

Trend analysis in hand hygiene from the early COVID pandemic to the post-COVID periods at a Tunisian University Hospital

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Abstract

Introduction: The COVID-19 pandemic has further underscored the importance of Hand Hygiene (HH) adherence as an effective measure for infection prevention and control. This study aims to evaluate trends in HH practices from 2020 to 2023 and assess the impact of the COVID-19 pandemic at the University Hospital of Mahdia (Tunisia).

Methodology: From June 2020 to October 2023, annual direct observations of HH were performed among health care workers (HCWs) at Mahdia hospital based on the "HygMain Hygiene audit" validated by the Practice Assessment Group of Hospital Hygiene in France. Data were collected through structured observations by trained doctors and hygienists. Compliance and relevance rates were analyzed for each observation period.

Results: A total of 993 HH opportunities were observed across five periods from 2020 to 2023, involving 731 HCWs, predominantly paramedical staff (54.4%). Among them, 478 (65%) were female. The overall HH compliance was 22.1%, with a higher compliance rate after patient contact (28.4% vs 39%, $p = 0.08$). Overall, HH compliance increased significantly during the COVID-19 pandemic, peaking at 33.1% in 2022 before declining to 14.7% in 2023. Similarly, the overall HH relevance rates rose from 6.5% in 2020 to 30% in 2022, but fell to 19.4% in 2023. Compliance was higher in high-risk departments and during invasive procedures.

Conclusions: The study highlights the positive impact of the COVID-19 pandemic on HH, though the post-pandemic adherence rate has declined. Continuous monitoring and institutional support are essential to enhance and maintain compliance levels, ensuring long-term improvements in infection control practices.

Key words: hand hygiene; compliance; health personnel; COVID-19; patient safety; Tunisia.

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Introduction

Patient safety is a fundamental principle of healthcare and a legal right, aimed at preventing harm by reducing medical errors and adverse events [1]. As unsafe care poses a global public health challenge with significant financial costs, prioritizing patient safety helps mitigate risks and enhance healthcare environments [2]. Thus, building a strong safety culture among healthcare workers (HCWs) is mandatory to reduce preventable harm. Patient safety is critically threatened by healthcare-associated infections (HAIs), which lead to increased morbidity, mortality, and healthcare costs [3]. The burden of HAIs is a global issue, impacting hundreds of millions of patients across both developed and developing countries [4,5]. The

HAI rate is significantly higher in developing countries, affecting over 15.5% of hospitalized patients compared to 7.6% in developed countries [4,6]. Unfortunately, published data about HAIs in developing countries are scant [7]. In Tunisia, the overall HAI rate was 10.9% in 2017 [8–10].

According to the World Health Organization (WHO) [11], 70% of HAIs are preventable mainly through good hand hygiene (HH) since it interrupts the chain of infection transmission. In fact, non-adherence to HH by HCWs is a key pathway for the transmission of multi-resistant microorganisms among patients, staff, and the hospital environment [5]. HH Compliance (HHC) is universally recognized as the simplest, most effective and economic way to prevent HAIs [12–17]. A

multicenter study performed in the Mediterranean region in 2002 reported an overall compliance rate of 27.6% [18]. There is a notable lack of surveys published about HH in Tunisia. A study conducted in 2015 at the University Hospital Sahloul reported a HHC rate of 32.1% [19].

The COVID-19 pandemic has underscored the global necessity for enhanced HH adherence among HCWs [20]. Multiple recent studies have reported a significant increase in HHC during the pandemic [21,22]. However, subsequent studies have documented a decline in compliance during later pandemic waves and in the post-COVID era. For example, adherence rates dropped from 27.31% to 17.3% at a University Hospital in France and from 60% to 54% in nine hospitals in the US [23,24]. In low and middle-income countries, maintaining high HHC after the COVID-19 outbreak is challenging, with rates varying between 5% and 50% [25]. This can be related to several factors, including limited resources, inadequate infrastructure, and a lack of established HH culture [25,26]. According to our knowledge, no studies have been published in Tunisia examining the impact of the COVID-19 pandemic on HHC. In the absence of national data and given the variability of HH practices across healthcare settings, generating local evidence is essential to guide interventions and inform infection prevention policies at national levels.

