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Analyzing the occupational exposure risks of dental healthcare workers from the perspective of repeated occupational exposure

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Abstract

Background Healthcare workers in dental hospitals frequently experience repeated occupational exposures (ROEs). In our study, we aim to analyze these repeated exposures among dental healthcare workers (DHWs), assess the risk levels of different risk factors, and explore the significance of ROE data for infection control in dental hospitals.

Methods Based on hospital statistical data, we categorized the occupational exposure incidents at West China Hospital of Stomatology over the past seven years into initial and repeated exposures. We analyzed the association of various risk factors, including personnel types, gender, treatment locations, timing of occupational exposure, and pathways of occupational exposure, with the occurrence of repeated exposures. The Statistical Package for Social Sciences (SPSS) 21 was used to conduct chi-square analysis and binary logistic regression analysis, with the significance level set at $p < 0.05$.

Results Compared to students, hospital dentists with teaching qualifications exhibited a higher risk of ROEs. The risk of repeated exposure for dental students was 60% lower than that of hospital dentists ($P = 0.003$). However, gender, treatment locations, timing of occupational exposure, and pathways of occupational exposure did not significantly impact the repeated exposures among DHWs.

Conclusions Our study demonstrates that the analysis of repeated occupational exposures (ROEs) is meaningful. In our study, hospital dentists with teaching qualifications had the highest risk of ROEs, compared to dental students, hospital dental nurses, and dental nurse students. This means that among individuals who have already experienced occupational exposure, hospital dentists are more likely to experience repeated exposure. Meanwhile, gender, treatment locations, timing of occupational exposure, and pathways of occupational exposure did not have a significant impact on the occurrence of ROEs.

Keywords Occupational exposure, Dental healthcare workers, Infection prevention and control, Dental hospital

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Introduction

Due to the nature of their work and the working environment, healthcare workers often face a higher risk of direct exposure to the spread of infectious diseases and sharp injuries, which frequently results in occupational exposure. Among healthcare workers, occupational exposure refers to instances where healthcare workers come into contact with hazardous substances or pathogens during the processes of diagnosis, treatment, and care [1]. This exposure typically involves hazardous substances or pathogens coming into contact with damaged skin through needles, sharp instruments, splashes, or entering the eyes, nose, mouth, and other mucous membranes [2] These situations can potentially lead to the spread of infectious diseases. According to data from the Centers for Disease Control and Prevention (CDC) in the United States and the European Agency for Safety and Health at Work, healthcare workers in hospitals in the US and Europe report over 385,000 and 1 million cases of needlestick injuries (NSIs) annually, respectively [3]. The World Health Organization (WHO) estimates that out of the global population of 35 million healthcare workers, around 3 million experience occupational exposure to blood each year [4]. In studies conducted in developing countries, the incidence of occupational exposure throughout healthcare workers' careers can even reach 100% [5].

Currently, at least 20 different pathogens are transmitted through occupational exposure, such as Hepatitis B virus (HBV), Hepatitis C virus (HCV), and Human Immunodeficiency Virus (HIV) [3, 6]. Occupational exposure has become a significant cause of healthcare workers contracting HCV, HBV, and HIV [7]. It is estimated that annually, more than 150,000, 70,000, and 500 healthcare workers are infected with HCV, HBV, and HIV, respectively, due to occupational exposure [4]. While management measures for post-exposure to HIV and HBV are relatively well-established, there is currently no vaccine available for HCV, and the effectiveness of post-exposure prevention for HCV is also less than ideal [8]. These diseases pose catastrophic risks to healthcare workers experiencing occupational exposure. Furthermore, even if actual transmission of infectious diseases does not occur, occupational exposure can have significant negative impacts on the psychological well-being of healthcare workers, the motivation of medical students, and the financial and medical quality burdens on hospitals [5, 9–12].

In fact, the risk of occupational exposure among dental healthcare workers (DHWs) is exceptionally high, making it one of the professions with the highest exposure risks [13] On one hand, DHWs frequently encounter infectious patients and pathogens. The oral cavity of a healthy individual serves as a ecological niche for numerous bacteria, fungi, and viruses, thereby providing ample potential pathogens for occupational exposure [14]. During the diagnosis and treatment of oral diseases, patients are required to remove their masks, exposing the oral and nasal cavities, which may contain pathogens from blood, saliva, and respiratory aerosols, making them more prevalent in dental clinics [15, 16]. Moreover, certain systemic infectious diseases exhibit characteristic manifestations in the oral cavity, often leading patients to seek treatment at dental hospital, including bloodborne infections such as AIDS, syphilis, among others [17, 18]. Even Hepatitis C infections and treatments can result in symptoms in the oral mucosa [19]. On the other hand, the treatment of oral and maxillofacial diseases necessitates the frequent use of small, sharp instruments such as files, dental burs, probes, as well as syringe needles, blades, and suturing needles, all of which are commonly utilized during procedures [19, 20]. The use and cleaning of sharp instruments undeniably escalate the risk of occupational exposure [19, 20]. Furthermore, the treatment procedures for oral diseases often entail working within confined spaces in the oral cavity with limited visibility, both of which contribute to occupational exposure resulting from healthcare workers' procedural errors [14, 20]. Two studies from Asia have reported occupational exposure incidence rates of up to 80% among dentists and 61.9% among dental nurses, underscoring the severe challenge of occupational exposure faced by DHWs [21, 22].

