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Short Communication

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Design of a glove dispenser to promote rational glove use and hand hygiene in an intensive care unit

Diseño de un dispensador de guantes para promover el uso racional de guantes y la higiene de manos en una unidad de cuidados intensivos

David Alexander Lemos Martínez[1], Helen Johana Ortiz Rojas[1*], Stephanie Pabón Lozano[2], Sergio I. Prada[1,3], Carolina Castro Gómez [4,5,6]

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Highlights

1. A glove dispensing system integrating hand hygiene guidance was developed and implemented in an ICU.
2. Two-step system promotes WHO hand hygiene guidance and appropriate glove use.
3. During pilot implementation, 88% of healthcare workers used a single pair of gloves per procedure.

[1]Fundación Valle del Lili, Centro de Investigaciones Clínicas, Cali, Colombia. *Corresponding author: helen.ortiz@fvl.org.co
[2]Fundación Valle del Lili, Gestión del conocimiento, Cali, Colombia.
[3]Universidad ICESI, Centro PROESA, Cali, Colombia.
[4]Fundación Valle del Lili, Medicina física y rehabilitación, rehabilitación, Cali, Colombia
[5]Institución universitaria Escuela Nacional del Deporte, Cali, Colombia
[6]Universidad Santiago de Cali, Grupo de investigación Salud y Movimiento, Cali, Colombia

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ABSTRACT

Introduction. Healthcare-associated infections continue to pose a significant challenge in intensive care units (ICUs), where inappropriate glove use and poor hand hygiene can contribute to pathogen transmission and the unnecessary consumption of resources. Gloves represent an essential protective barrier against exposure to potentially infectious biological material, including blood, body fluids, and secretions. **Objective.** To design, develop, and evaluate a glove dispenser intended to promote appropriate glove use and support hand hygiene practices in an intensive care unit (ICU). **Materials and Methods.** A technological design study was conducted between January 2023 and January 2024 following a five-phase development process: needs assessment, device specification, concept generation, prototype development and refinement, and final prototype construction. The process incorporated direct clinical observations, feedback from ICU healthcare personnel, iterative usability testing, and pilot implementation in a real clinical setting. **Results.** A glove dispenser prototype integrated with an alcohol-based hand sanitizer dispenser was developed, incorporating visual prompts based on World Health Organization recommendations to encourage appropriate glove use and hand hygiene. During pilot implementation, 50 healthcare workers participated. Exposure to body fluids was observed in 60% of procedures; glove use was indicated in 72% of cases; 88% of participants used a single pair of gloves per procedure; and 88% reported performing hand hygiene after glove removal. **Conclusion.** The proposed device represents a technological strategy designed to support appropriate glove use and reinforce hand hygiene practices. Its potential impact on infection prevention and resource optimization should be evaluated in future studies.

Keywords: Gloves; Technological Innovation; Infections; Prevention and Control

RESUMEN

Introducción. Las infecciones asociadas a la atención sanitaria representan un desafío en las unidades de cuidados intensivos (UCI), donde el uso inadecuado de guantes y la higiene de manos deficiente pueden contribuir a la transmisión de patógenos y al desperdicio de recursos. Los guantes protegen frente a la exposición a material biológico potencialmente infeccioso. **Objetivo.** Diseñar, desarrollar y evaluar un dispensador de guantes para promover su uso adecuado y apoyar la higiene de manos en una UCI. **Materiales y métodos.** Se realizó un estudio de diseño tecnológico entre enero de 2023 y enero de 2024 en cinco fases: identificación de necesidades, especificaciones del dispositivo, generación del concepto, desarrollo y perfeccionamiento del prototipo y construcción final. Se incluyeron observaciones clínicas, retroalimentación del personal sanitario, pruebas iterativas de usabilidad e implementación piloto. **Resultados.** Se desarrolló un dispensador de guantes integrado con uno de solución hidroalcohólica, con mensajes visuales basados en recomendaciones de la Organización Mundial de la Salud. Participaron 50 profesionales sanitarios. Se registró exposición a fluidos corporales en el 60 % de los procedimientos y el uso de guantes estuvo indicado en el 72 % de los casos. El 88 % utilizó un solo par por procedimiento y el 88 % informó realizar higiene de manos después de retirarlos. **Conclusión.** El dispositivo constituye una estrategia tecnológica diseñada para favorecer el uso adecuado de guantes y reforzar la higiene de manos. Su impacto sobre la prevención de infecciones y la optimización de recursos requiere evaluación en futuros estudios.