Thus, the current study aims to describe HH adherence and relevance trends from 2020 to 2023 and to assess the impact of the COVID-19 pandemic on HH practices among HCWs at University Hospital Taher Sfar Mahdia (Tunisia).

Methodology

Setting and study design

This is an observational prospective study among HCWs at the University Hospital of Mahdia. From 2020 to 2023, annual direct observations of HH among HCWs were performed by trained observers including doctors and hygienists from the Department of Preventive and Community Medicine. Observations were carried out during one month in June 2020, January 2021, October 2021, October 2022, and October 2023.

Data collection and sampling

Monitoring of HH adherence

The monitoring of HH adherence was conducted among health care professionals during unannounced observational visits conducted during routine patient care and ward rounds. During each visit, each

healthcare professional was observed only once, with a maximum of two HH opportunities recorded per individual. In order not to influence their practices, all the included participants were not informed previously about the audits. Direct observation of HH practices is recognized as the gold standard for measuring compliance [27]. We opted for the direct observation technique described in the WHO HH Technical Reference Manual [28]. HH indications (The five key moments) were clearly defined according to WHO guidelines. Based on the HygMain Hygiene guide [29], we defined the opportunities that are frequent situations, easily observable, involving all professional categories, and with present infectious risks. In data analysis, these situations were divided into two groups: Invasive procedures, including intravenous injections, peripheral venous insertion, or manipulation of intravascular devices, urinary catheter insertion or evacuator catheterization, and acts requiring a skin opening. Non-invasive procedures, such as acts necessitating additional contact-type precautions, handling of waste and soiled linens, care for healthy skin, and patient changes.

Sampling

All in inpatient departments of the University Hospital of Mahdia were included. Outpatient departments necessitating HH adherence due to direct patient interactions, the potential for performing invasive procedures, or exposure to biological fluids, were also concerned. This covered the Departments of Radiology, Biochemistry, and Microbiology. Professionals working in COVID-19 units and outpatient units with limited patient contact and a minimal risk of HAIs, such as the administrative department, consultations, occupational medicine, preventive medicine, and forensic medicine units, were not included.

In the University Hospital of Mahdia, a total of 2000 HCWs were employed during the study period. In the inpatient departments, the number is limited due to workforce migration and retirements that are not followed by adequate recruitment. The infection prevention and control activities are managed by only four staff members recruited in the Department of Preventive and Community Medicine. In Mahdia hospital, the approximate capacity of beds is 400, and the patient turnover is relatively moderate. To ensure representativeness between the included departments, a minimum of three HCWs from each professional category (medical and paramedical staff) were observed in each unit during all work shifts (morning, afternoon,

and night shifts). In order to minimize inter-observer variability and to permit comparison among surveys, the same observers performed the survey during the five periods. Prior to data collection, observers received standardized training on observation techniques and data recording procedures, in accordance with WHO recommendations. Regular meetings were held to reinforce standardization and address potential discrepancies in observation practices.

The HygMain Hygiene guide [29] specifies that the minimum number of observations required for each period is 106 observations. This calculation was based on a 0.05 probability of type one error (α), a 5% margin of error, and a 7.51% difference in HH compliance rates reported in the literature [30].

Study Instrument

The audit tool used, the HygMain Hygiene Audit, was originally created by the Hospital Hygiene Practice Assessment Group (GREPHH) and subsequently adapted at the hands of the National Infection Control Team in France [29]. This tool assesses each opportunity for factors including department, gender, professional categories, observation period, and aspects of hands before HH, as well as the type of HH practiced by HCW. It specifically evaluates three crucial components of HH performance: compliance, relevance, and technique quality across situations where full compliance is essential:

HH COMPLIANCE (ADHERENCE): Ensures that HH gestures are carried out whenever opportunities arise [30]. This excludes the use of alcohol-based scrubs for surgical procedures, as surgical teams at our hospital exclusively use medicated soap. HH Compliance Rate was calculated by dividing the number of completed HH actions by the available opportunities, then multiplying by 100. A rate above 50% is considered good compliance [31]. HH compliance was evaluated before patient contact, after patient contact, as well as before and after patient contact (Global adherence/Compliance rate).

HH RELEVANCE: Assesses whether the HH method aligns with the specific situation observed before, after and before and after patient contact. For this HH performance component, the observer checks if the type of HH (antiseptic hand wash or antiseptic hand rub) done by the HCW aligns with the WHO recommendations.