In reviewing previous studies, we have observed that occupational exposure among healthcare workers, including those in oral medicine, often occurs repeatedly, sometimes within a relatively short time frame [2]. Rawan et al. indicated that over the past five years, 48.9% of surveyed dentists experienced occupational exposure incidents two or more times [22]. Similarly, in two dental schools in China, 41% of surveyed dental students reported experiencing occupational exposure incidents two or more times [23]. While repeated occupational exposures (ROEs) among healthcare workers can have individual factors, it is crucial for infection control departments to pay attention when individuals who have experienced occupational exposure continue to encounter such incidents in their work. These issues may represent common challenges that warrant the attention of all colleagues. Analyzing the risk factors (such as personnel types, gender, locations, timing, and pathways of occupational exposure) from the perspective of ROEs may provide a unique viewpoint in studying occupational exposure and may facilitate the development of proactive infection control strategies and public health policies.

West China Hospital of Stomatology, a top-tier specialized hospital in China for dental medicine, boasts a substantial workforce capable of comprehensive diagnosis and treatment of oral diseases. Our study includes occupational exposure data from this hospital spanning from 2016 to 2022, with a specific focus on analyzing characteristics of ROEs. The aim of the study is to track the ROEs of DHWs and identify the risk factors including personnel types, gender, locations, timing, and pathways of occupational exposure.

Methods

This study adheres to the ethical review guidelines of West China Hospital of Stomatology. Ethical approval was granted by the Medical Ethics Committee of West China Hospital of Stomatology, Sichuan University (Approval No. WCHSIRB-2024-299).

In West China Hospital of Stomatology, all occupational exposure incidents are required to be reported to the Infection Control Department through a standardized reporting system. When DHWs experience occupational exposure, they are required to report the incident to their department supervisor and the Infection Control Department using a digital reporting form immediately. This form includes details such as the date, personnel type, information related to the exposure, and any immediate medical interventions. Subsequently, the Infection Control Department will provide follow-up procedures for the workers according to the established guidelines for occupational exposure.

This study analyzed the occupational exposure data from the Infection Control Department of West China Hospital of Stomatology, spanning from 2016 to 2022. The data collected from the Infection Control Department included the date of the event, masked personnel IDs (with names hidden), personnel types, clinical operation scenarios, instruments causing the injuries, and the department at the time of the incident. The inclusion criteria were any occupational exposures occurring in outpatient clinics, wards, and clinical auxiliary departments from 2016 to 2022. Excluded from the study were injuries occurring outside the hospital or unrelated to clinical work, as well as data with unclear or incomplete records.

During the seven-year period from 2016 to 2022, there were a total of 695 occupational exposure incidents at West China Stomatology Hospital, Sichuan University. After excluding visiting physicians and visiting nurses who had been involved in clinical work at the hospital for less than one year, as well as non-clinical reasons for occupational exposure, there were 642 cases of occupational exposure incidents among hospital dentists, dental students, hospital dental nurses, and dental nurse students.

In this study, the ROEs were defined as occupational exposure events occurring on the same individual within 7 years, excluding the initial exposure. From the perspective of ROEs, we categorize these occupational exposure incidents into three types. Type A: Occupational exposure incidents involving individuals who experienced exposure only once during the study period (no repeated exposure). Type B: The first exposure incident for individuals who eventually experienced ROEs. This category represents the initial exposure in individuals who later had repeated exposure events. Type C: Incidents occurring after the first exposure event for individuals with ROEs. This includes all subsequent exposures, whether it is the second, third, or more. So, Type A and Type B can be referred to as initial occupational exposures (IOEs), While Type C means ROEs. In Fig. 1a, there is a more intuitive representation of the three types of occupational exposure.

