Infection, Disease & Health 29 (2024) 51—60

Available online at www.sciencedirect.com

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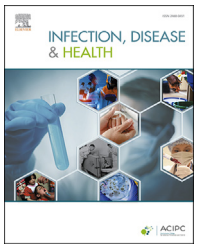

Research paper

A single plain ring is not associated with increased bacterial load on hands: An experimental study among healthcare worker students undertaking mock surgery

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Received 16 August 2023; received in revised form 6 October 2023; accepted 12 October 2023
Available online 22 November 2023

KEYWORDS
Ring;
Jewellery;
Hand hygiene;
Surgical scrub;
Chlorhexidine;
Infection

Abstract *Background:* Adequate hand hygiene is considered as one of the most effective strategies in healthcare-related infection prevention. The potential negative effect of rings in hand disinfection and thus, in increased nosocomial infections rates is still controversial. Therefore, the present study was designed with the purpose of examining if rings frequently exposed to surgical scrubbing were associated or not with increased bacterial counts.
Methods: 32 volunteers were randomized into 4 groups: A (no rings), B (participants wore a ring), C (no rings and performed surgical scrubbing with chlorhexidine every 48 h) and D (participants wore a ring and performed surgical scrubbing every 48 h). Glove juice samples were obtained at day 0 (T0) and after a 90-min mock-surgery on day 14 (T1). Quantitative (number of UFC/mL) and qualitative data (microorganism type) were collected as study variables.

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https://doi.org/10.1016/j.idh.2023.10.003

Results: All groups were comparable at T0. All ring carriers obtained negative cultures at T1. Ring presence was not associated with higher bacterial counts; comparisons between A vs B groups and C vs D groups showed no statistically significant differences ($p = 0.076$ and 1.000). T1 negative cultures were more frequent in participants performing surgical scrubbing every second day (93.8 % vs 75 %), although this difference did not reach statistical significance ($p = 0.332$).
Conclusions: The presence of single plain ring does not seem to be associated with an increased hand bacterial load. Regular surgical scrubbing with chlorhexidine impregnated sponges reduces bacterial contamination of hands, even in the presence of plain rings.

Highlights

- There is conflicting evidence about rings interfering in adequate hand hygiene.
- Most of this evidence comes from non-surgical disciplines.
- All ring weares in this study obtained negative cultures after surgical scrubbing.
- Frequent exposure to surgical scrubbing seems to reduce hand bacterial counts, even in the presence of rings.

Introduction

It is widely recognized that a high proportion of hospital infections are attributable to a lack of proper hand hygiene, which has led this practice to become one of the most effective preventive measures, widely studied and promoted globally. Innovative campaigns have been implemented and there is constant surveillance of possible risk factors that could compromise its effectiveness [1]. However, there is still controversy, with conflicting literature, about the potential negative effect on proper hand hygiene of plain rings worn by surgeons and other surgical staff, and thus, on the increased risk of surgical infection (Table 1).

As a working hypothesis for the present study, the authors suggest that exposing a ring to frequent washing with antiseptic substances, as part of routinary surgical scrubbing, may reduce the bacterial contamination of the ring to a level similar to that of the surrounding skin. This rationale may be responsible for the elimination of the biofilm already associated to ring wearing [2] and may explain why most publications reporting higher bacterial loads in health workers wearing rings come from non-surgical environments (Table 1). Consequently, in a surgical setting, rings may not favour the presence of pathogenic microorganisms in the hand, and therefore, may not be considered as a risk factor for surgical site infection.

The present study aims to provide evidence supporting the proposed hypothesis, by means of an experimental design which allows to control for a large number of confounding factors. The resulting conclusions may help to determine if current guidelines and recommendations dictating ring removal during surgical activity should be further subjected to evidence-based review [3].

Material and methods

This study aims to experimentally analyse two objectives; assess the influence of regular ring use by surgeons on increased bacterial colonization of the hand, and also to examine the effect of routine surgical scrubbing on reduced bacterial colonization of the hand, with and without ring wearing.

