Internet-of-things nail-printing technology using non-face-to-face contact

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**Background:** With the spread of coronavirus disease-19 (COVID-19), face-to-face contact in business and educational hubs has decreased. This is especially true for the beauty industry, where long-term contact with operators and customers is required. Therefore, the emergence of new alternative business models is essential.

**Objective:** The purpose of this study is to apply nonfacing and real-time three-dimensional (3D) nail-printing systems to cosmetic industries, educational institutions, and educational systems. Three-dimensional non-face-to-face printing equipment have enabled nail art to be precisely and remotely controlled, which facilitates the replacement of nail technology that is based on body contact.

**Methods:** From January to April 2020, the use of the internet-of-things (IoT)-controlled non-face-to-face and real-time 3D nail-printing systems was tested. Nail artists and customers were isolated, and more than 200 patterns were tested with non-face-to-face contact between Korea and the United States. A built-in IoT operating system was tested in an online platform, and the advantages and problems of non-face-to-face contact were systematically analyzed.

**Results:** The rapid development of IoT-controlled non-face-to-face and real-time 3D nail-printing systems was achieved to reduce entry barriers for nail art utilizing 3D-printing technology. The most crucial parts were determined to be reliably creating 3D shapes, reproducibility, economical operation, and timely maintenance.

**Conclusion:** The nail art business model, in which the education and business sectors depend entirely on face-to-face contact, has been disrupted and deemed unpredictable due to the social distancing norms that have been adopted for countering the COVID-19 epidemic. Nevertheless, secure and remote accessibility to non-face-to-face and real-time 3D nail-printing systems for nail artists were successfully applied and tested to respond to this situation.

**Keywords:** internet-of-things remote nail printing; nail art education; non-face-to-face; real time

**Introduction**

Since 2018, the issues of the ultraviolet (UV) skin exposure process, chemicals, and ground nail powder have raised concerns about the need for fundamental changes in the nail art industry based on the contact of client and operator [1-5]. The coronavirus disease-19 (COVID-19) pandemic in 2020 significantly affects tourism, manufacturing, trade, and education. In particular, the rapid collapse of the beauty, nail art, plastic surgery, and healthcare industries is expected because of the limited face-to-face contact. By applying additive manufacturing to a limited area, the traditional process can be converted into a 21st-century leisure and arts field with the use of three-dimensional (3D) printing technology [6-8]. Traditionally, cus-
tomers and nail artists share the same space, which limits the processing of UV-curable materials that utilize photoinitiating chemicals, gels, or adhesives. The use of these is problematic in confined spaces that create environmental pollution and health hazards requiring physical isolation at basic contamination levels [9-11]. The primary social-distancing method in the beauty art business has improved slowly and gradually.

Now, an entirely new concept of the nail beauty art industry is needed worldwide. It is evident that the risk of infectious diseases that spread quickly through physical contact is more severe than that of existing environmental problems. COVID-19 further accelerated the problems of the nail art industry, causing the industry to collapse. The problems still exist, but rather than merely solving these problems, an attempt must be made to revolutionize the beauty industry system itself [12].

Beauticians report that UV light treatment of nail gels has been used for more than 10 years, and damage from skin exposure to UV light is inevitable. In the technical application, improvement by an artistic approach falls far behind a scientific improvement. These issues have created opportunities and challenges in the field of equipment and materials for the introduction of 3D nail art [13-15]. Precise control over various 3D color structures of artificial nail tips to create a stylish and customized shape in a short time can be achieved by the adoption of 3D-printing technology by nail artists. Face-to-face contact with customers is familiar in a business model that conveys emotions with experienced 3D designers, but it can expose them to harmful environments and disrupt business. Therefore, it is necessary find an alternative to this familiarity.

Kim [16] reported that an internet-of-things (IoT) printing method could be used as an innovative approach to prevent simultaneous exposure of consumers and nail artists in close proximity. The economics and commercialization of nail art 3D printing have been analyzed for a business model in which consumers choose designs, ideas, and products from the web [17]. User-oriented custom 3D nail art manufacturing and delivery organizations have successfully tested advanced 3D nails that are different from the existing ones. The feasibility of the entire manufacturing and delivery chain through a noncontact IoT manufacturing system with various designs was verified [18]. This non-face-to-face contact and real-time printing technology has utilized IoT and AI in areas ranging from remote systems to drug delivery systems or telemedicine systems [25]. This fusion technology has reached a level where even ordinary people without artistic inspiration can use it. This study focused on teaching methods that can create artistic products remotely through IoT-controlled 3D-printing devices programmed in the cloud with its own designs, images, and photos.