Personnel types were categorized as follows: hospital dentists, dental students, hospital dental nurses, and

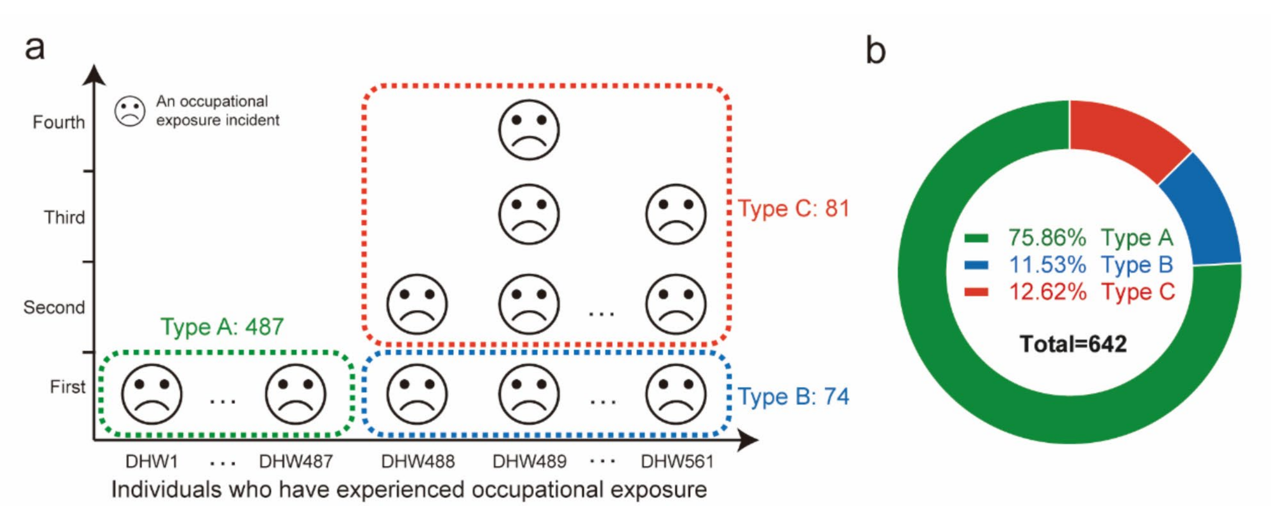

Fig. 1 Definition of the type of occupational exposure incidents, the number and the proportion of each type of incident. **a** shows the definition of occupational exposure incidents and the number of each type. **b** shows the proportion of each type of incident

dental nurse students. Hospital dentists referred to doctors formally employed by West China Hospital of Stomatology, possessing intermediate or higher professional titles and qualifications to provide clinical guidance to dental students. Dental students refers to dental students conducting clinical internships under the supervision of oral physicians, including both graduate and fifth-year undergraduate students. Hospital dental nurses were nurses officially employed by West China Hospital of Stomatology, qualified to guide clinical internships for dental nurse students. Dental nurse students were nursing students conducting clinical internships in dental care.

Treatment locations where occupational exposures occurred were classified as outpatient clinics, surgical operating rooms and wards, emergency departments, and clinical support units. The clinical support units encompass the laboratory department and sterilization supply rooms.

We categorize the timing of occupational exposure into three categories: during treatment procedures, during instrument changes, and after treatment. During treatment procedures referred to exposures occurring while healthcare workers were focused on patient care inside the mouth or body. During instrument changes indicated exposures happening when healthcare workers were retrieving or replacing instruments and were injured by improperly handled sharp objects. After treatment referred to exposures occurring while healthcare workers were handling medical waste or sterling instruments.

Table 1 The ROEs in West China Hospital of Stomatology, spanning from 2016 to 2022

Category	Details	*N*(%)
Personnel type	Hospital dentists	20(24.69)
	Hospital dental nurses	9(11.11)
	Dental students	46(56.79)
	Dental nurse students	6(7.41)
Gender	Female	63(77.78)
	Male	18(22.22)
Treatment locations	Outpatient clinics	68(83.95)
	Surgical operating rooms and wards	10(12.35)
	Emergency departments	2(2.47)
	Clinical support units	1(1.23)
Timing	During treatment procedures	35(43.21)
	During instrument changes	26(32.10)
	After treatment	19(23.46)
	Others	1(1.23)
Pathway	Syringe needles	16(19.75)
	Bars	19(23.46)
	Suture needles	15(18.52)
	Files	10(12.35)
	Probes	6(7.41)
	Knives	2(2.47)
	Splashed liquids	5(6.17)
	Others	8(9.88)

Statistical analysis involved using chi-square tests to assess differences in repeated exposure rates among different personnel types. Binary logistic regression analysis was used to analyze factors related to repeated exposure, including gender, personnel types, treatment locations, the timing of occupational exposure, and pathways of occupational exposure. Statistical significance level was accepted as $p<0.05$.

Results

From the perspective of ROEs, the number of Type A incidents was 487(75.9%), Type B incidents numbered 74(11.5%), and Type C incidents numbered 81(12.6%) (Fig. 1).