Palabras clave: Guantes; Innovación tecnológica; Infecciones; Prevención y control

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INTRODUCTION

Healthcare-associated infections (HAIs) remain a major cause of morbidity and mortality in the intensive care unit (ICU) due to the high frequency of invasive procedures, the presence of immunocompromised patients, and the need for constant use of personal protective equipment (PPE) [1-2]. Among PPE, gloves constitute an essential barrier against exposure to chemicals and body fluids [3]. However, unnecessary use or inadequate replacement can lead to failures in infection control and promote the indirect spread of pathogens [1,4-5]. Furthermore, adherence to hand hygiene may be compromised when excessive reliance is placed on gloves as a substitute [6,7]. Recent evidence shows that approximately one-third of glove use instances in ICUs are incorrect or unnecessary, implying a waste of resources and potential health risks [1,6,8]. In addition, the physical design of glove dispensers – including the method of dispensing, the orientation of the outlet hole, and glove exposure to air and previous hand contact – has been identified as a factor associated with contamination of unused gloves, dispenser surfaces, and the risk of cross contamination [2,6]. Comparative studies have shown that modified boxes or boxes with a downward-facing hole significantly reduce bacterial contamination on both the dispenser surface and the gloves themselves, compared to conventional designs [2,4,9]. Conventional dispensers also tend to generate material waste, either from the simultaneous removal of multiple gloves or from the unnecessary disposal of contaminated units. Implementing innovative designs could help reduce glove waste and contamination of the box surface, which in turn would reduce the risk of pathogen transmission in healthcare settings [4]. However, existing dispensing systems mainly seek to minimize glove contamination during removal and do not address behavioral factors related to improper glove use or the integration of hand hygiene into the glove-wearing process. During the initial needs assessment, several nonstandard methods for accessing and storing gloves were identified in the ICU, which could contribute to variability in glove-use practices. To address this issue, a glove dispenser was designed and paired with a standardized A-B process intended to promote proper glove use, reinforce hand hygiene, and improve resource efficiency. In this context, developing an optimized glove dispenser for ICUs—one that enables individualized, safe glove retrieval and minimizes unnecessary contact—represents a promising strategy to support appropriate glove use and hand hygiene. This study aimed to design, develop, and evaluate a glove dispenser for use in an ICU setting.

MATERIALS AND METHODS

Study design and setting: This was a technological design study conducted at Fundación Valle del Lili (Cali, Colombia) between January 2023 and January 2024. The development of the glove dispenser followed a structured process consisting of five phases: *i*) Phase 1: Needs Assessment: An initial observational assessment was conducted in the

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ICU to identify current practices related to glove use and storage. It was observed that gloves were frequently stored in boxes, bags, or disorganized groups. These conditions were associated with inconsistent adherence to hand hygiene practices and non-standardized glove use. Based on these observations, the need for a strategy to promote appropriate glove use and improve organization was identified. *ii)* Phase 2: Device Specifications: A prototype glove dispenser was designed with dimensions of 20 cm (length), 11 cm (width), and 6 cm (depth), including a 3-cm front opening. The device incorporated visual prompts intended to encourage appropriate glove use, including the message "Do you really need gloves?" and an additional sustainability message: "For a sustainable institution, let's optimize glove use." These elements were based on recommendations from the World Health Organization (WHO) Glove Use Pyramid [10].

The dispenser was designed to be integrated with an alcohol-based hand sanitizer dispenser, forming a two-step process (A–B): Step A: The alcohol-based hand sanitizer dispenser includes a sticker with instructions for proper hand hygiene. Step B: The glove dispenser displays printed information about the clinical activities that require glove use (**Figure 1**).