Study design

This was a prospective "in vitro" experimental study. Participants comprised 4 groups of 8 volunteer medical and nursing students each, who did not meet any of the exclusion criteria: dermatological diseases affecting the hands, frequent use of rings in the month prior to the study, active infection or antibiotics intake during the study, painted or artificial nails, unhealed wounds on the hands, surgical activity with real patients during the study period, frequent contact with potentially contaminated material (livestock, aquariums, gardening…) or allergy to antiseptics used during the study. Ethical approval was granted by the local ethics committee (reference CEI/CEIm: 2023-211-1).

Study groups

Participants were randomly assigned to one of the following four groups, and were followed for 14 days.

A. **Bare hands (control group, no rings):** during the study period participants performed regular hand and personal hygiene (daily shower, hand wash before and after meals, etc …), with commercially available soaps of

Table 1 Published evidence about ring use and healthcare related infections.

EVIDENCE SUPPORTING RING REMOVAL RECOMMENDATIONS

Author	Year	Discipline	Methodology	Conclusions
Field et al. [2]	1996	Dental surgery	Observational (prospective) 40 volunteers and dentists Skin sampling	*"Effective hand disinfection is difficult to achieve if rings and watches are not removed"*
Salisbury et al. [3]	1997	Hospital workers	Prospective cohorts 100 workers and students Skin sampling Soap	*"Hand washing was significantly less effective in reducing bacterial loads in the ring carrier group"*
Trick et al. [4]	2003	Intensive care	Prospective cohorts 66 nurses Glove juice sampling Alcoholic solutions vs soap	*"Ring wearing increased the frequency of hand contamination with potential nosocomial pathogens"*
Kelsall et al. [5]	2006	Surgical staff	Experimental 28 nurses-surgeons Skin sampling Chlorhexidine surgical scrubbing	*"Rings increase surface bacterial counts. Although scrubbing reduces these, there are more bacteria under rings than on adjacent skin or the opposite hand"*
Yildirim et al. [6]	2008	Intensive care	Prospective comparative 84 nurses Glove juice sampling Alcohol-based hand gel	*"Ring wearing increases the bacterial colonization of hands and alcohol-based hand disinfection might not significantly reduce contamination of the ring-wearing hands"*
Hatemongered et al. [7]	2010	Hospital workers	Observational (prospective) 3067 workers Visual criteria (no cultures) Alcohol-based hand gel	*"Wearing rings other than a wedding ring was associated with ineffective hand rub use (OR 1.8, 1.2—2.7)"*
Fagernes et al. [8]	2011	Hospital workers	Observational (prospective) 465 workers Glove juice sampling	*"The use of one plain finger ring increased the carriage rate of Enterobacteriaceae (odds ratio 2.71)"*
Ramon-Canton et al. [9]	2011	Hospital workers	Experimental 293 workers Visual criteria (no cultures)	*"84.3 % of ring carriers did not perform adequate hand hygiene"*
Khodavaisy et al. [10]	2011	Intensive care	Observational (prospective) 40 workers Skin sampling	*"Hands and their rings were contaminated with various types of microorganisms. Rings, watches, and bracelets should be removed before washing their hands and entering the ICU"*
Naeem et al. [11]	2015	Dentistry	Prospective cohorts 40 dentists Skin sampling	*"Bacteria and fungi were significantly more frequent in dentist's hand with rings than those without rings"*

(*continued on next page*)

Table 1 (*continued*)