In the 81 cases of ROEs, there were 20(24.69%) cases among our hospital dentists, 9(11.11%) among hospital dental nurses, 46(56.79%) among dental students, and 6(7.41%) among dental nurse students. Males experienced ROEs 18(22.22%) times, while females experienced it 63 (77.78%) times. In terms of treatment locations, the majority of incidents happened in outpatient clinics (68 cases, 83.95%), 10(12.35%) occurred in surgical operating rooms and wards, 2 (2.47%) in emergency departments, and 1 in clinical support units. Regarding the timing of repeated exposure, out of the 81 instances, 35(43.21%) occurred during treatment procedures, 26(32.1%)during instrument changes, 19(23.46%) after treatment, and 1(1.23%) during other timings (the doctor was injured while observing another doctor's procedure). The main pathway leading to repeated exposure were dental burs, syringe needles, and suture needles, with 19(23.46%), 16(19.75%), and 15(18.52%) occurrences respectively. Additionally, files, probes, splashed liquids, and knives caused 10(12.35%), 6(7.41%), 5(6.17%), and 2(2.47%) instances of repeated exposure, while other instrument types resulted in 8 instances of repeated exposure (Table 1).

We further analyzed the characteristics of ROEs and IOEs. Table 2 illustrates the differences in the composition ratio of Treatment locations, Personnel type, genders, timing, and Pathway between repeated exposure and initial exposure. According to the chi-square test for independence, there is a significant difference among different personnel types (Table 2 & Fig. 2, $P=0.015$). From the perspective of composition ratio, compared to IOEs, the composition ratios of hospital dental nurses, dental students, and dental nurse students in ROEs are similar or slightly decreased, whereas the proportion of hospital dentists in ROEs has apparently increased. In addition, ROEs did not demonstrate a significant association with the variables of gender, treatment locations, the timing, and pathways.

Table 2 Comparison between the ROEs and the IOEs, spanning from 2016 to 2022

Category	Details	IOEs	ROEs	*p*-value
		N(%)	*N*(%)	
Personnel type	**Hospital dentists**	**66(11.76)**	**20(24.69)**	**0.015**
	Hospital dental nurses	**59(10.52)**	**9(11.11)**	
	Dental students	**382(68.09)**	**46(56.79)**	
	Dental nurse students	**54(9.63)**	**6(7.41)**	
Gender	Female	418(74.51)	63(77.78)	0.585
	Male	143(25.49)	18(22.22)	
Treatment locations	Outpatient clinics	472(84.14)	68(83.95)	0.758
	Surgical operating rooms and wards	52(9.27)	10(12.35)	
	Emergency departments	24(4.28)	2(2.47)	
	Clinical support units	13(2.32)	1(1.23)	
Timing	During treatment procedures	239(42.60)	35(43.21)	0.378
	During instrument changes	138(24.60)	26(32.10)	
	After treatment	171(30.48)	19(23.46)	
	Others	13(2.32)	1(1.23)	
Pathway	Syringe needles	126(22.46)	16(19.75)	0.423
	Bars	113(20.14)	19(23.46)	
	Suture needles	63(11.23)	15(18.52)	
	Files	59(10.52)	10(12.35)	
	Probes	48(8.56)	6(7.41)	
	Knives	42(7.49)	2(2.47)	
	Splashed liquids	42(7.49)	5(6.17)	
	Others	68(12.12)	8(9.88)	

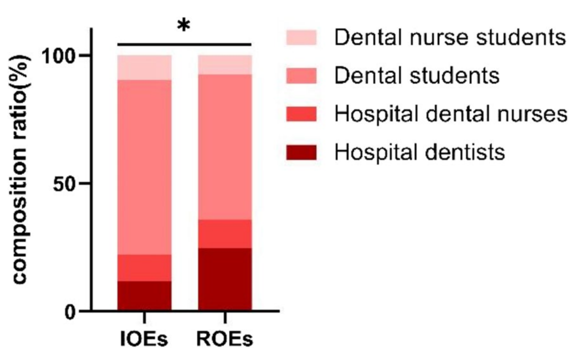

Fig. 2 A visual representation of the composition ratios of personnel types in IOEs and ROEs

Next, we established a binary logistic regression model, and the result of the Hosmer-Lemeshow test showed $p=0.994$, indicating a good fit of the binary logistic regression model. According to the binary logistic regression results, the risk of repeated exposure for dental students was 60% lower than that of hospital dentists (CI:0.22,0.73, $p=0.003$), or in other words, the risk of ROEs for hospital dentists was 2.5 times higher than that of dental students (Fig. 3 & Table 3). The risk of repeated exposure for dental nurse students was approximately 61% lower than that of hospital dentists, with marginal significance ($p=0.09$). From the perspective of pathways, the risk of ROEs from suturing needles is 5.37 times higher than that from knives (OR=5.37, $p=0.04$) (Table 3).

We also summarized the risks for the ROEs in the same individual, by comparing Type B and Type C. From the perspective of timing, 40 out of 81 repeated exposures (49.4%) occurred during the same operational circumstances as previous exposures (Fig. 4). Besides, among the 81 repeated exposures, 20 instances (24.7%) shared the same pathway as previous occupational exposures (Fig. 5).

