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Review Article

Review on Prevalence, Risk Factors, and Research Advancements on the Use of Medical Gloves Concerning Hand Dermatitis Among Health Care Workers

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ABSTRACT

The COVID-19 pandemic has led to a significant surge in glove usage, as recommended by the World Health Organization. Despite efforts to ensure the quality and safety of gloves, glove-associated skin diseases such as hand dermatitis have become ubiquitous, particularly among health care workers. This review discusses the prevalence, causes, and risk factors of hand dermatitis, as well as research efforts in medical gloves in the past decade to overcome glove-related hand dermatitis. Research papers from 2013 to 2022 were reviewed, selecting only 49 relevant papers from the Ovid, PubMed, and Scopus databases. The average prevalence of hand dermatitis among health care workers increased from 21.08% to 37.24% upon the impact of the COVID-19 pandemic. The cases are likely due to allergies to latex proteins, rubber additives, and accelerators commonly found in gloves. Using alternatives to latex gloves, such as accelerator-free and latex-free glove options, can help reduce allergy-induced hand dermatitis. Strict hand hygiene practices, such as frequent hand washing and the use of sanitizers, are also contributing factors in contracting hand dermatitis. Over the past decade, glove research advancements have focused mainly on reducing or immobilizing latex proteins. These include the use of biodegradable dialdehyde, sodium alginate, arctigenin, bromelain, papain, UV-LED, prototype photoreactors, and structure-modified nanosilica with silane A174. Two effective hand dermatitis preventive measures, i.e. an additional layer of glove liners and the use of gentle alcohol-based hand sanitizer, were recommended. These advancements represent promising steps towards mitigating hand dermatitis risks associated with glove usage.

1. Introduction

The estimated expansion of the global protective glove industry will increase from $24.20 billion in 2022 to $33.26 billion by 2029, demonstrating a compound annual growth rate of 4.6% during the forecast period from 2022 to 2029 [1]. According to analysis from fortune business insights, the global market demonstrated a substantial growth of 16.85% in 2020 compared to that in 2019 [1]. With the emergence of the coronavirus disease 2019 (COVID-19) pandemic, gloves have become essential to almost everyone, and they are used by not only health care workers (HCWs) but also workers in the food and beverage, cleaning, manufacturing, and laboratory sectors.

Since 1900, numerous studies [2–5] have demonstrated that glove usage causes adverse skin reactions that affect glove wearers, regardless of their geographical location, culture, or race. Reported adverse skin reactions include irritant contact dermatitis, allergic contact dermatitis, and contact urticaria [6]. Hand dermatitis (HD) is a systemic inflammatory skin condition mainly characterized by dry, itchy, and red skin affecting the entire hand, including the fingers [7].

Our study focused on medical glove wearing by HCWs. Medical gloves are disposable gloves used by health care professionals to

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maintain aseptic conditions, prevent cross-contamination, and protect both wearers and patients from potential infection or exposure to harmful substances. Medical gloves are typically made from latex, nitrile, or vinyl materials.

HCWs are required to wear medical gloves for a long period of time for self-protection when handling patients with COVID-19. This has led to an increase in glove-related HD reported among HCWs [8]; hence, this issue needs to be reviewed. With the increasing number of marketed latex glove alternatives, reviewing current medical gloves and their research advancements is vital to overcoming glove-related HD. However, most of the currently available reviews only delve into latex allergy and risk factors and do not further review the alternatives available or recent ongoing research advancements in tackling these issues. Therefore, we observed a research gap that needs to be filled with the following research question: have medical glove alternatives and recent research advancements actively and practically managed glove-related HD among medical glove users over the past 10 years.

Various research papers have been published over the past decade addressing glove-related HD issues. Therefore, this research mainly aimed to review the prevalence, risk factors, current medical gloves, and research advancements to overcome glove-related HD over the past decade (2013–2022). Particular attention will also be paid to the coronavirus disease 2019 (COVID-19) pandemic period, when HCWs were required to wear gloves while at work. This study had three specific objectives. The first objective was to determine the prevalence, causes, and risk factors for glove-related HD. The second specific objective was to understand glove alternatives produced to overcome skin dermatitis caused by latex gloves. Finally, the third specific objective was to summarize current research advancements in glove innovation to tackle glove-related skin problems.

2. Material and methods

Three electronic databases, Ovid, PubMed, and Scopus, were accessed to study relevant recent articles and research papers published in the past 10 years, ranging from 2013 to 2022, on medical gloves and HD. A combination of search terms such as “medical gloves” and “hand dermatitis” in titles and abstracts were used in searching fields within the restriction limit of original articles, editorials, letters, or reports published between 2013 and 2022. Medical subject heading terms or synonym words, together with Boolean operators, were utilized for all database searches. The reference lists of the relevant articles were examined to screen for inclusion and exclusion criteria in the current review.

Studies were considered if they met the following inclusion criteria: (i) written and published in English; (ii) related to medical gloves; (iii) directly or indirectly related to HD; (iv) published within the past 10 years from 2013 to 2022; and (v) with clear methodology and results reported without confusing terms. Owing to the abundance of papers on this topic, the additional inclusion criteria of (vi) only original articles or manuscripts were included. Studies that did not meet the inclusion criteria were excluded. The other exclusion criteria included (viii) duplicate articles, (ix) studies related to animal studies, and (x) retracted papers.