EVIDENCE AGAINST RING REMOVAL RECOMMENDATIONS				
Author	Year	Discipline	Methodology	*Conclusions*
Waterman et al. [12]	2006	Veterinary	Experimental 20 veterinary students Glove juice sampling Chlorhexidine surgical scrubbing	*"There is no compelling evidence to suggest that surgeons wearing rings possess higher bacterial counts under their gloves during surgery"*
Wongworawat et al. [13]	2007	Surgical area	Randomized controlled 60 staff and students Several hygiene agents	*"The presence of rings does not negatively impact the effectiveness of alcohol-based hand sanitizers. Use of waterless alcohol-chlorhexidine lotion resulted in the lowest bacterial count"*
Al-Allak et al. [14]	2008	Surgery	Prospective cohorts 20 surgeons and anaesthetists Skin sampling	*"Wedding rings are not a significant source of bacterial contamination following surgical scrubbing"*
Stein et al. [15]	2009	Orthopaedics	Observational (retrospective) 2127 surgeries	*"There is no correlation between wearing a plain wedding band and an increase of postoperative infections. The incidence of postoperative infections significantly decreased when the surgeon wore a wedding band"*
INCONCLUSIVE EVIDENCE				
Author	Year	Discipline	Methodology	*Conclusions*
Fagernes et al. [16]	2007	Hospital workers	Prospective cohorts 234 workers Glove juice sampling	*"Wearing a single plain finger ring did not increase the total bacterial load on the hands, nor was it associated with an increased rate of carriage of S. aureus or nonfermentive gram-negative rods. However, they were associated with an increased rate of Enterobacteriaceae carriage"*
Fagernes et al. [17]	2009	Hospital workers	Experimental 200 workers Glove juice sampling	*"Wearing finger rings increases the carriage rate of nonfermentive gram-negative bacteria and Enterobacteriaceae on the hands of healthcare workers. However, no statistically significant differences in the incidence of transmission of nonfermentive gram-negative bacteria or Enterobacteriaceae were detected"*
Arrowsmith et al. [18]	2014	—	Systematic review	*"This review could not locate any trials that investigated the effect of theatre staff wearing rings in surgical infection rates"*

their choice, with no other restrictions or indications for their regular activities.

B. **Hands with a ring:** participants wore a plain ring during the study period, without interruption, and followed the same indications than group A.
C. **Bare hands with frequent surgical scrubbing:** Volunteers in this group performed a full surgical scrub on alternate days with a chlorhexidine impregnated surgical brush-sponge for 5 min. On top of that, they followed the same instructions than in group A (regular personal hygiene)
D. **Hands with ring and frequent surgical scrubbing:** Subjects wore a plain ring during the study period, and followed the same premises than group C; i.e. regular personal hygiene and full surgical scrubbing every second day.

Surgical scrub

Participants in groups C and D performed a full surgical hand and nail washing every second day with a chlorhexidine-impregnated sponge (*Clor-Scrub® 4 %, 20 ml Chlorhexidine digluconate, Imark-Hospital™, Spain*) so as to simulate the usual routine of a surgeon with frequent surgical activity. Subjects were familiar with surgical scrubbing prior to the commencement of the study, but were also instructed to perform the technique recommended by The World Health Organization in order to standardize the proceeding [4].

Rings

Participants in groups B and D wore a silver plain ring, without inlays or engravings, for the duration of the study. They wore it continuously for 24 h a day, on the dominant hand ring finger, only being allowed to remove it occasionally for short periods of time (for example, for 60—90 min if they were going to practice a sporting activity where it might bother/harm them).

Cultures — microbiology

Baseline sampling (T0): All participants underwent an initial culture of the dominant hand. It was established that hands could not be washed in the 2 hours before sample collection. This sample collection was carried out in the Microbiology Laboratory of Hospital Universitario Insular (Las Palmas de Gran Canaria, Spain). A variant of the glove juice method was used to suspend bacteria from participants' hands inside the gloves [5—9]. Participants put on sterile gloves (*Protexis® Latex Surgical Gloves, Cardinal Health™, USA*) (Fig. 1, left image) and 2 mls. of sterile PBS (phosphate buffered saline) were pipetted into each finger of the glove using a sterile Pasteur pipette. Subsequently, maintaining the sterility of the process, the participants' hand was rubbed so that the bacteria adhering to the skin were suspended in the juice inside the glove, and then the hand was shaken for approximately 1 min (Fig. 1, right image). The resulting liquid was then extracted from the inside of the glove and placed in sterile containers, which were labelled and placed in a refrigerator for seeding and subsequent culture.