Discussion

As mentioned earlier, healthcare workers in dental hospitals often face a high risk of occupational exposure. One of the manifestations of this high risk is the phenomenon of ROEs among healthcare workers. Reviewing previous studies, a substantial body of literature has reported the serious issue of ROEs among DHWs [22, 23]. Analyzing the hospital infection exposure data from 2016 to 2022, we found a significant number of individuals experiencing ROEs within the hospital. This piqued our interest in analyzing these ROEs events from the records, as we believe it holds significant importance. Firstly, ROEs may reflect underlying issues that need addressing in hospital infection control. Factors leading to repeated exposure may signify loopholes in protocols or areas where operational procedures need improvement. Understanding which occupational exposures are harder for healthcare workers to avoid can guide hospitals in targeted occupational exposure prevention training. Secondly, studying ROEs helps in a more precise analysis of risk factors. Due

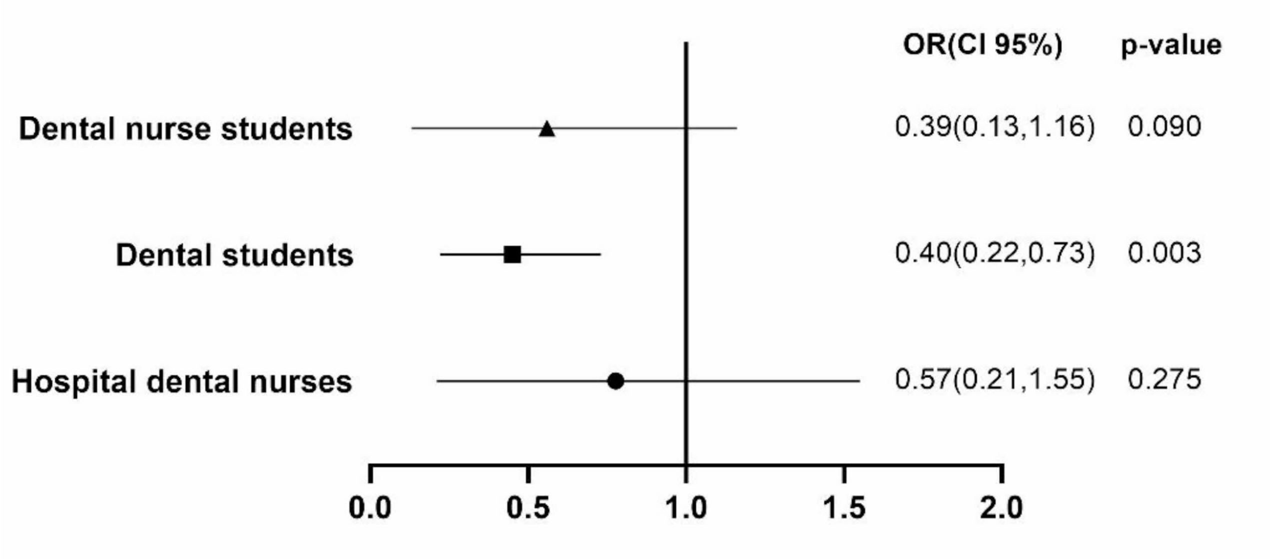

Fig. 3 The OR of ROEs for hospital dental nurses, dental students, and dental nurse students compared to hospital dentists

Table 3 Odds ratios of the association between variables and the ROEs

Category	Details	OR(CI 95%)	*p*-value
Personnel type	Hospital dentists	1	
	Hospital dental nurses	0.57(0.21,1.55)	0.275
	Dental students	**0.40(0.22,0.73)**	**0.003**
	Dental nurse students	0.39(0.13,1.16)	0.090
Gender	Female	1	
	male	0.71(0.39,1.32)	0.282
Treatment locations	Outpatient clinics	1	
	Surgical operating rooms and wards	0.95(0.39,2.30)	0.947
	Emergency departments	0.40(0.08,1.93)	0.402
	Clinical support units	0.67(0.08,5.68)	0.673
Timing	During treatment procedures	1	
	During instrument changes	1.48(0.73,3.00)	0.271
	After treatment	0.99(0.47,2.10)	0.978
	Others	0.66(0.08,5.75)	0.708
Pathway	Knives	1	
	Bars	2.64(0.56,12.38)	0.219
	Suture needles	**5.37(1.08,26.74)**	**0.040**
	Files	2.51(0.50,12.56)	0.263
	Probes	2.41(0.45,12.81)	0.304
	Syringe needles	2.24(0.48,10.49)	0.308
	Splashed liquids	2.48(0.44,13.85)	0.300
	Others	2.26(0.45,11.41)	0.325

to challenges in attaining the number of service instances, relying solely on questionnaire data often yields a composition ratio of occupational exposure influencing factors. While this ratio somewhat reflects factors contributing to occupational exposure, it's not the best indicator of risk factors. Analyzing repeated exposure data allows for calculating the repeated exposure rates among different personnel types, providing a more accurate reflection of exposure risks across various professions. Lastly, studying ROEs in records helps reduce errors caused by underreporting. Many past studies have shown that even with strict reporting requirements for occupational exposure in healthcare institutions, a significant number of cases still go unreported [24]. This limitation affects exposure rates and the calculation and analysis of risk factors based on hospital records. However, studying repeated exposure events in hospital records allows for analyzing the rates and risk factors of repeated exposure within a

