

## Article

# Safe Nail Clippers for Finger Flesh Injury Prevention

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**Abstract:** As people age, their toenails become thick and hard, making it difficult to trim them. Diabetic patients are prone to nerve and vascular damage due to high blood sugar, affecting blood circulation and sensation in the peripheral limbs. We developed a safety nail clipper designed specifically for the elderly and diabetic patients for healthcare. Trimming nails is a regular activity, and existing nail clipper designs lack warning mechanisms, increasing the risk of skin damage for diabetic patients during nail trimming. The elderly or diabetic patients often have poor vision in trimming their nails, which may lead to cutting too deep and causing paronychia or wounds. Tissue necrosis, suppuration, and infection may occur, potentially resulting in amputation. Therefore, based on the understanding of the difference in conductivity between the nail and skin and using LED indicators, we provided a protective mechanism for diabetic patients with abnormal peripheral limb sensation by using a nail clipper. When it touched the skin, the LED light illuminated to avoid cutting too deep and protect the nail bed.

**Keywords:** Nail, Clippers, Prevention feature

## 1. Introduction

Diabetes is the fifth top ten cause of death in Taiwan. According to the statistics of the State Administration of Health, there are about 2.3 million diabetic patients in the country, and about 160,000 new cases are added every year. Kidney disease ranks ninth among the top ten causes of death. Both are important chronic diseases that endanger the health of our people [1]. According to medical insurance statistics, there are 20,000 to 30,000 new patients with chronic kidney disease (CKD) in Taiwan every year. By the end of 2010, the number of patients had reached 450,000. Thousands of patients with early-stage CKD progressed to end-stage CKD each year [2]. In end-stage renal disease, dialysis treatment or a kidney transplant are required according to the statistical presentation of end-stage renal disease (ESRD) in the United States in 2022. The incidence rate in Taiwan is 525 per million population, and the prevalence rate is 2,302 per million population. 492,096 people chose hemodialysis (HD) for renal replacement therapy with an increase of 1.7% from 65% in 2018 [3]. In Taiwan, a total of 12,475 patients were diagnosed to require new dialysis in 2019, with an average age of 67.5 years. 5,970 patients with diabetes are added every year for dialysis [4]. The previous research focused primarily on the care of renal and dialysis patients. Clinically, patients who need dialysis suffer from multiple comorbidities, which bring a lot of inconvenience to their lives. For example, a large number of people with diabetes have poor blood sugar control. Retinopathy and neuropathy even lead to decreased kidney function, eventually causing kidney failure and the need for dialysis. In addition, many patients are elderly, and their quality of life is greatly affected by the disease and treatment. With age, the nails (toe) thicken and harden [5], making it difficult for the elderly to trim their toenails. In diabetic patients, high blood sugar easily causes damage to the nerve and vascular system, thereby affecting blood circulation in the extremities and causing paresthesia. Therefore, elderly people or people with diabetes experience the following difficulties when cutting nails.

- (1) Neuropathy and paresthesia: Nerve damage affects nail growth [6]. Secondary to neuropathy or abnormal foot posture and gait, toes, and toenails may be damaged or deformed by nesting into shoes or each other. Neuropathy causes paresthesias, which prevents the patient from feeling the pressure and position of the clipper on the nail. Especially if it happens to the toes, it is possible to unknowingly get cut during a toenail clipping or to have a sharp point left when clipping the toenail. Corners or edges, these spiky toenails buried in ingrown toes or ingrown toenails can also lead to injury and infection [7].
- (2) Impaired vision: Long-term poor blood sugar control may cause retinal damage, leading to vision loss in diabetic patients [8], or vision loss in the elderly, who may not be able to see their nails clearly when cutting them.

- (3) Infection: Diabetic toenails and surrounding infections caused by Gram-negative bacteria, yeast, or fungi are common [7]. Infections lead to discoloration and thickening of the nail tip and gradually spread to the entire nail to become thick and brittle. Neuropathy and hyperglycemia increase the risk of infection and injury, especially since the nails or adjacent skin are often damaged by deformed or sharp nails, so nail care of hands and feet is important [9]. Furthermore, deformed nails become sharp or broken and penetrate adjacent toes, causing wounds. Excessive manicures can also lead to injury and infection [7]. In addition, onychomycosis is an important factor in diabetic foot ulcers [10]. If there is no good foot care, the quality of life may worsen or cause serious complications.
- (4) Easy to bleed: The nail fold (the skin that produces the stratum corneum) is a window for observing microcirculation through a capillary microscope. Patients with advanced diabetes often show dilated capillaries [11]. High blood sugar affects the elasticity of blood vessel walls and makes them fragile. Especially when cutting nails, cutting too deeply or cutting into the fingertips or skin makes the nail bed of diabetic patients more likely to bleed because diabetic patients are prone to blisters, bleeding, and ulcers around the fingernails. If combined with arterial embolism, more severe splinter bleeding will occur [9].