Final sampling (T1) — Mock surgery: 14 days later, all participants performed a surgical hand wash with a chlorhexidine gluconate sponge (*Clor-Scrub® 4 %, 20 ml Chlorhexidine digluconate, Imark-Hospital™, Spain*) for approximately 5 min following the beforementioned standardized hand washing technique. The scrubbing train consisted of two custom made hand washers with sterile saline solutions and two containers to collect the liquid used in the process (Fig. 2). After this, participants dried their hands with sterile surgical towels and put on sterile surgical gloves (*Protexis® Latex Surgical Gloves, Cardinal Health™, USA*). For 90 min, they sat around a table set up with sterile fields, hands facing down (Fig. 3). This duration was considered as average for a medium-length surgical procedure; it was considered that in lengthier surgeries there is usually a glove change after that time. Then, juice samples were taken following the described methodology in T0. In addition, participants wearing a ring dropped it into a sterile recipient containing BHI (Brain Heart Infusion enrichment broth).

Each T0 and T1 sample of glove juice was manually seeded following a quantitative technique, using 10 μL calibrated loops. Blood Agar, MacConkey Agar and Sabouraud Agar were used as cultured media, and in the final sampling (T1), BHI liquid enrichment medium was also used for ring culture. The plates were incubated at 35—37 °C for 48 h in the oven, after which the number of CFU/mL was read. In addition, the Sabouraud Agar culture medium was left until the seventh day in the oven to observe fungal growth. In the final sampling, in the BHI broth of the ring participants, growth was also assessed for turbidity at 48h, followed by a pass on Blood Agar and Chocolate Agar, which

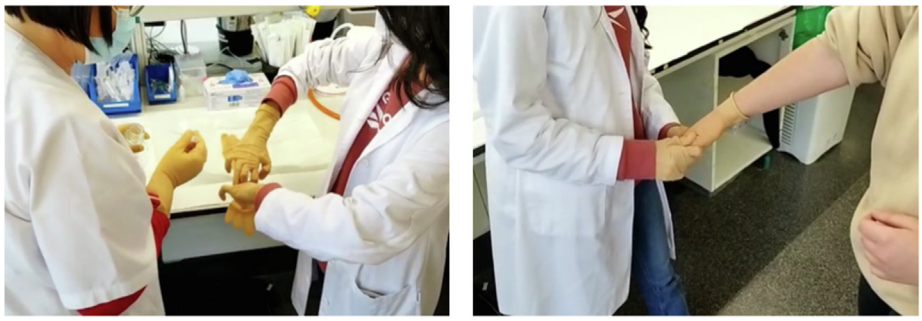

Fig. 1 T0 juice glove sampling technique.

Fig. 2 Surgical scrubbing before mock surgery (T1).

Fig. 3 Mock surgery (T1): gloved hands remained facing down on a sterile surgical field for 90 minutes.

was read after further 48 h of incubation. A mass spectrometry technique (*MALDI-TOF®, Bruker™, USA*) was employed to qualitatively identify the microorganisms.

Outcomes

The variables analysed during the microbiologic study were.

- **Quantitative analysis**: defined as number of colony-forming units (CFU/mL).
- **Qualitative analysis**: defining the types of microorganisms isolated in each sample.

Statistical analysis

Data analysis was performed using Jamovi (*The jamovi project (2022) Version 2.3*) and R (*R Core Team 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria*) software. Categorical variables were summarized as frequencies and percentages and numerical variables as means and standard deviations or medians and interquartile ranges (IQR = 25—75 percentile) depending on whether or not the assumptions of normality were met. Percentages were compared using the Chi-square test ($\chi 2$). Means were compared using the Fisher test and medians using the Wilcoxon test for independent data. Statistical significance was set at $p < 0.05$.