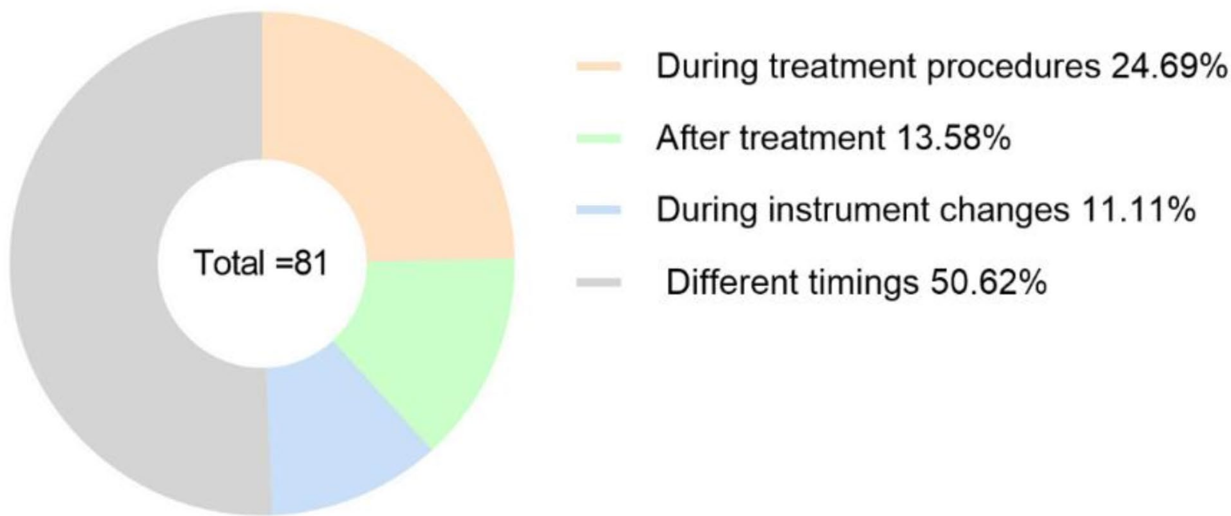

Fig. 4 The proportion of ROEs occurring due to the same timing as previous exposures

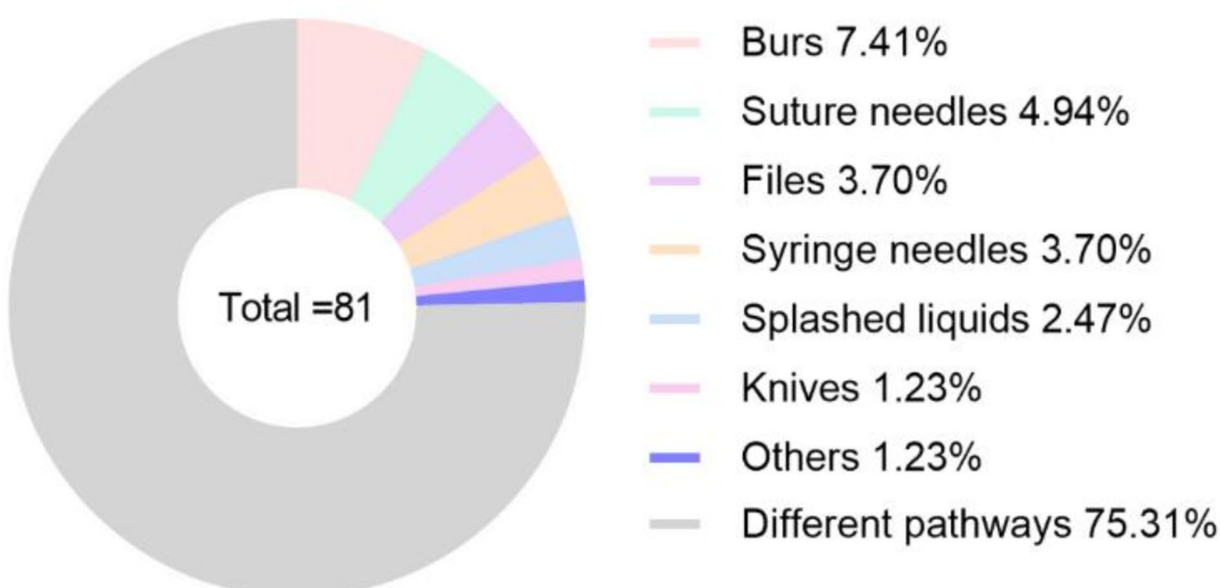

Fig. 5 The proportion of ROEs occurring due to the same pathway as previous exposures

relatively willing-to-report group at least, potentially reducing errors caused by underreporting and providing a more accurate understanding of risk factor severity.