The papers for study inclusion were sorted into their respective related subtopics for discussion, based on the information available in each original article or manuscript. Data were extracted from eligible papers into a spreadsheet according to the basic research details of the author, year, title, DOI, and findings of the paper.

3. Results

From the Ovid, PubMed, and Scopus databases, 170, 179, and 173 relevant papers were extracted, respectively. In total, 522 studies were identified through the database searches. Subsequently, 160 duplicate samples were identified and excluded. Data duplications were identified by comparing the titles and abstracts of each article. After duplication, the remaining records included 362 papers, and all 362 papers underwent both title and abstract screening.

The titles and abstracts of 362 studies were screened before full-text screening of potentially eligible articles. A total of 191 papers were excluded during title and abstract screening, and 171 full-text articles were screened. According to the stated eligibility criteria, 122 papers were excluded for the following reasons: 60 nonoriginal articles, 1 retracted paper, 1 duplicate publication, 10 nonEnglish articles, 10 insufficient details, 8 limited relevance, and 32 out of scope. Finally, 49 studies were included in the review. Fig. 1 summarizes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for the article selection process. The 49 papers included in this review were sorted into their respective subtopics based on information gathered from the articles or manuscripts. There were five subtopics, and a table was prepared for each subtopic.

3.1. Prevalence of glove-related hand dermatitis among health-care workers

Primarily, the focus of this review lies in examining the incidence of HD related to glove usage. The exploration of disease prevalence is crucial for adept public health administration, research initiatives, and the formulation of strategies aimed at preventing, managing, and treating illnesses within a given population. From our search, we found that there were ten studies conducted on health-care workers in nine countries. These studies investigated the prevalence of glove-related HD among HCWs and described many professions, from nurses to dentists, including different specialties (e.g. surgery, intensive care, and radiology), to illustrate the diversity of potential exposures in the health care sector.

Through our research, we observed that several Asian countries, including Malaysia, Thailand, China, and Brunei, participated in their respective studies to identify the prevalence of HD among HCWs. A total of three studies [9,10] were conducted in Thailand surveying the prevalence of HD and reported an average prevalence of HD of 16.77%. The prevalence of HD was 6.75% in China [11] and 25.20% in Malaysia [12]. On average, the prevalence of HD in the Asian countries was 13.36%, and Malaysia had the highest glove-related HD percentage among the other countries.

European countries, including Bulgaria [13], Croatia [14], Italy [15], and Portugal [16], recorded HD prevalence percentages of 31.60%, 56.10%, 12.30%, and 3.56%, respectively. The average prevalence of glove-related HD in all these western countries is 25.89%, which is higher than that in Asian countries by 12.53%. This may be attributed to the research in Croatia [14] being an outlier with 56.10% of HD, causing a spike in HD prevalence when the average was calculated. A study conducted in Portugal [16] has reported the lowest number of HD (3.56%), which might be attributed to previously implemented preventive measures. Although we also searched data from the African region, only one paper [18] from South Africa was identified with a record of 25.00% of HD prevalence.

Apart from a country-based analysis, a study [9] in Thailand examined the prevalence of HD among HCWs in nonclinical and clinical departments and reported a significant difference between the two groups. The glove-related HD percentage was 11.0% among the HCWs in the nonclinical department and 24% among those in the clinical department.

Three studies were identified, which focused on the prevalence of HD among HCWs in the dentistry departments [14–16], where