Materials and methods

IoT-enabled tele-nail printer

A way to upload and use image files to a cloud system was designed to build 3D structures based on the IoT, and equipment and technology can be used to create works of art with this technique (http://naiplove.com). As Fig. 1 shows, when a design file is selected by a client or recommended by AI, the selected file is sent to the cloud [8]. The selected file is then analyzed taking printing systems and web systems rely heavily on the development of printable particles and the basic science of printing technology [19-22]. A real-time, high-speed printing system that can communicate remotely from ordering items to attaching nails, as well as a web system to manage this, is required. Only the initial implementation of this new supply chain can revive the crumbling nail art business.

From January to April 2020, more than 200 designs of nails and their effectiveness were evaluated through web-based non-face-to-face contact and real-time printing technology. A fundamental study using 3D-printing technology, such as IoT, artificial intelligence (AI), and high-viscosity materials using piston-type extrusion and screw-type extrusion, was described in prior research [23,24]. Three-dimensional printing technology has utilized IoT and AI in areas ranging from remote systems to drug delivery systems or telemedicine systems [25]. This fusion technology has reached a level where even ordinary people without artistic inspiration can use it. This study focused on teaching methods that can create artistic products remotely through IoT-controlled 3D-printing devices programmed in the cloud with its own designs, images, and photos.

![Fig. 1. Conceptual diagram of internet-of-things (IoT)-enabled 3-dimensional nail-printing technology, non-face-to-face contact, and optimized nail size design through web-based control [8]. R-PI, Raspberry Pi.](http://naiplove.com)
into account premeasured customer information, such as nail size and bending, and the optimal nail position is calculated. The print file thus determined is sent to a user-specified location or to the printer equipment closest to the user. The transferred information file is recognized by a Raspberry Pi device and displayed on the display panel at the top of the printer (Fig. 1). Personal nail size information is sent, along with the design file. Artificial nails are printed through a 3D-printing process, enhancing the ability of optimized equipment to print 2D shapes using the conformal projection printing method [26,27].

This research was conducted to solve the problems mentioned above. It can provide information and 3D-nail-art-related advertisements, movies, videos, and multimedia contents provided outside the printer and on the monitor. The method in this study is to provide an operating system using an advertising-type 3D printer that can efficiently use time and space through a monitor mounted on a computer.

Web-based control
Another innovative method developed in this study is to provide a web platform for managing 3D printers in a cloud-computing environment capable of personalized advertising, Internet service, subtitle broadcasting, local broadcasting, full advertising, and public messaging, along with monitoring of equipment process and functions [16]. The mobile application enables the user to control printing remotely, and the final product is delivered at the door, thereby eliminating any physical contact. The control device interworks with the user terminal according to the relay of the platform on the network and makes the overall control of the device through the user terminal possible. The control device transmits the image to the user terminal on the display panel. The apparatus consists of hardware for controlling a 3D printer and Raspberry Pi hardware for controlling a display panel. The cloud server works with servers on the network to store and manage nail art information, such as drawings, designs, or materials to be manufactured or produced by a nail printer. The user receives a unique authentication code. When the code is entered, the machine can access the customized design from the 3D-printer work database. The 3D printer then decodes the encrypted information for printing the requested nail design. The 3D printing of nails initiates right after the server confirms the sequence of the order and the user delivery information.

Results and Discussion
An experiment was conducted between Korea and the United States for a long-distance, non-face-to-face contact test of nail art. In particular, the creatively developed, original, and lively artwork developed to emphasize the display of beauty nails was designed with improved precision and touch feeling, which is not comparable to the traditional development of handmade nails. Conventional nail art deals with the handling of gel or glue, including a photoinitiator, which consists of UV curing material, and a UV solidification process. This procedure takes place where the customer and the nail artist share space with physical contact, which leads to exposure to infections (CO-VID-19 in this case) and health hazards by UV radiation. In this study, a 3D printer is used—more specifically, an advertising-type 3D printer operating system capable of using the IoT. Cultural trends have made people less patient. Visually stimulating the user through the display on the printer while waiting for the printing to be complete can help the user relax. Advertisements have evolved significantly this century, exposing people to visual stimuli, and the display on the 3D printer can take advantage of the massive impact of advertising. Nail beauty art can be created in a non-face-to-face manner that can be controlled from the web, with advertising occurring upon contact. It is no exaggeration to say that the range of influence of advertising is broad and represents modern society. The display can show advertisements, along with a live video of the process of printing, which can further pique the interest of users. Therefore, the use of 3D printers with displays can more efficiently provide customer satisfaction.