HH TECHNICAL QUALITY: Includes adherence to proper HH steps and duration, considering the quality aspects of hands before HH: Absence of jewelry, and well-maintained nails without polish or artificial nails.

Regarding short sleeves, due to the hospital provision of long-sleeved coats, their use was deemed appropriate.

Statistical Analysis

Data were entered and analyzed using SPSS software, version 25. For the description of qualitative variables, frequencies and percentages were utilized. To assess trends in prevalence over time, the Chi-squared test for trend was utilized. The assumptions of this test, including independence of observations and adequate expected cell counts, were verified before analysis.

Comparisons of categorical variables between periods and studied factors were conducted using the chi-square test.

To evaluate the impact of the COVID-19 pandemic on HHC among HCWs at our hospital, the study period was divided into three phases:

EARLY PANDEMIC PERIOD: We defined June 2020 as the early pandemic period because drastic government measures effectively controlled the pandemic by that time. These measures, including closing borders and implementing lockdowns, brought the infection rate to zero by June 2020 [32]. During this period, there were minimal cases and a low need for resuscitation or oxygen beds. Additionally, it was a time for preparing for the pandemic, although no major improvements or strategies were implemented during this phase. The first patient was admitted to the COVID-19 unit at University Hospital of Mahdia in September 2020. Before this, a few positive cases were consulted in the emergency department.

THE PEAK COVID PANDEMIC PERIOD: in January 2021, October 2021, and October 2022

THE POST-COVID PANDEMIC PERIOD: in October 2023. This classification was determined by the Tunisia epidemiological statistics [32] and the Official COVID-19 report from the WHO database [33].

Furthermore, binary logistic regression analysis was conducted to ascertain factors influencing HH compliance and relevance during each period. This was performed using a descending approach, in which all variables with a $p < 0.20$ in univariate analysis were initially included, then progressively removed step by step to retain only statistically significant variables. Adjustment for confounding was ensured by systematically including variables identified as potential confounders based on the literature.

Throughout all statistical tests, p below 0.05 was regarded as statistically significant.

Ethical considerations

The study protocol was approved by the Institutional Ethics Committee of Mahdia University Hospital under approval number CEM-20251215. The direct observations as well as the measurement tool were anonymous, and the results were handled confidentially. All procedures in our study respect participant privacy, professional integrity, and ethical principles.

Results

General characteristics of the observed opportunities, HCWs and HH practices in the current study:

A total of 993 HH opportunities were recorded, with 227 in June 2020, 174 in January 2021, 180 in October 2021, 262 in October 2022, and 150 in October 2023. The observations involved 731 healthcare workers (HCWs), with a predominance of paramedical staff, 397 (54.4%), followed by 242 physicians (33%), and 92

housekeeping staff (12.6%). Among them, 478 (65%) were female.

Table 1 provides a description of the observed situations and the HH types over five periods.

The majority of HH practices 468 (65%) were observed during the morning shift. Regarding the aspect of HCW hands before HH, over 64% (469) had hands free of jewelry, and 83.3% (609) maintained natural, short, and unpolished fingernails.

As shown in Figure 1, surgical hand washing was the most relevant technique practiced by HCWs (85.9%).

HH Compliance and Relevance Trend among HCWs at the University Hospital of Mahdia from 2020 to 2023

HH compliance trend in the University Hospital of Mahdia

The overall HH adherence rate was 22.1% in our hospital, with a higher compliance rate after patient contact (28.4% vs 39%, $p = 0.08$). Figure 2 resumes

Figure 1. Relevance of hand hygiene techniques among healthcare workers from 2020 to 2023.