Clinical staff in a university-affiliated dental teaching hospital can be categorized into four roles: hospital dentists, dental students, hospital dental nurses, and dental nurse students. Previous research has suggested that the type of personnel can influence the occurrence of occupational exposure due to differences in skill levels. Typically, students are considered to face a relatively high risk of occupational exposure, possibly even higher than their supervisors, due to their lack of experience [20, 23, 25, 26]. Consequently, the focus of occupational exposure education has traditionally leaned towards students. In our study, whether it was the first-time exposure or repeated exposure, dental students accounted for the highest proportion. According to the traditional interpretation, one might conclude that students have the highest exposure risk. However, the high proportion of students in exposure incidents does not necessarily mean that their occupational exposure risk is higher. For example, this could simply be due to the fact that there are more students overall. Therefore, by comparing the composition ratios of risk factors between first-time exposures and repeated exposures, we can avoid this issue. Specifically for personnel types, this comparison effectively reflects the rate of repeated exposure. Shockingly, hospital dentists had the highest risk of ROEs over these seven years, and this finding was statistically significant. In contrast, the risk of the ROEs was lower for dental students and dental nurse students. It is undeniable that hospital dentists often engage in more complex and intricate tasks, which may increase the risk of occupational exposure. Previous research has also found that more experienced doctors may be less inclined to adhere to occupational exposure prevention strategies [22, 27]. Hospital dentists may be the focal group for occupational exposure education in the foreseeable future.

Gender is one of the factors influencing occupational exposure. However, previous studies have shown varying impacts of gender on occupational exposure due to differences in study populations. A study conducted in Australia focusing on dentists and dental students indicated that females were more likely to experience occupational exposure in the form of needlestick injuries [20]. Some studies suggest that males are more prone to occupational exposure, with male healthcare workers even facing significantly higher risks compared to females [28, 29]. In our study, we examined the risk of ROEs among male and female healthcare workers in dental hospitals and found no significant differences, not even slight ones. This finding aligns with many other studies that have not observed significant gender differences in occupational exposure [22, 30]. While gender may influence an individual's fear of occupational exposure events and adherence to operational standards [31], we believe that these influences can be mitigated through training and other factors, which may explain the lack of significant gender impact on ROEs in our study.

Due to the varying nature of work undertaken in different areas of a hospital, occupational exposure risks differ across these settings. Previous research has commonly indicated that operating rooms, where frequent contact with patient fluids and sharp instruments is required, are associated with higher risks of occupational exposure. Studies from King Khaled Eye Specialist Hospital have shown that, for ophthalmologists, the operating room accounts for 60.7% of needlestick-related occupational exposure events [6]. Research from Ethiopia also highlights the operating room as the most common site for bloodborne occupational exposure [4]. Additionally, the nature of emergency work may be related to the occurrence of occupational exposure; the high intensity of emergency work and inadequate rest can elevate exposure risks [32, 33]. In our study, we categorized workplaces within a dental hospital as outpatient clinics, surgical operating rooms and wards, emergency departments, and clinical support units. The results indicated no significant differences in causing ROEs among outpatient clinics, surgical operating rooms and wards, emergency departments, and clinical support units in our hospital. Many dental procedures are performed in outpatient clinics, where healthcare workers frequently come into contact with high-speed rotating burs, various sharp instruments, patient fluids, and aerosols. From this perspective, outpatient departments in dental hospitals are also common sites for occupational exposure. Previous research has not extensively explored the occupational exposure risks between departments in dental hospitals. We believe that various workplaces in dental hospitals may carry higher risks of occupational exposure, particularly outpatient clinics whose risks should not be underestimated and may be similarly high as those in ward and operating rooms. However, we acknowledge that the sample size of exposure events in emergency rooms and non-clinical departments in this study is limited, and the analysis results may deviate from real-world scenarios.

Occupational exposure is commonly associated with the patient treatment process. In previous research, the challenges faced during treatment procedures are considered the greatest due to the limited space, poor visibility, and patient movements [19, 21, 23]. However, during our statistical analysis, we found that occupational exposures occurring during treatment procedures are only a part of the overall occupational exposure. Unfortunately, many occupational exposures also occur during instrument changes and after treatment. Our results show that the risk of repeated exposures during these three timings does not significantly differ. This implies that all three timings require healthcare workers' attention and caution. Further analysis of 81 ROEs incidents revealed that 49.4% of these occurred during the same timing as previous exposures (Fig. 4). Although this striking figure may be related to broad grouping in the study, it does reflect the level of occupational exposure risk during these three timings. Occupational exposures during instrument changes and after treatment are particularly concerning, which may be related to healthcare workers' attitudes and hospital training. Ensuring standardized procedures and protocols is crucial in reducing occupational exposure risks.