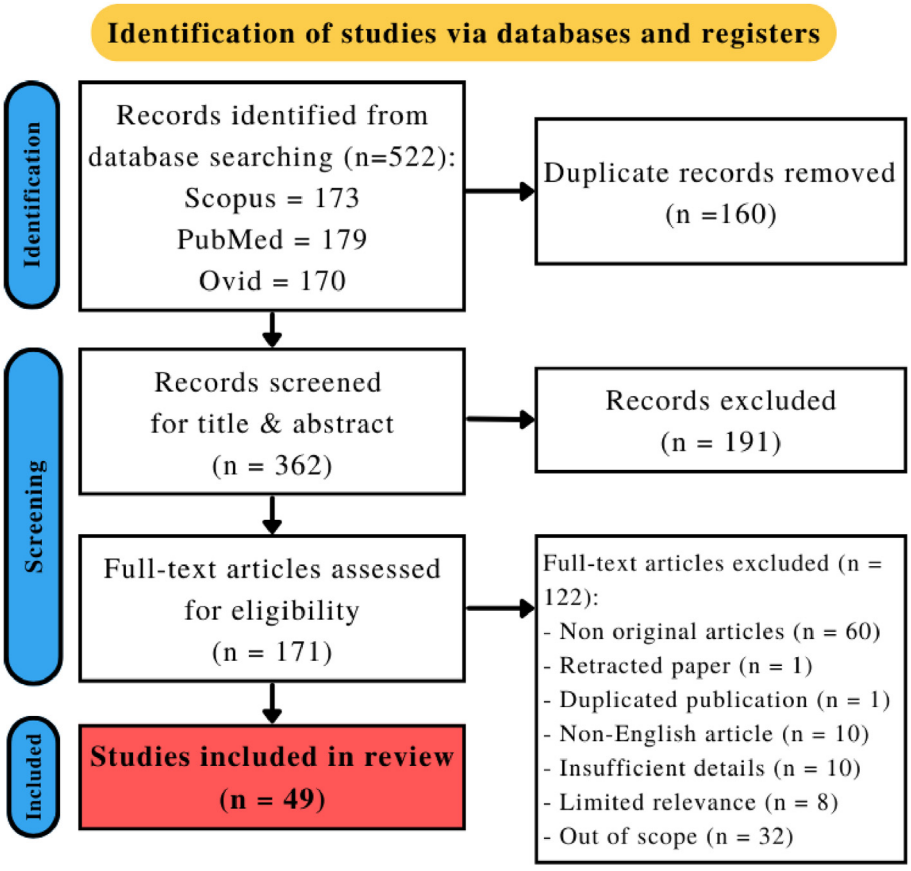

Fig. 1. PRISMA flowchart for database search and study selection. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

the average prevalence of HD was 37.63%. A study conducted in Kelantan [12], a state in northern Malaysia, has revealed that 94.7% of the dental professionals and dentistry students used powdered latex glove, among whom the students were highly affected individuals with HD.

In 2014, a study [17] conducted on 4529 HCWs generally indicated that 13.3% of them were affected by HD, and nurses were among the highly affected professionals, amounting to 83.0% of the population. In fact, the two surveys [10,11] selected nurses as the target population. However, these studies focused solely on female nurses because there are more females than males in the profession. A World Health Organization report [18] on gender equity in health care occupations published in 2019 revealed that 67% of HCWs were females, and most female workers dominated the nursing workforce. The studies [11,17] recorded an average prevalence of HD of 12.38% among nurses. The tabulated results are presented in Table 1. The next section discusses the prevalence of glove-related HD, particularly during the COVID-19 pandemic.

3.2. Prevalence of glove-related hand dermatitis during the COVID-19 pandemic

The COVID-19 pandemic has recently been among the main topics of research conducted by clinical scholars. Among others, topics of research involve the effects of catastrophic disease on the health care sector, that is, the shortage of HCWs in combating the widely spread COVID-19 and how COVID-19 has challenged HCWs mentally and physically. Regarding our research, we discovered nine published papers on glove-related HD during the pandemic that affected HCWs. These studies were conducted by scholars from various regions, including Germany [19], Singapore [20], Italy [21], Saudi Arabia [22], China [23], Turkey [24,25], India [26], and Denmark [27]. The similarities in their research are that all cross-sectional studies were conducted using surveys. While the remaining studies focused their research mainly on health care professionals, scholars from Saudi Arabia surveyed the prevalence of HD among the general population in the country.

China [23], having the least number of study participants (n = 61), has been reported to have the highest prevalence of HD among HCWs, with China indicated as among the most affected countries among their population at 88.50%. Meanwhile, Denmark [27], with the highest number of study participants (n = 2125), had only a 14.7% 1-year prevalence of hand eczema. The significant difference could be attributed to the lower number of outliers data in studies conducted in China and the use of only latex gloves among health care professionals.

In addition, most study [22,24,25] participants exhibited common symptoms of HD, such as dry and itchy skin and rashes. A study [22] conducted on the general population of Saudi Arabia with a total of 582 respondents comprising 52.6% women and 47.4% men has revealed that in a 6-month period, the prevalence of HD among them was 34.0%. The prevalence of HD increased tremendously during the pandemic, not only among health care professionals, but also among the general population. This makes glove-related HD a concern that should be emphasized more and considered by all parties. In addition to the medical personnel, the public should be monitored and treated continuously. The tabulated data comparing the prevalence of HD among HCWs is presented in Table 2. Based on the various studies cited, the pandemic has apparently increased the prevalence of glove-related HD among HD users. Based on Table 1, the average prevalence of HD among HCWs before the COVID-19 pandemic was only 21.08%. With the emergence of