When elderly or diabetic patients cut their nails (toenails), they often cut their nails too short due to poor eyesight, resulting in paronychia or wounds. Especially for diabetic patients, once a wound occurs, it is difficult to heal, and eventually the limb may have to be amputated due to tissue necrosis, suppuration, and infection. Protecting finger/toenails and doing good foot care is important daily health care for diabetic patients. It was found that a high proportion of the causes of chronic kidney disease were accompanied with poorly controlled diabetes, which coincided with the statistical results of the Taiwan Society of Nephrology for the main diagnosis of diabetes as high as 47.9% of new dialysis patients [4]. The comorbidity of diabetes and kidney disease requires multi-faceted and comprehensive care. In particular, poor blood sugar control in diabetic patients leads to difficulties in diabetic foot wound healing or skin care, which directly affects the patient's quality of life. On the other hand, many people with diabetes suffer from poor peripheral sensation due to neuropathy. Coupled with retinopathy, vision is affected, which makes it difficult to cut nails (toes) or cut them too deeply or accidentally. Cutting the belly of the finger (toe) can cause wounds and even serious complications. As we age, the nail bed gradually thickens and becomes brittle, making it difficult to trim thickened nails (toes) with ordinary nail clippers. Therefore, to protect the safety of dialysis patients, diabetics, or the elderly when trimming their nails, a safety protective nail clipper was developed. A nail clipper structure was designed to conform to thickened or brittle nail beds. We developed a safe nail clipper using different conductivity coefficients of the nail bed and skin. Electronic devices were integrated to warn and protect when the nail clipper was inserted too deep to take care of the patient's daily health.

Medical care focuses on treating disease and prolonging life, while nursing focuses on health care and quality of life. Collaboration between medical and nursing professionals can improve the overall quality of care. Clinically, many diseases are caused by failure to prevent and treat lesions in time. Therefore, the prevention of disease or comorbidities is extremely important for patients with chronic diseases including nail clipping. For people with diabetes and the elderly, a small cut can lead to diabetic foot infection, infection, and even amputation or life-threatening injury. In addition, being unable to take care of themselves or needing to assist others with personal hygiene behaviors, the patients are affected by their psychological well-being or quality of life. Therefore, the developed nail clipper can be used to provide healthcare for the elderly and patients with diabetes and solve their pain points.

## 2. Materials and Methods

General nail clippers include upper and lower blades and an operation panel, and the rear ends of the upper blade and the lower blade are pivotally connected as one. In the front ends of the upper and lower blades, there are blades aligned with each other so for incision between the two blades. The width of the cutout is determined by the distance between the two cutting edges. Generally speaking, the separation distance is determined by the length of the pivot axis of the operating plate between the upper and lower blades, and the length of the pivot axis is usually fixed. When cutting nails, the operating panel drives the upper blade to approach the lower blade along the pivot axis, so that the two blades move relative to each other, thereby clamping and cutting the nail. Most people with diabetes experience symptoms of nail curling, ingrown toenails (paronychia), and onychomycosis. They have poor blood circulation and may develop wounds that are difficult to heal if their toenails are trimmed incorrectly. Sometimes, the limb needs to be amputated due to tissue necrosis, suppuration, and infection. Therefore, nail problems can easily cause foot wounds, such as curled nails, also known as pincer nails or depressed nails, with the unnatural downward bending of the nail. This causes pain in the nail area. If left unchecked, it shrinks the nail bed [12]. The cause of curling nails is that the nail bed tissue on both sides of the nail shrinks and loses support, causing the nails on both sides to bend down. Ingrown nails grow into the finger flesh. In the early stage, ingrown nails are only painful, but because they are prone to infection of the paronychia paronychia. Onychomycosis is a fungal infection of fingernails or toenails, resulting in discoloration, deformation, thickening, desquamation, rough and brittle