Many studies have paid great attention to the pathways of occupational exposure [4, 14, 20, 33]. Various dental procedures performed by dentists often involve the use of high-speed dental handpieces and sharp instruments, which are essential tools for treating most oral diseases [34]. Occupational exposures frequently involve sharp instruments [34], and in this study, sharp instruments were identified as the primary cause of occupational exposure. Both initial and ROEs commonly involve injection needles, dental burs, suturing needles, files, probes, and knives. Dental prosthesis, orthodontic appliances, and sharp teeth of patients can also cause occupational exposures and repeated exposures, although data on these are relatively limited in this study. Additionally, aerosols and spatter generated during procedures such as high-speed dental handpiece use and irrigation are important pathways for occupational exposure. In our study, we compared the proportions of these pathways between initial and ROEs and found mostly no significant differences. However, in the analysis using binary logistic regression, the risk of ROEs due to suturing needles was over five times higher compared to scalpels and was statistically significant. Nevertheless, due to the small sample size, further research is needed to verify whether this result reflects clinical practice. Therefore, these factors can be considered equally important in causing ROEs among DHWs, and no pathway should be disregarded by healthcare workers themselves or hospital infection control departments. Furthermore, our statistical analysis of the reasons for multiple occupational exposures in the same individual showed that the proportion of repeated exposures through the same pathway was as high as 24.7% (Fig. 5). It is important to note that many exposure pathways can be prevented through simple preventive measures. For instance, wearing face shields and goggles can protect against exposure caused by splashing and spattering. Despite this, statistics still show that some healthcare workers experience ROEs due to splashes, indicating a lack of seriousness among a minority of healthcare workers regarding occupational exposure. This suggests that many healthcare workers may not have learned from previous exposures, which could also indicate insufficient training provided by hospitals. From another perspective, current control strategies are not yet sufficient to completely prevent occupational exposures caused by certain pathways (especially sharp injuries and needlesticks). Hospitals need to strengthen training for healthcare workers and develop updated control strategies.

We believe that data on ROEs can guide the direction of infection control efforts in hospitals. Analyzing data on ROEs can help identify high-risk groups within the hospital for occupational exposures. Consequently, we can provide more targeted prevention education for individuals experiencing ROEs, which is advantageous for achieving better control of occupational exposures with limited resources. Targeted prevention and control training should involve intensifying training efforts for high-risk groups while providing more effective educational methods. Some studies suggest that solely providing occupational training or skill training may not effectively reduce the occurrence of occupational exposures [21]. Some conventional teaching methods often convey knowledge that is dry, difficult to understand, and not synchronized with clinical work [21]. Tailored prevention education for different groups is necessary; for instance, experienced doctors may not be engaged by generic educational materials. Research from Iran suggests that enhancing healthcare workers' perception of risks and understanding the severity of occupational exposure risks may be crucial for improving occupational exposure control [35].

ROEs may also indicate areas for improvement in equipment and operational processes. Previous research has indicated that using safer equipment and adopting safer operational procedures are undoubtedly beneficial for reducing occupational exposures [36, 37]. The occurrence of ROEs may indicate deficiencies in certain instruments or operational procedures in terms of safety. For example, research suggests that avoiding unnecessary use of sharp suturing needles can reduce needlestick injuries [38]. High-quality evidence demonstrates that using blunt needles significantly reduces the risk of surgical personnel and their assistants contracting infectious diseases during a series of surgeries by reducing the number of needlestick injuries [9]. This approach may also be applicable in dentistry. Furthermore, reducing occupational exposures occurring during non-treatment operations is also a critical area for consideration. Currently, researchers are also working on developing new medical waste disposal devices, instruments transfer, and retrieval devices in an attempt to reduce occupational exposures [39, 40]. Although ideal results have not yet been achieved, we believe that improving the usability and effectiveness of medical waste disposal devices may be a crucial pathway to reducing persistent occupational exposures.

Conclusions

Analyzing ROEs provides practical insights. In dental teaching hospitals, hospital dentists with teaching qualifications are more likely to experience repeated exposures compared to students. This suggests that the focus of educational efforts should be directed towards this kind of DHWs. Additionally, there are no significant differences in the impact of different treatment locations, timing and pathways of occupational exposure on the occurrence of ROEs. However, it is important to acknowledge that these factors may present equally high risks, and maintaining vigilance towards them is essential.

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Authors' contributions

All authors participated in the study. The study design was conducted by YZ, ZL and JX. Material preparation was performed by YZ and QX. Data analysis was performed by JX, PP and FS. The manuscript was written by JX, PP and YG. All authors have read and approved the final version of the manuscript.

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Data availability
Data will be made available on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was granted by the Medical Ethics Committee of West China Hospital of Stomatology, Sichuan University (Approval No. WCHSIRB-2024-299).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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