Table 1
The prevalence of hand dermatitis among health care workers

No.	HD prevalence (%)	Occupation (affected by HD)	Number of study subjects	Gender	Types of gloves used	Country	References
1.	25.20	Dental officers-16.0%, Dental nurses-15.4%, Dental surgery Assistants- 22.7%, Dental students-34.7%, Dental clinic helpers-11.2%	357	Male – 25.5% Female – 74.5%	Powdered-94.7%, Non-powdered- 3.1%, Both- 2.2%	Malaysia	[11]
2.	18.00	Nurses	899	Female	Latex glove	Thailand	[10]
3.	6.75	Nurses	8485	Female	Latex glove	China	[11]
4.	12.30	Nurses	2053	Male – 24.5% Female – 75.5%	Nonpowdered latex gloves	Italy	[15]
5.	25.00	Intensive care unit-81.8%, Labor ward + antenatal clinic -68.2%, Obstetrics and gynecology-46.0%, Casualty -87.5%, Outpatient department-50.0%, Postnatal ward -45.5% Neonatal unit (including NICU) -19.6%, Central sterilization and supply department-57.1%, Operating theatre-8.6%, Radiology-100.0%, High care -33.3%, Thuthuzela-25.0%	158	Female – 98.1% Male – 1.9%	Latex gloves	South Africa	[19]
6.	13.30	Physician/dentist-5.2%, Registered nurse/ practical nurse- 83% Technician/scientist-6.9% Physiotherapist -1.4%, Hospital housekeepers - 3.4%	4529	Male – 10.4% Female – 89.6%	Powdered gloves- 55.7%, Powder-free gloves-13.8% Both types- 30.4%	Thailand	[17]
7.	56.10	Students second year - 6.1%, Students fourth year-40.6%, Students sixth year-58.5%, Dental professionals-64.8%	444		Latex glove	Croatia	[14]
8.	19.00	Clinical-24.0%, Nonclinical-11.0%	400	Male – 23% Female -77%	Latex glove	Brunei	[9]
9.	3.56	Administration- 0.49%, Nursing assistants-5.11%, Nurses -4.81% Physicians -3.36%, Diagnosis and therapeutics technicians -0.70%, Other technicians -1.77%, Surgery -8.47%, Clinical -3.70%, Support services -0.74%	1741	Male - 23.15% Female -76.85%		Portugal	[16]
10.	31.60	Dentists	1477	Male- 37.10%, Female-62.90%	Latex gloves-33.1%, Nitrile rubber gloves-73.9%, Polyvinyl chloride gloves-7.1%, Neoprene gloves-0.2%	Bulgaria	[13]

HD, hand dermatitis.

Table 2
The prevalence of hand dermatitis during COVID-19

No.	Population	Number of study subjects	Prevalence of hand dermatitis	HD symptoms	Country	References
1.	Veterinarians	122	50.0% (1-year prevalence)	NA	Germany	[19]
2.	General population	582	34.0% (6 month prevalence)	Dryness -54.8% Erythema- 22.2% Itching -30.2% Fissures- 12.9%	Saudi Arab	[22]
3.	Doctors, nurses, and allied HCWs –direct physical interaction with COVID-19 patients	416	11.73%	Itch/Rash -72.2% Xerosis - 75.0% Urticaria - 13.9%	Singapore	[20]
4.	Clinical, nonclinical postgraduates, nurses, and laboratory technicians who used PPE	415	29.60%	NA	India	[26]
5.	Nurse	175	42.90%	Cracked skin -78.3% Itching -76.0% Dry skin - 60.0%	Turkey	[24]
6.	Nurses, physicians, clinical technicians, cleaners, and caregivers.	601	45.9% (1-Year prevalence)	Redness - 68.2% Dry skin with Scaling/flaking -71.8% Itching- 62.0% Fissures/cracks - 57.1%	Turkey	[25]
7.	HCWs	2125	14.7% (1-year prevalence)	NA	Denmark	[27]
8.	Clinicians	230	18.00%	NA	Italy	[21]
9.	Doctors and Nurses	61	88.50%	Dry skin - 55.7% Itching -31.2% Rash - 23.0%	China	[23]

HD, hand dermatitis; HCWs, health care workers; PPE, Personal Protective Equipement.

COVID-19, the average prevalence of HD has increased to 37.24%. This is highly related to the use of personal protective equipment and intense hand hygiene measures for self-protection during the rapid spread of the highly contagious virus worldwide.

4. Discussion

4.1. Causes and risk factors of hand dermatitis

In the ever-evolving realms of medical research and public health, unraveling the origins and contributors of HD stands as a crucial endeavor. This pursuit is fundamental in crafting effective strategies aimed at preventing, diagnosing, and treating HD. In pursuit of our primary objective, we delved into an exploration of the causes and risk factors associated with HD, revealing insights gleaned from seven pertinent papers on causative factors and findings from eleven studies that shed light on relevant risk factors. The main cause of allergic or irritant contact in HD is rubber accelerators, which are used in the glove manufacturing process to accelerate rubber vulcanization. From the six studies [28–33] on nonpatients and the seventh study [34] conducted among patients with glove-related HD, the chemicals that often cause contact dermatitis include thiurams, carbamates, carba mix, mercaptobenzothiazole, mercapto mix, thioureas, 1,3-diphenylguanidine, and isopropyl phenyl paraphenylamine diamine mix.