Results

The study was conducted with 32 volunteers, 30 medical and two nursing students who were randomized into 4 groups of participants. Group A consisted of 5 men and 3 women, all of whom were right-handed. Group B consisted of 5 women and 3 men, one of whom was left-handed, the rest of the participants being right-handed. Groups C and D consisted of 6 women and 2 men each, with only one left-handed participant, belonging to group D.

T0 results

According to baseline cultures, all groups were comparable in terms of initial seeded CFUs, which ranged from (3000—100,000 CFU) (Table 2). Microorganism recovered in order of prevalence were coagulase negative Staphylococcus (all but one sample), Micrococcus sp, Bacillus sp, Acinetobacter sp, *Staphylococcus aureus*, *Klebsiella oxytoca*, Pantoea sp, Pseudomonas sp, *Serratia liquefaciens*, *Candida parapsilosis*, Rothia sp, and *Psychrobacter sanguinis*.

T1 results

After the mock surgical procedure, 5 samples showed CFU growth; two of them with 100 CFUs, which could be considered as a sample contamination. 80 % of positive results were found in group A (50 % of the samples in that group). The quantitative results of T1 cultures are summarized on Table 3; microorganisms recovered were coagulase negative Staphylococcus (3 samples), Micrococcus sp

Table 2 T0: baseline sampling.

Initial CFU/mL					
Participants	Group A	Group B	Group C	Group D	p-value
1	80000	3000	60000	100000	**0,315**
2	100000	80000	90000	80000	
3	90000	100000	70000	60000	
4	50000	80000	60000	60000	
5	100000	40000	60000	30000	
6	15000	100000	20000	100000	
7	80000	50000	30000	80000	
8	100000	100000	30000	100000	

CFU: colony forming units.

Table 3 T1: final sampling.

Final CFU/mL					
Participants	Group A	Group B	Group C	Group D	p- value
1	0	0	100	0	**0,357**
2	0	0	0	0	
3	0	0	0	0	
4	100	0	0	0	
5	2200	0	0	0	
6	0	0	0	0	
7	70000	0	0	0	
8	1300	0	0	0	

CFU: colony forming units.

(3) and *S. aureus* (1). Ring carriers obtained 0 CFUs in all their T1 cultures.

Comparison of bacterial colonization in ring users and barehand participants

- **Without regular surgical scrubbing (group A vs group B)**

Comparison between the two groups shows that 50 % of participants in group A obtained positive T1 cultures, while no positive samples were obtained within group B specimens; this difference did not reach statistical significance ($p = 0.0769$). The number of microorganisms found in the samples did not reach statistical significance either (Table 4): 3 samples tested positive for had *Micrococcus* sp, 2 for CoNS and 1 for *S. aureus*.

Table 4 Comparison of T1 results for A and B groups.

	GROUP A		GROUP B	p-value
CFUs/mL	0	4 (50.0 %)	8 (100.0 %)	0.076
	≥100	4 (50.0 %)	0	
Number of microorganisms	0	4 (50.0 %)	8 (100.0 %)	0.076
	1	2 (25.0 %)	0	
	2	2 (25.0 %)	0	

CFU: colony forming units.

- **With regular surgical scrubbing (group C vs group D)**

Table 5 shows only one volunteer in group C with a positive CFU count in T1, corresponding to CoNS; the remaining samples in group C and D resulted negative, resulting this difference not statistically significant.

Comparison of bacterial colonization of hands in groups with and without regular surgical scrubbing (Group AB vs Group CD)

Of the 16 volunteers in group AB (no surgical scrub group), 12 (75.0 %) had 0 CFU/mL in T1, while In the CD group (surgical scrub groups), 15 samples (93.8 %) were negative. Although there were fewer positive cultures in the groups that performed surgical scrubbing, this finding did not reach statistical significance (p-value = 0.3326). No difference was found for the type and number of microorganisms found (Table 6). *Micrococcus* sp. grew in 3 samples belonging to the AB group; *CoNS* was found in 3 samples, (2 AB — 1 CD); and 1 AB volunteer tested positive for *S. aureus*.