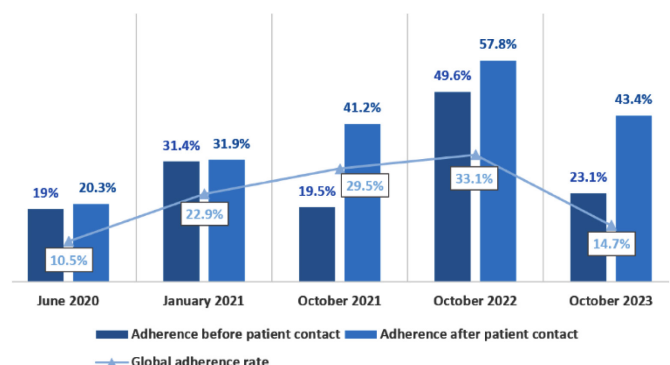
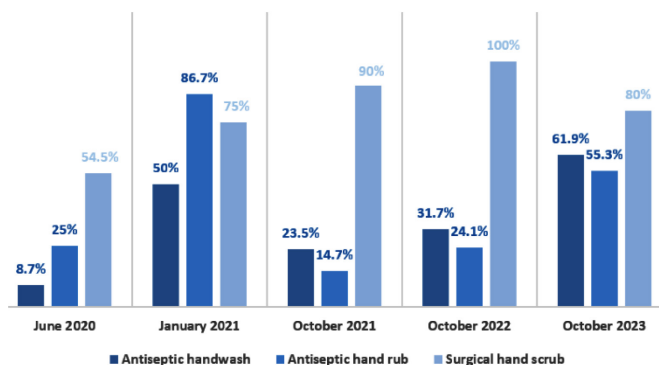


Figure 2. Hand hygiene adherence before, after patient contact, and global rates: the 2020-2023 trends at University Hospital Taher Sfar Mahdia (The Chi-squared test for trend $p = 0.005$).

Table 1. Hand Hygiene Observations by Department, Type, and Situations during the five periods at the University Hospital of Mahdia (Tunisia) (N = 993 observations).

	June 2020 n (%)	January 2021 n (%)	October 2021 n (%)	October 2022 n (%)	October 2023 n (%)	Total
Department						993
High risk (Intensive care units, Gynecology, Neonatology and Operating theaters)	79 (34.8)	68 (39.1)	100 (55.5)	117 (44.7)	35 (23.2)	399
Other units	148 (65.2)	106 (60.1)	80 (44.5)	145 (55.3)	115 (76.8)	594
HH Type						497
Antiseptic handwash	46 (59.8)	45 (56.3)	99 (67.8)	81 (72.3)	42 (50)	313
Antiseptic handrub	20 (25.9)	15 (18.7)	35 (24.3)	20 (17.8)	37 (44)	127
Surgical hand scrub	11 (14.3)	20 (25)	10 (6.9)	11 (9.9)	5 (6)	57
Observed situations						993
Handling of waste and soiled linens	47 (20.7)	32 (18.4)	22 (12.2)	32 (12.3)	9 (6)	142
Care for healthy skin	112 (49.3)	63 (36.2)	45 (25)	68 (25.6)	49 (32.7)	337
Change of patients	6 (2.5)	1 (0.5)	9 (4.9)	20 (7.6)	17 (11.3)	53
Peripheral venous insertion	14 (6.6)	27 (15.5)	35 (19.4)	43 (16.5)	17 (11.3)	136
Intravenous injections, any manipulation of an intravascular device or blood exposure.	28 (12.3)	14 (8)	41 (22.7)	38 (14.5)	26 (17.3)	147
Urinary catheter insertion, evacuator catheterization or urinary exposure.	4 (1.7)	12 (6.9)	13 (7.2)	19 (7.4)	3 (2)	51
Act requiring additional contact-type precaution	2 (0.8)	1 (0.6)	4 (2.2)	29 (3.5)	40 (2.7)	47
Act requiring a skin opening	14 (6.1)	24 (13.8)	12 (6.6)	23 (8.8)	7 (4.7)	80

compliance rates by periods showing that the HHC increased from 10.5% in 2020 to 33.1% in 2022 ($p = 0.02$). Then, this prevalence significantly decreased, reaching 14.7% in 2023 ($p = 0.01$).

HH relevance evolution during the study period

From 2020 to 2023, the average HH relevance rate was 21.3%. As indicated in Figure 3, the HH relevance rate was the lowest in June 2020 (6.5%) and the highest in October 2022 (31%). In 2023, HH relevance significantly decreased, reaching 19.4% ($p=0.01$).