nails, and nail separation [13]. Onychomycosis is the most common nail lesion. The above three foot symptoms are troublesome and serious for diabetic patients. These symptoms need to be properly maintained when trimming nails. However, with the current design of nail clippers, the cutting opening is too small and cannot be adjusted. Therefore, a nail clipper cannot be used directly when nails are thickened or deformed abnormally. Therefore, special nail clippers must be used for trimming, and these special nail clippers need to be operated by professionals or artificial hands. For diabetic patients, it is inconvenient to trim them at home. Although there are nail clippers on the market that adjust the size of the cutting opening by adjusting the length of the pivot, people must operate and adjust repeatedly due to the limitation of the length of the nails after entering the cutting opening. For diabetic patients with poor vision, the operation is still difficult. Most special nail clippers are designed with beveled blades, which are cut by oblique entry during operation. The self-operated operator cannot measure the distance between the nail length and the skin from the side, and the wound caused by the cut is not easy to heal, further increasing the difficulty of subsequent treatment.

### 3. Results

#### 3.1. Design

In the design of the blade, the principle of different conductivity between fingernails and fingertips needed to be considered to avoid possible damage caused by nail clipping. Human skin is a good electrical conductor, so when the nail flesh of one palm of the human body touches the nail blade and the fingers of the other palm touch the finger electrode, the power supply module applies a trace current to the skin through the nail blade. Then, the trace current passes through the human body and the main body to form a loop, and this trace current passes through the signal-amplified circuit and becomes a larger output current. The output current was sent to the warning light module to make the warning light module emit light in the developed nail clipper. In this way, the user was reminded that the nail clipper had touched the nail flesh, effectively preventing the nail clipper from accidentally injuring the nail flesh or being injured by going too deep when trimming the nail. When the nail clippers were in use, if they touched the “finger pads”, the LED warning lit up, allowing the user to cut the “nails” to avoid cutting the finger pads. On the contrary, when the armor knife touched the nail of the finger, the conductivity of the nail became much lower than that of the pulp (skin and finger flesh), so the human body and the main body did not form a circuit, so the warning light module was illuminated.

#### 3.2. Components

- Nail clippers, the bottom is a “cutter”, and the upper part is a “rocker”.
- There are two sets of covered nail clippers, namely “nail shell” and “rocker cover”, which function as electrical insulators.
- Circuit board: Above the tail section of the armor knife, it contains batteries, LED lights, signal amplification circuits, and armor knife electrodes.
- Finger electrode plate: Located at the bottom of the nail clipper. When using, you need to touch the electrode plate with the finger that operates the nail clipper.
- The main circuit board and the electrode plate are fixed on both sides of the tail section of the knife using screws and nuts. The screws and nuts also have conductive functions (Fig. 1).

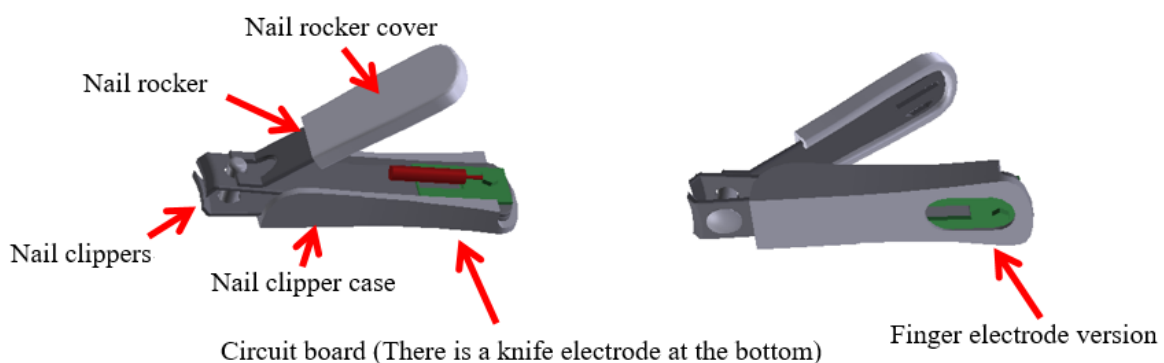


Fig. 1. Function and structure of each component.