Thiurams, including tetramethylthiuram monosulfide, tetramethylthiuram disulfide, dipentamethylenethiuram disulfide, and tetraethylthiuram disulfide, have been identified as primary rubber accelerators that induce allergic contact HD among HCWs [35]. Thiuram is commonly found on latex and polyisoprene gloves. Among seven papers referring to identifying the causes of HD, six papers [28,30–33] have identified thiurams to cause allergic or irritant contact with HD in >50% of the participants. Carbamate is also a common accelerator used in almost all types of gloves, including latex, nitrile, polychloroprene, and polyisoprene gloves [36]. Carbamates can be classified into four main types: zinc dibutyldithiocarbamate, zinc diethyldithiocarbamate, zinc dimethyldithiocarbamate, and zinc dibenzyldithiocarbamate. In comparison between the three carba chemicals, zinc diethyl dithiocarbamate was identified to heavily cause allergy, with a positive patch test in 3.5% and 12.5% of individuals. Furthermore, a study conducted in Sweden [34] has indicated that 12 out of 16 tested patients (75%) were allergic to 1,3-diphenylguanidine, i.e. diphenylguanidine was detected in Carba mix accelerators, which are mostly used in polyisoprene and polychloroprene gloves [36]. Mercaptobenzothiazole is an accelerant used in the production of latex, nitrile, and polyisoprene gloves [36], which has been identified to cause adverse skin reactions in certain users. The tabulated results are presented in Table 3. Our findings are similar to the results of two other reviews published in 2016 [36] and 2021 [37], which identified thiuram as the largest cause of glove-related HD. Considering that thiurams and several other chemicals such as carbamates, mercapto mix, and 1-3-diphenylguanidine are the main causes of glove-related HD, minimizing the use of these chemicals is important to reduce the occurrence of HD among its users.

Apart from allergens detected in gloves, intensive hand hygiene measures, such as frequent hand washing with soap or hand wash liquids, and the use of sanitizers and disinfectants during the COVID-19 pandemic were also identified as among the other risk factors for HD [38]. Among the four research articles [19,22,26,27], frequent hand washing was reported to cause a significant increase in the odds of developing HD. The use of alcohol-based hand sanitizers and disinfectants has been reported to cause skin dryness, leading to skin irritation or HD [39–42]. A commonly advised hygiene method, hand washing and the use of hand sanitizers and

Table 3
Allergen causing hand dermatitis

Compound	Geier et al. [28]	Pontén et al. [32]	Warshaw et al. [29]	Buttazzo et a [30]	Ibler et al. [31]	Hamnerius et al. [32]	Japundžić et al. [33]
Thiurams	13.50%	50.00%	NA	1.75%	5.00%	1.90%	1.90%
Zinc Dibutyldithiocarbamate (ZDBC)	0.18%	NA	NA	NA	NA	NA	NA
Zinc Dibenzyldithiocarbamate (ZBDC)	0.20%	NA	NA	NA	NA	NA	NA
Zinc Dimethyldithiocarbamate (ZIRAM)	NA	NA	NA	NA	NA	0.30%	NA
Zinc Diethyl Dithiocarbamate (ZDEC)	3.51%	12.50%	NA	NA	NA	NA	NA
Carba mix (DPG, ZDEC, ZDBC)	NA	NA	NA	3.40%	3.00%	NA	1.90%
Mercaptobenzothiazole (MBT)	2.86%	NA	1.38%	0.65%	NA	NA	NA
Mercapto mix (Cyclohexylbenzothiazyl-Sulfenamide + Dibenzothiazyl Disulfide + Morpholinylmercaptobenzothiazole)	1.92%	NA	1.08%	NA	NA	NA	1.00%
Thioureas	0.57%	NA	NA	NA	NA	NA	NA
1,3-Diphenylguanidine (1,3-DPG)	2.78%	75.00%	NA	NA	NA	2.30%	NA
Isopropyl Phenyl Paraphenylamine Diamine (Ippd) mix ((IsopropylPhenyl Paraphenylenediamine + CyclohexylPhenyl Paraphenylenediamine + Diphenylparaphenylenediamine)	NA	NA	NA	0.83%	NA	NA	NA

disinfectants could, in extreme situations, cause increased skin permeability, stripping the skin of natural oils and moisture, resulting in roughness and irritation [43]. Dry and compromised skin creates an environment conducive to various diseases, potentially elevating vulnerability to bacterial infections and viral penetration into the skin [43]. Traditional alkaline soaps have also been demonstrated to be harsher on hands than common glycerin soaps and syndets. Additionally, a few studies [19–21,23] have identified that prolonged glove wearing in a day is also associated with the onset of HD symptoms.

4.2. Marketed gloves and hand dermatitis

Latex and nitrile are the most commonly used medical gloves for HCWs. Latex gloves are made from latex gloves, which provide excellent flexibility, comfort, and tactile sensitivity. The latex material conforms well to the shape of the hand and offers a snug fit. Nitrile gloves are made of a synthetic rubber material, which has several advantages over latex gloves. They do not contain latex gloves, which reduces the risk of allergic reactions. Nitrile gloves are considered latex-free and suitable for individuals who are sensitive to latex or have latex allergies.

In our study, we identified two papers reporting HD affecting latex glove wearers more than nitrile glove wearers, with the data from the first study [39] indicating 73% of HD in latex glove wearers and only 48.7% in users of either powder-free or nitrile gloves. In the second study [40], 27.42% of HCWs were affected by latex gloves, and only 17.65% of them were affected by nitrile gloves. This is attributed to contact urticaria, which remains a major concern in latex glove wearing. Nitrile gloves are suitable alternatives for individuals with a latex allergy. However, nitrile gloves were also unable to fully prevent glove-caused dermatitis owing to the rubber additives and accelerators used in nitrile gloves. A Swedish study has demonstrated that nitrile gloves can contribute to contact dermatitis because of their rubber additives. The study results [32] revealed that 5.67% of contact allergies to rubber additives were related to exposure to nitrile gloves.