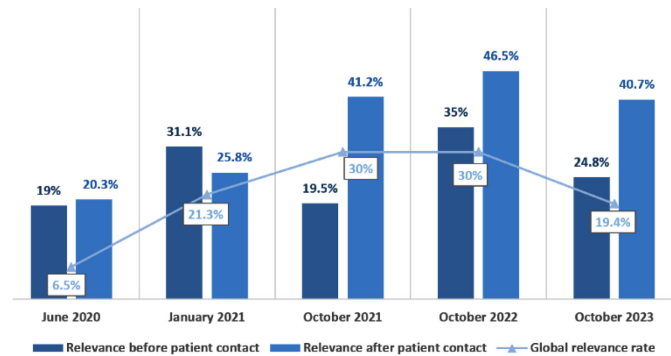
The COVID-19 impact on HH compliance and relevance at the University Hospital of Mahdia

HH adherence and relevance significantly increased during the COVID-19 pandemic compared to the early COVID-19 pandemic period, with the global adherence rate rising from 10.5% to 28.5% ($p < 0.001$) and the global relevance rate increasing from 6.5% to 27.1% ($p < 0.001$). In the post-COVID period, both global adherence and relevance declined but remained above early COVID pandemic levels at 14.7% and 19.4%, respectively. Adherence and relevance before patient contact followed a similar trend, peaking during the pandemic and decreasing afterward. However, adherence after patient contact remained unchanged, while relevance increased significantly (23.1% vs. 43.4% for adherence and 24.8% vs. 40.7% for relevance, $p < 0.001$).

Related Factors to HH Compliance among HCWs at the University Hospital of Mahdia from 2020 to 2023

Results of univariate analyses by period are presented in Table 2. The binary logistic regression was conducted for each period. Findings for the early COVID-19 pandemic and the peak covid pandemic

Figure 3. Hand hygiene relevance trend: a 2020-2023 analysis at the university hospital Taher Sfar Mahdia (The Chi-squared test for trend $p < 0.001$).



periods showed that HH adherence was more prevalent in high-risk units (OR=6, IC [2.2-15]), during invasive procedures (OR=5.5, IC [1.9-15.3]), and morning shifts (OR=5.8, IC [1.5-20]). However, no multivariate model was found for the post pandemic period.

Discussion

According to our knowledge, few published studies in the Middle East and North African region have assessed the impact of the COVID-19 pandemic on HH compliance rates among HCWs. Based on direct observations from 2020 to 2023 among HCWs in Mahdia University Hospital, the current study revealed that the overall HH compliance rate increased significantly from 22.1% to 33.1% during the COVID-19 pandemic. A significant decline was found after the pandemic (14.7%). This demonstrates the temporary effect of heightened awareness during health crises and highlights the need for sustained institutional interventions to maintain HH compliance.

Despite the advantages of alcohol-based solutions with emollients in terms of skin health and time

Table 2. Factors Influencing Hand Hygiene Adherence by study period At the University Hospital of Mahdia (Tunisia): Univariate analyses.

	June 2020		January 2021		October 2021		October 2022		October 2023	
	Adherence %	<i>p</i>	Adherence %	<i>p</i>	Adherence %	<i>p</i>	Adherence %	<i>p</i>	Adherence %	<i>p</i>
Department		< 0.001		< 0.001		0.008		< 0.001		0.80
High risk departments	24.1%		38.8%		40.4%		54.4%		14.8%	
Other departments	2.4%		7.2%		17.6%		15.6%		16.5%	
Gender		0.215		0.02		0.715		0.71		0.11
Male	16.7%		29.3%		30.6%		32.8%		23.6%	
Female	8.8%		13.9%		30.7%		30.2%		11.7%	
Healthcare workers classification		0.125		0.185		0.47		0.45		0.19
Medical staff	18.4%		24.5%		34.1%		36.1%		9.1%	
Paramedical staff	8.8%		15.6%		28.1%		31.3%		19.4%	
Observation period		0.165		0.01		0.224		0.91		0.12
Morning	14.8%		26.3%		35.6%		33.2%		18.6%	
Afternoon and night	6.1%		4.2%		27.3%		32.7%		1.1%	
Observed situation		< 0.001		< 0.001		0.02		0.01		0.16
Invasive procedure	31.3%		37%		38.1%		41.1%		21.2%	
Noninvasive procedure	4.7%		7%		18.6%		23.5%		15.9%	