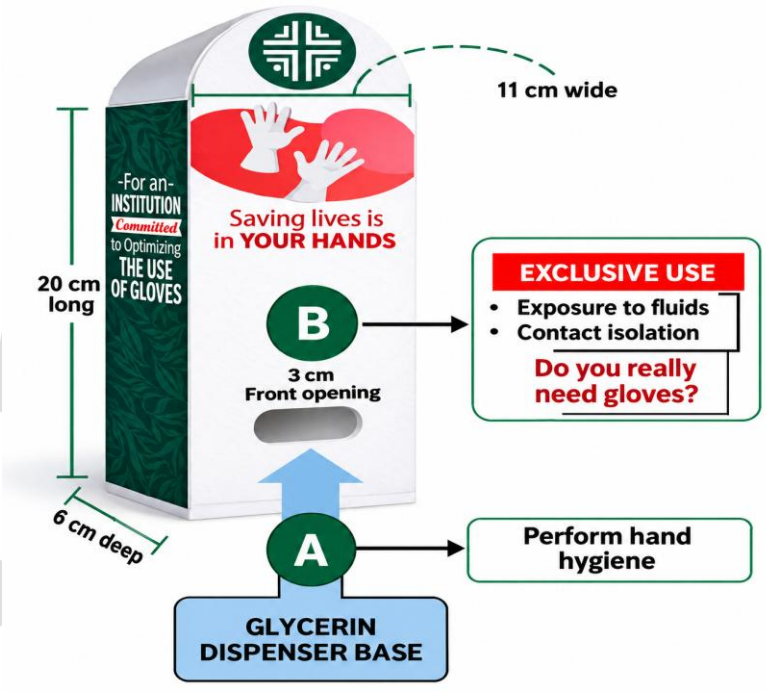


Figure 1. Prototype glove dispenser and device specifications. The figure illustrates the device

Phase 3: Concept Generation: The device concept was developed based on direct observation and feedback from healthcare personnel, obtained through structured interviews and observational assessments. A participatory approach was used to identify opportunities to improve glove use practices and reduce unnecessary handling. Design considerations focused on facilitating individual glove dispensing and minimizing contact with unused gloves.

Phase 4: Prototype Development and Refinement: Initial concepts were translated into sketches and schematic representations. Low-fidelity prototypes were constructed for exploratory testing of functionality and usability under controlled conditions. Based on user feedback, iterative modifications were made, leading to the development of medium-fidelity prototypes (**Figure 2**).

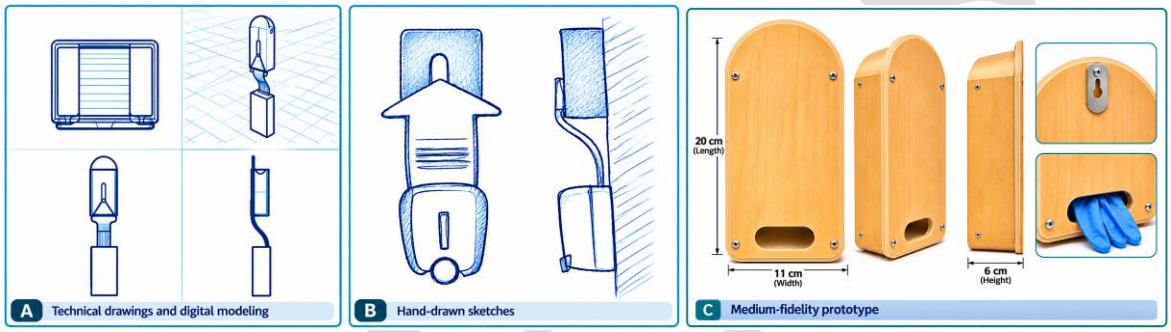


Figure 2. Low- and medium-fidelity prototypes. **(A)** Preliminary technical drawings and digital modeling from different perspectives. **(B)** Hand-drawn sketches. **(C)** Medium-fidelity prototype made of wood, measuring 20 cm in length, 11 cm in width, and 6 cm in height.