Discussion

The most important finding of this work is that regular use of the ring does not appear to increase the bacterial load of the hand after surgical scrubbing. None of the ring wearers' cultures were positive in the final T1 sampling. A main

Table 5 Comparison of T1 results for C and D groups.

		GROUP C	GROUP D	p-value
CFUs/mL	0	7 (87.5 %)	8 (100.0 %)	1.00
	≥100	1 (12.5 %)	0	
Number of microorganisms	0	7 (87.5 %)	8 (100.0 %)	1.00
	1	1 (12.5 %)	0	

CFU: colony forming units.

Table 6 Comparison of T1 results for AB (no surgical scrubbing) and CD (surgical scrubbing) participants.

		GROUP AB	GROUP CD	p-value
CFUs/mL	0	12 (75.0 %)	15 (93.8 %)	0.332
	≥100	4 (25.0 %)	1 (6.2 %)	
Number of microorganisms	0	12 (75.0 %)	15 (93.8 %)	0.398
	1	2 (12.5 %)	1 (6.2 %)	
	2	2 (12.5 %)	0	

CFU: colony forming units.

strength of this study is its randomized and experimental nature, where a number of potential confounding factors (differences in participant characteristics, baseline bacterial loads, hygiene protocols, antiseptic agents ...) have been controlled, and all participants showed comparable baseline microbiology, which awards robustness to the presented findings. Furthermore, to our knowledge, this is the first study to employ a methodology of surgical scrubbing every 48 h to test the effect in ring bacterial colonization of frequent exposure to chlorhexidine.

Prior to this study there has been no clear evidence to determine whether the use of a plain ring increases the bacterial inoculum on the surgeon's hand, with contradictory and inconclusive literature (Table 1). Previous publications such as those by Waterman T et al. [9], Wongworawat M et al. [10], Al-Allak A et al. [11] and Pitak-Amnop P et al. [12] obtained results similar to those of this study and argue that there is no correlation between the use of rings and an increased bacterial counts. In the study by Waterman T et al. [9], with a smaller sample size (n = 20) although pre-wash and post-wash sample collection and a "mock surgery" are performed, participants are not attached to a predefined hand hygiene protocol, and the baseline and final samplings are carried out within hours of difference. One of the strengths of the present study has been to adjust the methodology as much as possible to the daily working routine of a surgeon.

On the other hand, other studies suggest that there is a direct correlation between the use of rings and higher bacterial counts. Trick et al. concluded that rings increase the bacterial colonization of the hand [13]; in this study, surgical scrubbing was not performed; instead hand hygiene was conducted with non-medicated soap, ethyl alcohol-based gel and medicated wipes with benzalkonium chloride [13] Similarly, in the study by Yildirim et al. [14], they did not perform strict surgical scrubbing either, but used an alcohol-based antiseptic solution for routine hand hygiene. In the present study, surgical scrubbing was not only vigorous and standardized for all participants but also used the most effective antiseptic agent, 4 % gluconate chlorhexidine, according to previous studies [10]. This could be interpreted as an evidence of surgical hand washing with chlorhexidine acting as an efficient decontaminating routine for rings, in contrast to other povidone-iodine or alcohol-based solutions [10,15] In other work by Jacobson G et al. [16], with results favouring a negative effect of rings on CFU/mL counts, participants wore between two to five rings on each hand, which apart from being distant for the relatively common situation of using an only ring, may have also contributed to increased bacterial counts.

Regarding the microorganisms found in the initial sampling, *coagulase-negative Staphylococcus* was the most frequent, followed by *Micrococcus* sp, *Bacillus* sp, *S. aureus*, *K. oxytoca* and *Acinetobacter ursingii*. After surgical lavage, *coagulase negative Staphylococcus* and *Micrococcus* sp were the most frequent, followed by a single culture with *S. aureus*. As can be seen, in the cultures of our series all were commensals of the skin microbiota and some opportunistic pathogens such as *K. oxytoca*. *S. aureus* was also isolated as the only primary pathogen in both samplings, being isolated in the culture of a participant from group A (2200 CFU/mL) in the final sampling, although this is not surprising since the rate of nasal carriers of *S. aureus* among healthcare personnel is high [17]. It should be noted that the findings of the microorganisms mentioned above are similar to those found in other studies [14] Fagernes et al. reported that rings were associated with an increased rate of Enterobacteriaceae carriage [18—20]; in our study this was found in T0, but after surgical regular scrubbing, Enterobacteriaceae were no longer cultured in T1 in hands with jewellery.