efficiency [34–40], antiseptic handwashing was still the preferred method in our survey (62.9%). These findings are consistent with those reported by a survey conducted at Charles Nicolle Hospital in Tunisia, showing that 82% of HCWs used handwashing over alcohol-based hand rub (ABHR) (17.1%), as well as with other studies conducted through direct observation in developing countries such as Benin and the Democratic Republic of the Congo [41–43]. Since June 2020, there has been a notable increase in the consumption of ABHR in our hospital, rising from 25.9% to 44% by October 2023 ($p = 0.02$). This increase can be attributed to enhanced awareness during the COVID-19 pandemic. However, this rate is still relatively low [44]. This can be explained by the fact that practices are influenced by familiarity and habit, a lack of knowledge where HCWs mistakenly believe that handwashing is more effective in reducing microorganisms, and insufficient availability of ABHR [45]. A recent study performed in Uganda showed a significant increase in HH compliance, from 9.2% to 56.4%, after introducing ABHR in three clinical departments, with a significant decrease in HAI rate in two departments [46]. While hypoallergenic products offer benefits, assessing skin tolerability would be beneficial [47].

Concerning the respect of hand aspect before HH, similar findings were reported in a 2010 French study [48]. In England, the National Health Service focused on this aspect across all healthcare facilities to improve infection control. This dress code requires medical personnel in patient areas to minimize clothing and accessories below the elbows [49,50]. This underscores the importance of hospital-wide enforcement of dress codes and hygiene protocols to reinforce consistent HH practices.

Regarding the relevance of the HH technique, we found that surgical hand washing was the most accurately performed. This reflects the critical role of maintaining infection control standards in high-risk procedures [5]. It suggests that HCWs remained vigilant, particularly in surgical and sterile settings. These results indicate that high-risk settings can maintain higher standards, suggesting targeted training in other units may help improve overall HH technique adherence. Concerning antiseptic hand rub execution, 84.3% of HCWs appropriately applied the technique during the pandemic, but compliance declined over time. Several factors contributed to the decline in relevance of the HH technique, including time constraints, environmental challenges, limited awareness, and the decrease in COVID-19 infection and

death rates [32]. A 2018 Tunisian study revealed that only 10% of nurses correctly identified the recommended HH steps and just 22.9% executed them accurately [42]. Thus, sustained educational efforts with collaboration between the Preventive Medicine Department and inpatient departments are essential for improving HH practices.

The overall HH adherence rate observed in our study was 22.1%, which aligns with findings from published research in Ethiopia (22%) [51] as well as other developing countries [33]. However, this rate is still below the 31.6% reported in a recent Tunisian study at University Hospital Sahloul in Sousse [19] and remains far from the range of 54.7% to 66% documented in other studies of the Arab world [52,53]. In the current study, a significant improvement in HH adherence was found from 10.5% in June 2020 to 33.1% in 2022 ($p = 0.02$). However, by October 2023, adherence regressed to 14.7% ($p = 0.01$). This suggests that maintaining consistent adherence requires ongoing reinforcement and institutional support to prevent future declines.

In our hospital, HCWs demonstrated higher compliance after patient contact compared to before, highlighting self-preservation as a key motivator for HH. This pattern highlights a critical target for behavior change interventions to balance self-protection and patient safety. In October 2022, compliance reached 49.6% before and 57.8% after patient contact, but by October 2023, adherence had dropped to 23.1% and 43.4%, respectively. This pattern is well-documented in the literature, with studies suggesting that HCWs often prioritize their own safety over patient safety [54,55], which can compromise the fundamental goal of HH: protecting both patients and healthcare providers. Misconceptions, such as using gloves as a substitute for HH, especially during the COVID-19 pandemic, are believed to contribute to low compliance [56]. This emphasizes the importance of enhancing the patient safety culture among HCWs in order to maintain the balance between self-protection and patient care. We found that the global rate of HH relevance was 21.3% with a significant increase (30%) during the COVID-19 pandemic, but then a decrease in October 2023 (19.4%). These findings are consistent with the results reported by Bouafia *et al.* (2011) in Tunisia, showing an overall HH relevance rate of 16.1%, with 20.1% before patient contact and 13% after [57]. This indicates that HH practices in Tunisia lacked both compliance and relevance, mainly due to the non-adoption of patient safety culture by HCWs, as reflected in their improper attitude, improperly structured, and insufficient

resources in our hospitals [58]. Although many studies addressed HH adherence, few have specifically examined its relevance, revealing a notable gap in the literature.