This study does not print the picture on the nails—it prints the product of the imagination of the user in a non-face-to-face state. It provides the ability to apply makeup on the nails quickly. Nails are available in all face-to-face contacts, while opportunities to view advertising and movies on the media for nail art are also provided. It is predicted that multifunctional 3D printers will eventually attract people’s attention, as smartphones did. Successful separation can be achieved so that the nail can be safely removed without person-to-person contact. The drawback of the 3D printer is that the user is required to wait during the printing process. It takes time to remove nails carefully, which extends the wait time further.

With the recent spread of COVID-19, the need for non-face-to-face contact beauty-art technology has increased, making remote diagnosis a rapid social response. The potential of non-face-to-face or contactless material delivery systems was evalu-
ated, and they were found to be applicable through the fusion of licensed remote diagnostic treatment and cosmetic nail art technology.

A strategy was established to secure the core skills for using printable materials on nails. Through this study, non-face-to-face printing systems were tested using printing materials for cosmetic nails. The possibility of using a functional material on a sensor with a nail gel to confirm an individual’s health or to diagnose remotely a body reaction to the surrounding environment, such as a virus, was identified. The specific research goal was to maximize the synergistic effect of printing and beauty techniques. For localization of non-face-to-face material printing systems, four patented Korean IoT printing systems were introduced and tested successfully. The platform, controlled via image, text, and RIP, controls the remote data delivery system on behalf of the existing United States web platform (https://www.naiplove.com) and manages the data process on the newly established Korean web cloud, as shown in Fig. 2.

Through the convergence of the 3D-printing method for the field of nail beauty and remote health verification, a personalized design was successfully provided for the field of nail art (Fig. 2). This was done by utilizing the equipment of Biomedical 3D Printing Inc. (Seoul, Korea) and the analysis technology on the web base of the K-Innovation Center in the United States, the

Fig. 2. Non-face-to-face contact and real-time control three-dimensional (3D) printing technology hands-on test images through a web-control system between Biomedical 3D Printing, Inc. (Seoul, Korea) and Makers’ Station (TX, USA).

Fig. 3. New design features for a non-face-to-face contact three-dimensional nail printer from the website (http://naiplove.com).
use of low capacity. Fig. 2 shows the web-based control system, one of the crucial elements of this study on non-face-to-face contact and real-time control 3D-printing technology through a web-control system between Biomedical 3D Printing, Inc. and Makers’ Station (TX, USA). The design was uploaded, and the equipment was separated (http://makerspiece.com). It was confirmed that 200 nail designs could be delivered on the web or selected by AI and successfully printed at a given site.

Fig. 3 shows the results of efforts to improve nail design and color, one of the causes of delays in traditional nail art. To this end, the research group of the K-Innovation Center designed approximately four times the size of a 3 cm×6 cm nail and optimized the design. New design features for non-face-to-face noncontact 3D nail printers through the website (http://naiplove.com) have been successfully realized and are expected to grow into a new design field of nail art. A system was implemented that enables anyone to design, take good photos, and print on nails in real time.

Because of COVID-19, the world economy has been disrupted. The beauty industry based on face-to-face contact is not expected to recover easily and will take longer to recover traditionally. In this study, a fully face-to-face contact and real-time nail-printing technology was developed that can be accessed and controlled from anywhere in the world by applying a web-based system, as shown in Fig. 4. The final nail shape is achieved through a non-face-to-face real-time nail-printing system, web-based design control, and other technical conformal projection printing methods applied simultaneously.

In conclusion, product uncertainty, which arises due to the inconsistencies in the proficiency of nail artists and their inefficient working hours, has decelerated the growth of the traditional nail industry. As a result, scientific improvements have been made in this field. These issues have created opportunities and challenges for new technologies for nail art, such as the IoT, 3D printing, and materials supply. Beginning with the convergence of AI and IoT, the use of 3D-printing technology for non-face-to-face and real-time 3D nail-printing systems has been successfully applied to businesses, engineering, science, and education. These technologies are growing into a separate market that is differentiated from the traditional nail art business based on physical contact.

Conflicts of interest

The author has nothing to disclose.

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