Another relevant finding of this piece of research is that regular surgical washing seems to reduce bacterial colonisation of the hands. In the comparison between the groups with (AB) and without (CD) regular surgical hygiene, a noticeable difference was found, although no statistically significant (25.0 % vs 6.2 % of positive specimens respectively). However this 6.2 % correspond to a non-ring carrier with just 100 CFU/mL, which may be considered as a sample

contamination; we hypothesize a larger sample may provide significant differences in this particular comparison.

Lastly, we observed that ring carriers obtained fewer positive cultures (i.e. none) than bare hands participants. A similar observation was also noted by Stein et al., reporting a decreased surgical infection rate after the surgeon started to wear a wedding band [21]. This "protective effect" of the ring may be explained by a more thorough scrubbing technique performed by ring carriers, as described in Stein article. However, it also needs to be stressed that many health workers are not aware of rings acting as potential bacterial reservoirs [22], highlighting the importance of promoting effective hand hygiene strategies, especially among ring users. Clarifyingly, in the experimental study carried out by Al-Allak et al., anaesthetists obtained higher bacterial counts in their rings after surgical scrubbing, compared to surgeons, more familiarized with the technique [23], and Ramon-Canton et al. quantified in 84.3 % the share of ring carriers performing inadequate hand hygiene [24].

Like all studies, this one also has a number of limitations. A main fault may be the sample size, with budget limitation as the underlying reason. In addition, an analysis of glove perforation was not performed in this study because during the mock procedure, participants did not perform any sort of activities with their hands, limiting the possibility of breakage or perforation of gloves. Lastly, it may be hypothesized that some of the samples taken showing positive results could be attributed to accidental contamination during handling and processing procedures. In this sense, it could have been more appropriate to have a negative control group, where one sample plate was exposed to the environment for each sample analysed, in order to establish a negative reference. However, we have taken accountability of these factors to improve potential future study designs in this field.

Although more evidence is needed to establish formal guidelines for the use of rings during surgery, the results obtained in this study support the idea that rings are not an important source of bacterial colonization and, therefore, their removal prior to entry into the operating theatre does not seem a priority as long as surgical scrubbing is performed properly and routinely. In addition, this study may be employed to recommend frequent surgical scrubbing in healthcare workers in order to reduce bacterial hand contaminations, and hence, the risk of healthcare-associated infections. This recommendation may also be applicable to non-scrubbed staff in the surgical area, as they also contribute to surgical site infection incidence [25].

Conclusions

There has been no clear evidence to determine whether the use of a plain ring increases the presence of bacterial microorganisms on the surgeon's hand, as there is contradictory and inconclusive literature. In the present study all cultures from ring wearers were negative. The most important finding of this work is that it does not appear that regular use of the ring increases the bacterial load of the hand. Regular surgical scrubbing with chlorhexidine impregnated sponges seems to decrease bacterial contamination of hands, even in the presence of plain rings.

Ethical considerations

Ethical approval was granted by the local ethics committee (reference CEI/CEIm: 2023-211-1). Informed consent is not applicable.

Authorship statement

Eva María Aguiar Cabrera conducted conceptualization, investigation and draft writing. Sergio Barroso Rosa developed conceptualization, investigation, supervision, review and editing. María del Mar Ojeda Vargas was responsible for investigation and methodology. Carmen Nieves Hernández Flores managed data curation and formal analysis. Elena María Hernández Costa participated in investigation and resources.

Conflicts of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Funding

This study received no specific funding sources.

Provenance and peer review

Not commissioned; externally peer reviewed.

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