The design process consists of three key stages, the initial freehand sketch and its schematic representation, digital modeling using technical drawings, and the medium-fidelity physical prototype.

A pilot version was subsequently implemented in a real clinical setting to assess operational performance and gather qualitative feedback from healthcare staff. These inputs guided the refinement of the final prototype. *Phase 5: Final High-Fidelity Prototype:* The final prototype was manufactured using 4-mm-thick crystal acrylic with a mirrored finish. The device included a 4 × 2 cm front opening, a hinged access door, and a top stop for glove storage. A directional visual element (arrow) was incorporated to guide its intended use. The final version was evaluated under routine clinical conditions to assess its functionality, durability, and usability.

Participant selection, data collection and prototype evaluation: Healthcare professionals were selected through convenience sampling from ICU staff, including nursing assistants, nurses, physiotherapists, and physicians. Those responsible for patients under contact isolation or involved in critical clinical situations requiring emergency interventions were

excluded. Random selection was not feasible because staff assignments varied according to rotating schedules and patient allocation. To ensure representation of different professional groups, personnel lists provided by unit coordinators were used. A total of 50 ICU healthcare professionals were included, with each participant constituting an observation unit and undergoing one 30-minute observation session during routine clinical activities over the course of one month.

Data collection was performed using a structured checklist based on WHO recommendations on glove use and hand hygiene. Trained investigators conducted standardized observations under real clinical conditions and recorded the information in dedicated data collection forms. During the prototype's implementation, healthcare staff provided feedback on the ease of use and functionality of the glove dispensing system. These observations and user comments informed iterative refinements of the prototype before development of the final version.

Statistical analysis: Descriptive statistics were used to summarize the data. Categorical variables are presented as frequencies and percentages. No inferential statistical analyses were performed because the purpose of the pilot implementation was to describe prototype feasibility, usability, and observed glove use practices under routine clinical conditions.

Glove Consumption Classification: The research team developed a three-level classification framework (high, medium, and low) based on clinical and healthcare-related criteria. These criteria were used to estimate glove usage needs based on patients' clinical status and care needs, not to measure actual glove consumption. The classification framework used in the study is presented in (**Table 1)**.

Data Availability: The data supporting the findings of this study are not publicly available due to ethical and confidentiality restrictions. As the dataset includes observational information involving healthcare personnel, public disclosure is restricted to protect participant privacy and ensure compliance with applicable ethical and data protection requirements.

RESULTS

Final high-fidelity prototype characteristics: The final prototype of the glove dispenser measured 11 × 20 × 6 cm, with a total height of 25 cm (**Figure 3**). The device was constructed from 4-mm-thick acrylic and included a front opening, a hinged access door, and a directional visual element to guide its use. The prototype was evaluated under routine ICU conditions to assess its functionality, stability, and operational performance. Qualitative feedback from healthcare staff helped identify strengths and areas for improvement. Based on this feedback, structural modifications were implemented, including adjustments to the dispensing system that enabled bidirectional glove extraction.

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Table 1. Clinical and care-related criteria for classifying glove-use requirements.

Clinical and Care-Related Factors	Criteria		
	High	**Medium**	**Low**
Hemodynamic status	Hemodynamically unstable; high-dose intravenous support	Hemodynamically stable; intravenous support	Hemodynamically stable; no support
Hemodynamic monitoring	Advanced invasive monitoring	Invasive monitoring	Non-invasive monitoring
Respiratory support	Invasive/non-invasive mechanical ventilation; respiratory therapy ≥3 times per shift	Invasive/non-invasive mechanical ventilation; respiratory therapy less than 3 times per shift	No oxygen support or low-flow oxygen
Renal replacement therapy	Dialysis or hemofiltration	Dialysis	—
Mobility and urinary care	Reduced mobility, bedridden; diapers and/or urinary catheter	Reduced mobility, bedridden; diapers and/or urinary catheter	Independent in performing activities
Nutritional support	Parenteral nutrition	Parenteral or enteral nutrition	Established oral intake
Drainage	High-output drains per shift	Moderate-output drains per shift	Minimal-output drains per shift
Diarrhea	High-output diarrheal episodes	Two or fewer episodes of diarrhea	—
Blood product transfusion	Required	Required	—
Open abdomen with VAC system	Present	Present	—
Other procedures	—	—	Peripheral venipunctures

