropper automation, intelligence is also reflected in the progress of flow control technology. Some high-end rubber head dropper has been able to control with computer programs, automatic absorption, transfer, distribution of high-throughput, high-precision liquid, and integration with automation equipment and intelligent systems. For example, in gene sequencing experiments, a large number of samples require precise liquid operations, which can be quickly and accurately completed by automated gel tip pipette systems, which greatly improves experimental efficiency and data reliability.

4.2 Diversification of dropper shape and size

In fine and diversified medical operations, the shape size of rubber tip dropper is optimized and expanded along with the refinement and diversification of medical operations. In addition to conventional straight tube dropper, in order to adapt to different experimental and clinical operation scenarios, various shapes of dropper have appeared, such as bent tube type, long tube type and short tube type. For example, in ophthalmic surgery, the use of a bent tube type rubber tip dropper can make it more convenient for the

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patient to drop the liquid medicine at a specific location in the eye, thus avoiding the inconvenience or damage that a straight tube dropper may cause to the eyes. This design improves While the operation is convenient, it also reduces the patient's discomfort during the operation. in addition, that size of burette are also rich. from basic research experiments to large-scale clinical treatment, micro-diameter burette can handle micro-tubes of liquid, and wider diameter burette can handle larger volumes of liquid. for example, accurate transfer and distribution of micro-liquids is an important step in the process of drug development. The use of micro-diameter rubber tip pipette, can accurately control the transfer of trace liquid, so that experimental errors are reduced, data reliability is improved. And larger diameter pipette in large-scale clinical treatment, liquid transfer and preparation can be quickly and efficiently completed, treatment efficiency can also be improved. In addition, in the operation of comfort, safety and other aspects of the design of the pipette. Some of them adopt ergonomically designed dropper, so that operators are not easy to feel fatigue during long-term use. At the same time, the material and surface treatment of dropper are optimized to make it more durable and easier to clean. These improvements not only improve the service life of dropper, but also reduce the generation of medical waste in line with environmental design concept.

5. Key innovations in modern medical applications

5.1 Automation and intelligent integration

Gel tip pipettes are gradually integrated with automated equipment and intelligent systems, which is realized under the development trend of modern medical laboratory automation and intelligence. Some high-end gel tip pipettes are designed to automatically absorb, transfer and dispense high-throughput, high-precision liquids through computer program control, and are compatible with automated liquid handling workstations and robots. For example, in gene sequencing experiments, a large number of samples need to be processed accurately. The automated gel tip pipette system can quickly and accurately complete these operations, which greatly improves the efficiency and data reliability of the experiment. In addition, the intelligent gel tip pipette also integrates sensors and wireless communication technology for real-time recording and transmission of liquid operation data such as liquid volume, number of drops, and running time. This data is not only helpful for quality control and data management in laboratories, but also provides the basis for more medical decisions, such as real-time adjustment of experimental conditions, accuracy of experimental results, and monitoring of liquid temperature and concentration through sensors[3].

5.2 Personalized customization and environmental design

Personalized customized rubber tip dropper With the increasing diversification of medical needs, people gradually pay attention to it. Some manufacturers begin to provide special rubber tip dropper with special shape, size or function according to the specific needs of customers to provide customized services. For example, the dropper tailored to meet the requirements of precise liquid operation is customized for some special experimental devices or clinical operation scenarios[4]. At the same time, the development of rubber head dropper has also become a very important development direction is environmental protection design. In the material selection, in the dropper manufacturing application of more degradable, recyclable materials, the impact on the environment has been reduced. In addition, some dropper design through structural design optimization, pay attention to reusability and easy cleaning, so that the dropper after use easy to clean disinfection, prolong the service life of the dropper, reduce the generation of medical waste[5].

5.3 Multifunctional integration and intelligent development

In the future development process of the rubber tip dropper, it is not a simple liquid transfer tool, but towards the integration of multiple functions and intelligent development. Some dropper in addition to absorption of basic liquid, dripping function, but also may have liquid concentration detection, temperature measurement and other more integrated functions. In terms of intelligence, the gel tip dropper can automatically adjust the operating parameters according to the user's usage habits and specific medical scenarios with the help of AI and machine learning technology, so as to realize more intelligent liquid operation. For example, in the process of drug preparation, the intelligent gel tip dropper can automatically accurately absorb and mix a variety of drug ingredients, and improve the accuracy and efficiency of drug preparation according to preset formulas[3].