During the four-year follow-up period, there was a significant increase in HH adherence, particularly during the COVID-19 pandemic. Similar patterns of initial improvement were observed worldwide [23,24]. For example, a prospective study conducted in an Indian tertiary hospital, based on direct observations over six months, showed a significant rise in HH adherence from 26.7% to 68.4%. Globally, the pandemic served as a pivotal accelerant for the enhancement HH adherence [59], even in the context of staffing shortages and increased workloads. In our study, the improvement included both before and after patient contact, but it was more pronounced after patient contact, which is consistent with literature [36]. A study conducted in Ethiopia showed that the major driving factors for the rapid changes in hygiene behavior were increased awareness, fear and panic of potential transmission of the COVID-19 virus, and improved access to HH products [60]. However, after the pandemic, a significant decline in the global HH adherence was observed in our setting. This downward trend aligns with findings from several other studies [23,44], which found similar declines in compliance related to the decline of COVID-19 cases and mortality rates [33], the introduction of the vaccination program for HCWs and the reduction in perceived threat. Thus, HCWs returned to pre-pandemic habits. We found that the decline in adherence before patient contact was more pronounced (33.5% Vs 23.1%). However, adherence after patient contact remained unchanged. A study carried out in China reported a similar result, showing that HH compliance was sustained beyond the study period [30].

In terms of HH relevance, we observed a significant increase during the COVID-19 pandemic followed by a decline as the pandemic subsided. Given that much of the existing literature focuses primarily on HH adherence with a lack of studies evaluating HH relevance, it was difficult to compare our results. In addition, according to our knowledge, no published studies about the COVID-19 impact on HH practices among HCWs in Tunisia were found.

Regarding related factors to good HH adherence, many studies have observed that nurses tend to demonstrate higher HH compliance than doctors [30]. This may be due to the demanding workloads, frequent patient interactions, and time pressures that nurses experience. In multivariate analysis, we found that HH

adherence was significantly higher in high-risk units. Our results are similar to those reported in a multicenter study in the Mediterranean region [18]. Additionally, a recent Tunisian study conducted at the University Hospital of Sahloul showed that HH compliance in the ICUs was the highest compared to other units [19]. We also found that HH adherence was higher in the morning shift, which aligns with literature findings [58]. This difference could be explained by the reduced number of HCWs leading to increased workloads, the limited control, and the lack of resource availability in night shifts compared to morning shifts.

This study is subject to limitations, and various efforts were made to minimize their impact. Primarily, the observation bias, or the Hawthorne effect, where individuals alter their behavior when they know they are being observed. To mitigate this, we did not inform HCWs about the audit in order to avoid influencing their behaviors. Second, we note the interobserver variability bias. To address this, trained observers from the Department of Preventive and Community Medicine performed data collection, and consistency was maintained by having the same observers conduct all surveys across the five study periods. Third, selection bias could arise from excluding HCWs in the COVID-19 unit. This was due to the fact that data collection in these units was difficult and biased. In fact, entering the COVID-19 unit requires wearing personal protective equipment, which was affordable only for COVID-19 HCWs because of its short supply. In addition, it was difficult to maintain the same sampling method as the other departments in view of the limited staff numbers working in these units. Because of the specific context, it was impossible to enter and assess HHC without explaining to them the aim of our presence. Fourth, the small sample size was related to the moderate patient turnover in our hospital. Fifth, the short observation timeframe, which was related to the limited human resources in our department, made extended observation periods unfeasible. Finally, the measurement bias resulted from the choice of the month of observation, which was related to the local epidemiological context during the COVID-19 peaks. Indeed, monitoring activities became more structured and organized in the subsequent study periods.

Conclusions

Our findings emphasize the urgent need to enhance HH adherence during the post-COVID era in hospitals by focusing on continuous education, regular monitoring, and infrastructure improvements. Maintaining the positive impact of the COVID-19

pandemic is particularly important in developing countries where resources are limited, but the need for effective infection control remains high.

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Authors' contributions

IM, BT, EH, NR, AK, and SEM participated in the conceptualisation, the design, the coordination, and the data collection of the study. IM and BT performed statistical analysis. IM, BT, EH, NR, AK, RG, MM, and MS drafted the manuscript. HBG, BM, HBH, FA, KM, SA and SEM revised and approved the final version.

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Conflict of interest

No conflict of interest is declared.

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