Device maintenance and cleaning: The dispenser maintenance protocol was structured in two phases. The first phase corresponds to routine cleaning, scheduled once a day or whenever visible residue is observed. The procedure consists of cleaning the external surface with a cloth dampened with disinfectant solution, followed by drying with a clean cloth to prevent moisture buildup or staining. The second phase of the maintenance protocol was scheduled weekly and consisted of: *i)* Removal of gloves from the dispenser. Gloves should be removed before cleaning to avoid the risk of cross-contamination; *ii)* Cleaning and disinfection. The external surface should be cleaned with a cloth moistened with disinfectant solution. Subsequently, the interior of the compartment is sanitized, ensuring that no liquid residues remain. The process is completed by drying with a clean, dry cloth to prevent moisture buildup or staining; *iii)* Verification and loading of supplies. The dispenser is checked to ensure it is clean and dry before placing the clean gloves back inside. This task was assigned to the responsible cleaning staff, who received the necessary instructions for its proper execution.

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Findings derived from the pilot implementation: The device was implemented in an ICU setting to assess its use under real-world conditions. Healthcare personnel from different professional groups participated, including nursing assistants (48%), nurses (36%), and physiotherapists (10%).



Figure 3. Final high-fidelity prototype of the glove dispenser. The device, constructed from 4-mm-thick acrylic, has dimensions of 11 × 20 × 6 cm, with a total height of 25 cm. Its key components are visible, including the front opening, a hinged access door, and the visual element designed to guide the user.

During the observed procedures, exposure to body fluids was recorded in 60% of cases, while glove use was indicated in 72% of cases. Most participants (88%) used a single pair of gloves per procedure, and hand hygiene after glove removal was observed in 88% of participants. According to the predefined glove consumption classification criteria, 44% of participants had medium consumption, 26% had high consumption, and 30% had low consumption (**Table 2**).

Table 2. Characteristics of healthcare personnel and observed glove use practices in the ICU

Variable	Category	n (%)
Professional category	Nursing assistant	24 (48.0)
	Nurse	18 (36.0)
	Physiotherapist	5 (10.0)
	Specialist physician	2 (4.0)
	Hospital physician	1 (2.0)
Glove consumption	High / Medium / Low	13 (26.0) / 22 (44.0) / 15 (30.0)
Glove use indicated	Yes / No	36 (72.0) / 14 (28.0)
Exposure type	Body fluids	30 (60.0)
	Blood	8 (16.0)
	Secretions	5 (10.0)
	No direct exposure	7 (14.0)
More than one pair of gloves	Yes / No	6 (12.0) / 44 (88.0)
Hand hygiene after glove removal	Yes / No	44 (88.0) / 6 (12.0)

Data are presented as n (%). *These results describe glove-use practices during the pilot phase and should not be interpreted as effects attributable to the device.

DISCUSSION

This study describes the design and implementation of a glove dispenser aimed at promoting appropriate glove use and supporting hand hygiene practices in an ICU setting. The device was designed in response to observed clinical needs, incorporating functional and behavioral elements to guide healthcare personnel in decision-making regarding glove use. Few studies specifically address the rational use and proper dispensing of gloves in hospital settings, and existing physical and behavioral barriers continue to contribute to their indiscriminate use. Guidelines from the WHO and the Centers for Disease Control and Prevention (CDC) emphasize that appropriate glove use and hand hygiene

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are essential components of infection prevention; therefore, devices that facilitate adherence to these practices may serve as a complementary strategy within infection control programs [2,10-11].