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6. Specific application and innovation of rubber-tipped dropper in the medical field

6.1 Application in clinical diagnosis

6.1.1 Sample collection and processing

With the continuous improvement of detection technology, the demand for sample size is decreasing, while the accuracy of operation is increasing. Through optimization design, modern gel tip pipette can accurately absorb and transfer trace liquids, reducing the risk of sample waste and cross contamination. For nucleic acid detection, the calibration gel tip pipette is used to accurately control the sample volume, thus ensuring the accuracy of the detection results[6].

6.1.2 Reagent addition

In biochemical detection and immunoassay, the gel tip pipette is used to add various reagents. The flow control technology of the new pipette makes the reagent addition more accurate, avoiding detection errors caused by excessive or insufficient. In addition, some pipettes also have anti-bubble design to ensure uniform mixing of reagents.

6.1.3 Adaptation of automated diagnostic equipment

With the development of laboratory automation, gel tip pipettes are designed to be compatible with automated diagnostic equipment. For example, disposable gel tip pipettes are widely used in automatic biochemical analyzers to reduce the risk of errors and contamination caused by manual operation[6].

6.2 Application in therapy

6.2.1 Accurate drug delivery

In clinical treatment, gel tip drippers are used for precise drug delivery, especially in scenes where drug dosage needs to be controlled. For example, in ophthalmology, ENT and pediatrics, gel tip drippers with flow control can accurately control the amount of drug delivered, reducing drug waste and adverse reactions[11].

6.2.2 The use of special drugs

For some special drugs (such as biological agents, chemotherapy drugs), the material and design of the rubber tip dropper need to meet higher requirements. For example, the use of chemical corrosion resistant materials can prevent the erosion of the dropper by the drug and reduce drug residues[6][7].

6.3 Application in drug research and development

6.3.1 High throughput screening

In the process of drug development, gel drop agents play a role in high throughput screening experiments, requiring rapid and accurate transfer of large amounts of trace liquids. Automated gel drop systems can achieve high throughput operations and improve experimental efficiency. For example, automated drop systems can quickly transfer and mix liquids in gene sequencing and drug screening experiments, thereby reducing human errors.

6.3.2 Integration of microfluidic technology

Microfluidic technology is a rapidly developing emerging technology, because of its miniaturization and integration advantages in biochemistry and medicine have been widely used. Microfluidic technology is an important direction in drug research and development, it requires high-precision liquid manipulation tools[9].

7. Market prospects and development trends

7.1 Growth in market demand

The market demand for gel tip drippers is further driven by the rapid development in the fields of scientific research, medical care and education. With the global population growth and aging, the medical demand continues to rise. Especially in the medical field, the application scope of gel tip drippers is expanding with the continuous advancement of medical technology and the increasing demand for

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diagnosis and treatment. For example, gene sequencing, drug development and clinical diagnosis, which require higher precision and performance of gel tip pipette, are driving the market expansion. In addition, the growth of gel tip pipette market has also been greatly promoted, with accelerated laboratory construction and increased scientific research projects. It is predicted that the gel tip pipette market will continue to grow steadily in the next few years, and the global gel tip pipette market is expected to reach a new height in 2031.

7.2 Technological innovation and competition pattern

The technological innovation of the rubber dropper industry is mainly concentrated in three aspects: materials science, intelligence and environmental protection design. At present, the technological innovation enterprises in the rubber dropper industry in China continuously carry out technological research and development and product upgrading to meet the diversified needs of the market, so as to improve the performance and quality of the dropper. For example, in materials science, not only chemical stability is good, but also through the optimization of processing technology, the application of new polymer materials and degradable materials with finer diameter control and smoother inner wall treatment is gradually increasing[2]. In terms of intelligence, the rubber tip dropper can automatically adjust the operating parameters according to the user's usage habits and specific medical scenarios with the help of artificial intelligence and machine learning technology, thus realizing more intelligent liquid operation[7]. In addition, more degradable and recyclable materials are applied in the dropper manufacturing to reduce the impact on the environment. Environmental protection design has also become an important direction for the development of the dropper[5]. In the future, the dropper industry will usher in more innovation and development opportunities. The relevant parameters of the liquid can be monitored in real time by intelligent sensors and transmitted to operators or medical information systems; degradable materials can reduce the amount of medical waste generated and the impact on the environment will be reduced. These technological innovations will further improve the performance and quality of the rubber tip dropper and promote innovative enterprises to occupy a large market share.

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