Apart from latex and nitrile gloves, the market also includes other types of medical gloves, such as nonpowdered and accelerator-free gloves. Nonpowdered gloves, also known as powder-free gloves, are medical gloves that do not have a powder coating on their inner surfaces. Using nonpowdered gloves is aimed at minimizing the risk of allergic reactions due to the powder coating. Accelerator-free gloves are manufactured without the use of accelerators, making them suitable for individuals with sensitivity to or allergies to these chemicals.

Users of accelerator-free gloves have been reported to exhibit a minimal trend of allergic contact dermatitis, based on two studies conducted in 2018 and 2019. A previous study [42] demonstrated that more than two-thirds of patients were completely free of HD symptoms when using accelerator-free gloves, whereas another study [43] reported negative patch test results for accelerator-free gloves in patients with a history of hand-contact eczema related to rubber glove use.

Regarding latex powder-free gloves, glove-related symptoms decreased by 10% from 2004 to 2009 when nonpowdered latex gloves with low protein release were made compulsory for workers with latex allergy or latex sensitization [44]. A study [15] has also demonstrated that the prevalence of HD caused by the use of nitrile gloves was higher than that cause by the use of latex gloves; hence, it was hypothesized that the contradictory results of past research occurred because of recently marketed low-protein powder-free latex gloves that could help reduce hypersensitivity reactions to normal latex gloves.

Conversely, scholars [34] have also conducted a study specifically investigating the cause of glove allergy among patients with glove-related HD, which displayed a high percentage of the patients being sensitive to 1,3-diphenylguanidine at 75%, whereas 87.5% of the patients were sensitive to cetylpyridinium chloride. One of the crucial findings highlighted in this study [34] was that the change from latex to latex-free gloves did not diminish the risk of sensitization toward synthetic rubber gloves and powder-free glove additives, as HCWs were still affected by the 1,3-diphenylguanidine rubber vulcanizing agent in synthetic rubber gloves and cetylpyridinium chloride, a lubricant commonly used in powder-free gloves. Marketed gloves and their effects on HD are summarized in Table 4.

Regarding our second specific objective of understanding alternatives to latex gloves, which cause skin dermatitis, the use of nitrile gloves, nonpowdered gloves, and accelerator-free gloves can reduce the occurrence of HD among users. The reported disadvantages of these glove alternatives can also be an evaluation point for glove manufacturers to produce better and safer glove products, which is one of the additional points focused on in this review. Although these alternatives minimize the occurrence of HD, no previous studies have provided promising data for the complete elimination of the risk of glove-related HD. Hence, we further illustrate glove research advancements and briefly discuss effective

Table 4
Marketed gloves and hand dermatitis

No.	Types of gloves	Effect on HD	Major findings	Country	Reference
1.	Latex, powder free, nitrile gloves	Glove powder - 73% of users Powder free, or nitrile gloves - 48.7% of users	Powder-free gloves reduce hand dermatitis	Greece	[42]
2.	Latex & nitrile gloves	Latex gloves - 27.42% of HCW Nitrile gloves - 17.65% of HCW	Latex gloves cause high HD compare to nitrile gloves	Portugal	[16]
3.	Nitrile gloves	Nitrile gloves - 5.67% of contact allergy to rubber additives	Nitrile rubber gloves also can cause hand dermatitis	Sweeden	[32]
4.	Accelerator free gloves	Accelerator free glove - >2/3 of patients free of HD symptoms	Switching from conventional medical gloves to accelerator-free medical gloves reduce HD	French	[44]
5.	Accelerator free gloves	Positive to DPG - 1/2 of tested subjects Accelerator-free gloves – 0%	Accelerator-free gloves reduce the occurrence of HD	Belgium	[43]
6.	Non powdered latex gloves	From >5% latex sensitization before 2000 reduced to no sensitization in 2007 & 2008	Decreased sensitizations and symptoms when using nonpowdered latex gloves	Italy	[15]
7.	Powder free latex and nitrile gloves	Skin symptoms related to gloves Latex - 5.1%, Nitrile - 23.6%	Low protein powder-free latex gloves show high reduction of immediate-type hypersensitivity reactions	Bulgaria	[13]
8.	Powder free latex and synthetic rubber gloves	DPG - 75% of the patients were sensitive Cetylpyridinium chloride - 87.5% of the patients were sensitive	Change from latex to latex-free gloves does not diminish the risk of HD	Sweeden	[34]

HD, hand dermatitis; HCW, health care worker.

preventive measures to overcome HD in the next subtopic with the hope of introducing useful approaches for glove advancement.

4.3. Glove research advances and preventive measures in overcoming hand dermatitis

Over the past decade, we identified seven research papers that depicted various advancements in overcoming HD through different strategies. In 2013, researchers [45] suggested the use of biodegradable dialdehyde sodium alginate to immobilize proteins on latex gloves. This is because proteins are distributed more uniformly in latex glove films with biodegradable dialdehyde sodium alginate, thereby effectively decreasing the extractable protein content. The reduction in the number of proteins would indicate a lower allergy prevalence for latex gloves.