### 3.3. Formatting of Mathematical Components

- (1) When the nail clippers were held with the right hand, the thumb of the right hand was placed on the bottom of the “finger electrode plate” of the scissors, the index finger on the end of the “rocker cover” to apply downward force to “cut the nails of the left index finger.”
- (2) Current signal path: The battery supplied voltage through the electrodes on the bottom of the motherboard (compared to the “finger electrode plate”). When the “nail clippers” touched the “finger flesh” of the left index finger and the right thumb touched the electrode plate of the finger, a small amount of current passed through the body to form a loop.
- (3) The “finger electrode plate” of the right thumb was connected to the “signal amplification” circuit and output current to the “LED indicator light” to complete the alarm procedure.
- (4) If the armor knife touched the “nail” of the left index finger, the LED light was not triggered, because the conductivity of the “nail” was much lower than that of the “finger flesh” (Figs. 2 and 3).

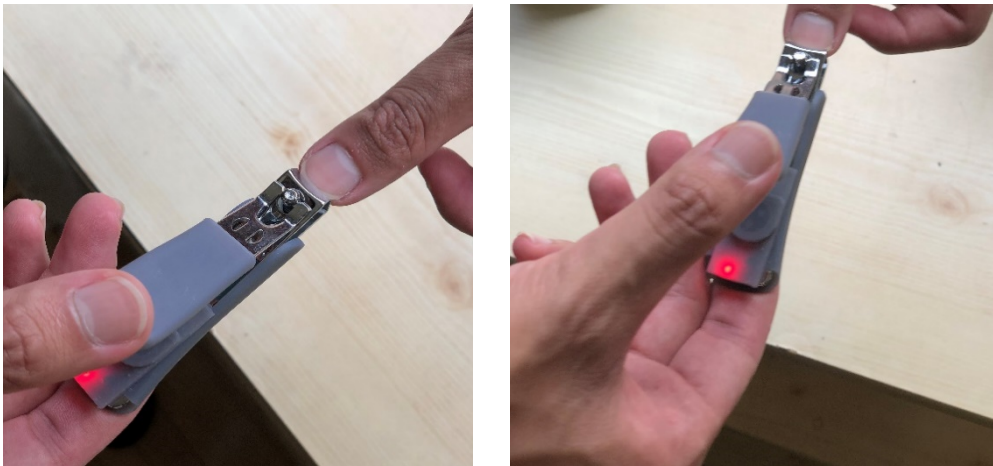


Fig. 2. Principle of action.

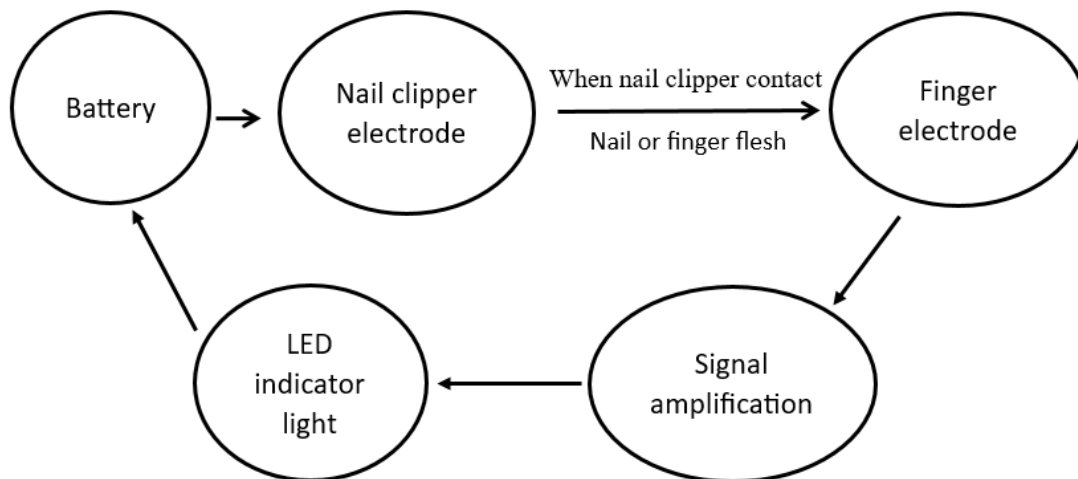


Fig. 3. Design principles and flow charts.