The development process adopted in this study aligns with user-centered design approaches, which are increasingly recommended for healthcare innovation and medical device development. These approaches emphasize iterative prototyping, stakeholder engagement, usability evaluation, and contextual adaptation to enhance acceptability and implementation potential. The current prototype was developed by incorporating direct clinical observations and staff feedback throughout the design process, consistent with established principles of user-centered medical device design [12-14]. However, evidence shows that conventional glove boxes and dispensers can easily become contaminated through daily exposure to environmental microorganisms. This problem, coupled with the emergence of antibiotic-resistant bacteria, exacerbates the threat to both patients and healthcare workers. Therefore, an appropriately designed glove dispenser could potentially reduce the contamination of disposable gloves [15].

Previous studies have shown that the design of glove dispensing systems is associated with differences in microbiological contamination. Assadian et al. compared the level of surface contamination around the opening of a newly designed vertical glove dispensing system with that of conventional glove dispensing boxes, finding lower counts of viable microorganisms in the vertical model [2]. Similarly, López-Figueras et al. demonstrated that 71.7% of gloves extracted from conventional horizontal boxes showed microbiological contamination, a figure that was drastically reduced to 30.4% in the alternative vertical dispensing model [11]. These findings highlight the relevance of considering device design as a factor that may influence handling and exposure of unused gloves.

In addition, incorporating visual or functional elements into the dispenser can serve as a reminder of appropriate glove use and the importance of hand hygiene before donning and after removing gloves [9]. In this study, the integration of messages based on WHO recommendations and the linkage with hand hygiene through the A–B process were intended to support this behavioral component. This integration is crucial, as gloves do not provide an absolute barrier against contamination, making immediate hand disinfection after removal essential [16-17]. Unlike the systems described previously—whose primary objective is to reduce glove contamination or improve the glove dispensing process—our device integrates hand hygiene guidance (Step A) with decision support for appropriate glove use (Step B). By addressing both the operational and behavioral factors influencing glove use, this combined intervention seeks to standardize practices in clinical settings.

This study acknowledges certain limitations that must be considered. First, the study was conducted in a single ICU, which may limit the generalizability of the findings. Second, no microbiological assessments, controlled comparisons,

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or cost–benefit analyses were performed. Third, the descriptive design does not allow causal relationships to be established between the implementation of the device and observed practices.

Nevertheless, a key strength of this study is the structured description of the design and implementation process of an adaptable device developed in response to a real clinical need, which may serve as a reference for future technological innovations in similar settings. Future research should include controlled and multicenter studies incorporating microbiological validation, evaluation of clinical outcomes, and analysis of resource utilization to determine the potential impact of this type of intervention.

CONCLUSIONS

This glove dispenser represents a technological innovation designed to promote appropriate glove use and reinforce hand hygiene practices in hospital settings. During pilot implementation, the prototype was deployed under routine ICU conditions, allowing an assessment of its usability and functionality based on feedback from healthcare workers. The device may support behavioral changes and resource awareness; however, its impact on infection prevention, patient safety, and resource optimization requires further evaluation through controlled and microbiological studies. This prototype could serve as a basis for future intervention studies assessing its effects on glove consumption, hand hygiene compliance, contamination, and healthcare-associated infection prevention.

ETHICAL CONSIDERATIONS

The study protocol (Protocol No. 2023.024) was approved by the Ethics Committee of Fundación Valle del Lili and was conducted in accordance with the ethical guidelines of the Declaration of Helsinki (2013).

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DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest during the course of this study.

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AUTHORS CONTRIBUTIONS

Lemos Martínez DA: Conceptualization, Validation, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project Administration. **Ortiz Rojas HJ:** Writing – Original Draft, Writing Review & Editing, Investigation, Visualization, Supervision, Project Administration. **Pabón Lozano S:** Writing Original Draft, Writing – Review & Editing. **Prada S:** Writing – Original Draft, Writing – Review & Editing. **Castro Gómez C:** Writing – Original Draft, Writing – Review & Editing, Investigation, Visualization, Supervision, Project Administration.

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