In addition, in 2016 and 2017, more naturally based compounds were suggested for the formulation of gloves. A study [46] conducted in 2016 has demonstrated the addition of arctigenin, a plant lignan, to latex gloves to prevent latex allergy by inhibiting type I/IV allergic reactions with the most suitable dose of 6 g/100 g. Another study [47] utilized natural proteases such as bromelain, an enzyme found in pineapple fruits and stems, papain, and proteolytic enzymes in the latex of tropical papaya plants to reduce the extractable protein content in finished dipped latex glove products. Bromelain and papain have been reported to reduce 11% and 8% of extractable protein, respectively [48].

A study [49] in 2018 illustrated another perspective of research advancement that involved the use of UV-LED photoreactor prototypes for the vulcanization of irradiated latex gloves to produce irradiated latex gloves that are carcinogen-free and contain protein allergens. In 2019, Wattanachai suggested a [50] change in the release agent in powder-free surgery gloves from cornstarch to calcium carbonate, as previous research has revealed that cornstarch contains proteins and bacteria that cause allergies and dermatitis. An article [51] published in 2021 suggested the use of silane-modified silica nanoparticles to reinforce deproteinized latex glove film in order to produce latex gloves containing only a small amount of protein with good mechanical strength.

In 2013, another group of scholars [52] also suggested in an article the method of dual crosslinking of carboxylated nitrile butadiene rubber latex. The use of the thiol-ene photoreaction could avoid allergenic reactions related to residual accelerator levels in dipped XNBR latex articles, such as in medical gloves, and will still be able to provide good mechanical properties with lower allergenic potential. Tabulated results for glove research advancements to overcome HD are listed in Table 5.

In 2022, four studies were conducted on preventive measures against HD. Studies have proposed wearing semipermeable, cotton, or polyethylene glove liners underneath latex or nitrile gloves to overcome HD. A case study [53] was conducted on a 44-year-old woman who worked as a cleaner in a hospital and presented with longstanding HD. The study concluded that wearing cotton and polyethylene glove liners underneath a nitrile/neoprene rubber glove would prevent direct skin contact with the protective gloves worn above; thus, HD could be prevented. Another study was [54] conducted in Iran, where the staff of the surgery room were instructed to wear cotton polyester gloves under surgical latex gloves. This method improves the symptoms of dermatitis. In addition, Heichel et al. compared the acceptance and tolerability of semipermeable gloves with those of cotton gloves. In their study [55], 199 patients with work-related symmetrical hand dermatoses were instructed to wear a cotton glove on one hand and a Sympatex glove underneath the cotton glove, and the severity was scored according to the Osnabrueck Hand Eczema Severity Index. Both the cotton glove and the Sympatex glove underneath a cotton glove were well tolerated among patients and reduced the severity of HD from 6.1 to 2.8 and from 6.3 to 2.8, respectively.

Wearing a cotton glove underneath another latex, nitrile, or other glove prevents direct contact of the latex and glove accelerators with the skin, and the cotton also absorbs sweat under the latex gloves. This proves that cotton gloves are capable of preventing HD, as excessive sweat production is one of the main triggering factors of HD.

As discussed earlier, frequent handwashing has also been identified as a high-risk factor for HD. A recent study [56] was conducted on patients with irritant HD for a period of 2 months to identify and implement suitable workplace interventions to recover them from irritant HD. Of the four workplace interventions implemented, two focused on handwashing. The first group of patients' current alcohol-based hand rubs (ABHR) were substituted with a different, gentler ABHR, whereas the other group was allowed to use ABHR alternating with gentle ABHR products. The ABHR used in this study consisted of 100% ethanol, 1-propanol, emollient, moisturizer, and fragrance, whereas the proposed substitute ABHR consisted of 70% ethanol, emollients, and moisturizer. All patients exhibited an improvement rate of 70%–90% from their