## 4. Discussion

The developed device was conceived in clinical practice by observing and interviewing dialysis patients due to the inconvenience in life caused by disease complications. Although it was a simple clipping of finger (toe) nails, careless operation led to injury, which even required amputation and increased the length of hospitalization. This increases medical costs and causes trouble and burdens to patients and their families. Therefore, it is important to understand the problems and needs of the patient side (target group) and find that most dialysis patients have diabetes. Due to high blood sugar, diabetic patients were likely to have problems such as retinal and neuropathy, poor vision, peripheral sensations of peripheral limbs becoming insensitive, and fingers

were easily injured when nails were cut. On the other hand, patients who need dialysis are elderly and often have thickened and brittle fingernails. Thus, it is difficult for them to use. The technological innovation and development of this protective nail clipper included two parts. The first part was the structure with spiral and elastic elements to adjust the opening size of the cutting port and the protective element to adjust the distance between the skin and the cutting port. The second part was to use the difference in conductivity between the nail bed and the fingertips to form a current through the human body and the main body so that LEDs displayed warning lights. Nail clippers were personal hygiene products, and improper use may cause cross-infection. It is recommended for each person to have multiple nail clippers for different functions or needs.

To develop a safe nail clipper, experts in materials, mechanical and electrical engineering, and the industry consulted. After many revisions, a safe protective nail clipper was designed and presented at the Taiwan Medical Technology Exhibition in December 2022. During the exhibition, people were invited to try out the nail clipper and feedback about the use experience. At present, industry-university cooperation has been carried out between Formosa Biomedical Technology Co., Ltd. and the College of Engineering of Mingchi University of Science and Technology to commercialize and mass-produce safe nail clippers after testing in the future.

The nail clipper is innovative as the structure and the protective function of electronic equipment were combined and the difference in conductivity between human nails and fingertips was used as a conductor. Taiwan is an aging society. The elderly need to learn to take care of themselves, including nail cutting. The developed nail cutter allows for the personal hygiene of people with chronic diseases and corresponding self-confidence and self-esteem to improve their quality of life.

## 5. Promotion

Taiwan is currently moving towards an aging, super-aging society. According to statistics, the elderly population in Taiwan is expected to increase to 5.59 million (63.1%) in 2030. In addition, the National Nutrition and Health Change Survey from 2010 to 2010 by the National Health Bureau found that the prevalence of diabetes among those over 18 years old was 11.1% (12.4% for men; 9.7% for women). It is estimated that approximately 2.186 million people in Taiwan have diabetes. , the total population of elderly people and diabetics is considerable, and nail clippers are personal hygiene products. It is recommended that they should be exclusive to individuals and not shared among family members. Therefore, there will be a certain market after commercialization in the future; the safety protection design principle of this research and development technology can also be developed and applied to nail trimming of infants or pets, meeting market demand.

## 6. Conclusions

We developed a nail clipper with a warning light for patients and the elderly to prevent wounds from cutting fingers when cutting nails. Such wounds likely cause tissue necrosis and infection. Hand or foot care is important for diabetic patients especially. It is also important to prevent diabetic patients from accidentally damaging the skin and tissue when cutting nails. The developed nail cutter is suitable for the elderly and diabetics and for infants and young children. Infants and young children often resist or twist when trimming their nails and have delicate skin and smaller fingernails. Thus, it is easy for them to be cut while trimming nails. The developed nail clipper can be used for diabetics and the elderly as well as for warning and protection of infants or pets.

**Author Contributions:** I-Chen Yu writing—original draft preparation. For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, I-Chen Yu; methodology, I-Chen Yu; software, I-Chen Yu; validation, I-Chen Yu, Yu-Ruei Chen, and Teng-Xuan Li; formal analysis, Yu-Ruei Chen , and Teng-Xuan Li; investigation, I-Chen Yu, Yu-Ruei Chen , and Teng-Xuan Li.; resources, I-Chen Yu, Yu-Ruei Chen , and Teng-Xuan Li.; data curation, I-Chen Yu; writing—original draft preparation, I-Chen Yu, Yu-Ruei Chen , and Teng-Xuan Li.; writ-ing—review and editing, I-Chen Yu, Yu-Ruei Chen , and Teng-Xuan Li.; visualization, I-Chen Yu; supervision, I-Chen Yu; project administration, I-Chen Yu. All authors have read and agreed to the published version of the manuscript.” All the authors’ contributions must be listed here.

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