Table 5
Glove research advancements to overcome hand dermatitis

No	Advancement	Purpose	Experimental	Effectiveness	References
1.	Biodegradable dialdehyde sodium alginate (DASA)	Immobilize proteins in latex gloves	Proteins were distributed more uniformly in the latex glove films with DASA.	Extractable protein content was lowered to a value of about 46 ug/g with 0.40% dasa (allergy protein threshold limit- 50 ug/g).	[44]
2.	Arctigenin (Plant lignan)	Prevent latex allergy by inhibiting type I/IV allergic reactions	A dose of 6 g/100 g of arctigenin was selected based on the results of arctigenin's in vivo antiallergic evaluation and its dissolubility in the final latex product.	Arctigenin showed anti-type I and IV allergic effects in vitro and in vivo, with good stability under latex glove manufacturing conditions.	[45]
3.	Natural proteases- bromelain & papain	Develop an economical method to reduce extractable protein in latex gloves.	Reduction percentage of the extractable protein from the dipped rubber products: Bromelain- (54 ± 11)%, Papain $-$ (58 ± 8) %.	Bromelain and papain -significantly reduce the total extractable protein in finished latex gloves.	[46]
4.	Ultraviolet light-emitting diodes (UV-LEDs) -Prototype photoreactor	For the vulcanization process, which produces latex gloves free from carcinogens and protein allergens.	Increase the capacity of irradiated latex gloves by enlarging the area of thin latex glove films to be irradiated with UA-A rays.	UV-LED photoreactor prototypes are more energy-efficient, long-lasting, and environmentally friendly than UA mercury irradiators	[48]
5.	Calcium carbonate	Alternative releasing agent to replace cornstarch (Allergan).	5% w/w calcium carbonate (formula 5% releasing agent calcium carbonate, 92.7% water, 1.8% lubricating agent, 0.4% antimicrobial agent, 0.1% other ingredient) produces the most similar result to 20% corn starch.	5% w/w calcium carbonate as an alternative to cornstarch could achieve gloves with comparable properties as well as a saving.	[49]
6.	Deproteinization + structure-modified nanosilica with silane A174	To produce latex gloves with less extractable protein and good mechanical strength compared to the standard.	The step of deproteinization was used to reduce the amount of protein from 0.42 wt% to 0.11 wt%, and structure-modified nanosilica with silane A174 was used as an additive to reinforce the deproteinized films.	The deproteinization method and corporation of 1 phr of modified sio2 produce gloves with less extractable protein and improved the mechanical properties.	[50]
7.	Dual crosslinking of carboxylated nitrile butadiene rubber latex employing the thiol-ene photoreaction	To avoid allergenic reactions related to residual accelerator levels in dipped nitrile gloves.	A dual curing process has been developed combining thermal and photochemical crosslinking reactions.	Two-step process makes the production of nitrile rubber latex gloves with good mechanical properties and a low allergenic potential.	[51]

baseline signs and symptoms, with a mean improvement of 80%. Thus, gentle ABHR has been demonstrated to reduce the severity of HD, although it cannot completely eliminate HD.

This review summarizes the research advancements over the past decade in ascertaining preventive measures to decrease the rate of gloves related to HD. These improvements can be utilized for further research and production and may be adopted into practice to reduce the prevalence of glove-related HD. Continuous research and assessment of safer glove advancements should also be conducted to reduce the number of gloves related to HD.

5. Conclusion

This research successfully reviewed the prevalence, causes, and risk factors of HD, as well as current research advancements in medical gloves to overcome glove-related HD. This review further discusses the prevalence of HD among various professions of HCWs, where statistics have also proven that COVID-19 highly affects the incidence of glove-related HD, i.e. the average prevalence of HD increased from 21.08% to 37.24% upon the impact of the COVID-19 pandemic. Apart from latex allergy, glove-related HD is mainly caused by rubber accelerators, including thiuram, carbamates, mercaptobenzothiazole, and 1-3-diphenylguanidine. This review also highlights that intense hand hygiene measures, such as frequent hand washing and the use of sanitizers, which we all considered effective in preventing viral infection, are contributing factors in contracting HD. Furthermore, these review findings also demonstrate that the use of nitrile, powder-free, and accelerator-free gloves helps in reducing glove-related HD, although it is not completely overcome. Research advancements include the use of biodegradable dialdehyde, sodium alginate [45], arctigenin [46], bromelain [48], papain, UV-LED prototype photoreactors, and deproteinization together with structure-modified nanosilica with silane A174 to reduce or immobilize extractable proteins from latex gloves, which overcomes latex allergy [49]. Research has also suggested replacing commonly used cornstarch with calcium carbonate in gloves to ensure the safety of users who are allergic to cornstarch [50]. Researchers have also developed a method of dual crosslinking of carboxylated nitrile butadiene rubber latex by employing a thiol-ene photoreaction to overcome the HD related to the use of accelerators in gloves [52]. This review also identifies two effective preventive measures for contracting HD: an additional layer of semipermeable cotton or polyethylene glove liners underneath latex or nitrile gloves and the use of gentle alcohol-based hand rubs as hand hygiene measures.

Clinically, severe HD is being treated pharmacologically using topical corticosteroids and calcineurin inhibitors. But the long-term use of these medications has produced side effects such as burning, stinging, or itching sensations. These adverse reactions developed because of the poor skin permeability of the drugs. Extensive research is being conducted on novel formulation methodologies, such as the use of nanoparticulate, micro-systems, and biopolymer hydrogel composites to improve skin bioavailability [57–63]. Another approach of glove innovation in minimizing the occurrence of HD associated with prolonged glove wearing is combining these novel formulation strategies with gloves in the effort to develop an efficacious delivery system for the treatment of HD.

The findings and data would serve as a useful reference source mainly for glove manufacturers to further develop glove advancement and glove users, as they would be aware of the differences in the various types of gloves available in the market they would be more cautious when deciding on glove wearing. Although the current glove alternatives on the market vary, we are still unable to ascertain their actual functionality and capability to prevent the occurrence of HD, as research on these gloves remains limited. The limitation of studies and research on the various types of glove alternatives on the market was also a limitation of this review, where most of the research published on these gloves only included latex and nitrile gloves. Hence, for future research, more studies should be conducted on newly manufactured gloves available on the market to establish HD data accordingly.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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