

Evaluation of the Effectiveness of Multi-dimensional Protective Care Interventions in Reducing Occupational Exposure Risks to Hydrofluoric Acid in Dental Practice

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Abstract: *Objective:* To investigate the efficacy of multidimensional protective nursing interventions in reducing occupational exposure risks to hydrofluoric acid in dental departments. *Methods:* The study was conducted between January 2024 and January 2025, involving 60 healthcare workers who were randomly assigned to groups. The control group (n = 30) received conventional occupational protective nursing care, while the observation group underwent multidimensional protective nursing interventions. *Results:* Following intervention, the observation group demonstrated significantly higher scores than the control group in knowledge of hydrofluoric acid occupational exposure, occupational exposure risk perception, and protective skill operation ($p < 0.05$). Emergency response capability scores and protective behavior implementation scores were also higher in the observation group ($p < 0.05$). Compared to the control group, the observation group exhibited higher occupational health satisfaction rates and lower occupational exposure incidence rates ($p < 0.05$). *Conclusion:* Multidimensional protective nursing interventions effectively enhance dental healthcare personnel's awareness and protective capabilities regarding hydrofluoric acid occupational exposure, improve compliance with protective measures, and significantly reduce occupational exposure risks. This approach warrants promotion and application in occupational protective nursing interventions within dental departments.

Keywords: Multi-dimensional protective care; Dental department; Hydrofluoric acid; Occupational exposure; Protection

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1. Introduction

In clinical dental practice, healthcare personnel frequently handle various chemical materials, including numerous irritants. Improper use or inadequate protective measures may cause harm to the human body^[1]. Hydrofluoric acid, as an etchant, is widely used in dentistry. This chemical reagent possesses strong corrosive and penetrating properties. During procedures, inadequate protective measures or non-standardized practices may lead to

occupational exposure incidents such as skin contact or respiratory inhalation of hydrofluoric acid. Mild cases may present with skin redness, swelling, pain, and mucosal burns, while severe cases may result in skeletal damage, hepatic and renal impairment, and pose a threat to individual safety^[2]. Therefore, effective protective nursing interventions are essential during hydrofluoric acid procedures in dentistry to prevent and reduce occupational exposure incidents. Multidimensional protective nursing interventions emphasize a comprehensive approach encompassing cognition, behavior, environment, and emergency response to establish a holistic protective system, thereby enhancing occupational exposure prevention efficacy^[3]. Based on this, the present study will implement multidimensional protective nursing interventions in dental departments to investigate their effectiveness in reducing hydrofluoric acid occupational exposure risks, aiming to provide evidence for optimizing occupational protection management in dental settings. The findings are reported below.

2. Materials and methods

2.1. General information

This study was conducted between January 2024 and January 2025, involving 60 healthcare professionals from the Department of Stomatology at our hospital. Participants were randomized into two groups of 30 each using a random number table. The control group comprised 12 males and 18 females, aged 24–45 years with a mean age of (34.53 ± 3.64) years. Professional titles comprised 15 junior, 9 intermediate, and 6 senior staff. The observation group included 11 males and 19 females aged 23–45 years (mean 34.39 ± 3.58 years), comprising 14 junior, 10 intermediate, and 6 senior staff. No significant differences existed between groups in these baseline characteristics ($p > 0.05$), rendering them comparable.

2.2. Methodology

2.2.1. Control group

Implement routine protective care within the group. Healthcare personnel undergo training upon induction regarding occupational hazards of hydrofluoric acid and fundamental protective measures, gaining knowledge of its properties and protective protocols. During routine operations, basic protective equipment such as masks, gloves, and work attire is worn as required. The operating area is regularly ventilated, with work surfaces wiped down daily using clean water. Following occupational exposure incidents, emergency procedures are carried out under the guidance of the nursing team leader.

2.2.2. Observation group

Implemented multidimensional protective nursing interventions within the group, addressing four dimensions: cognition, behavior, environment, and emergency response. Specific interventions are as follows.

(1) Cognitive dimension interventions

Organize monthly specialized training sessions for dental staff in the observation group on occupational exposure prevention for hydrofluoric acid. Content includes the chemical's properties, hazards, exposure risk factors, protective protocols, and emergency response procedures. Post-training assessments combine written examinations with practical evaluations; those failing must retake training until competent. Regularly disseminate hydrofluoric acid exposure case studies and protective tips via departmental work groups. Collaborate with hospital infection control specialists and dental practitioners to develop

a hydrofluoric acid protection handbook, ensuring key protective knowledge was prioritized. Display intuitive hydrofluoric acid protection flowcharts in treatment rooms to enhance staff awareness ^[4].

(2) Implement nursing interventions from a behavioral perspective

Based on clinical practices involving hydrofluoric acid in dental departments, establish comprehensive protective procedures for handling hydrofluoric acid. Clearly define key protective measures before, during, and after procedures. Prior to handling, wear acid-resistant gloves and protective clothing. Use containers made of polytetrafluoroethylene (PTFE) to store hydrofluoric acid; the use of ordinary glass or plastic containers is strictly prohibited. During procedures, strictly control hydrofluoric acid usage and prevent liquid splashes. Employ a dropper for dispensing rather than pouring. Post-procedure, promptly clean work surfaces: first rinse the surface three times with clean water, then wipe with a 5% sodium bicarbonate solution to neutralize residual hydrofluoric acid, and finally dry with sterile gauze. Establish clear waste disposal procedures: place waste in dedicated corrosion-resistant sealed containers for daily collection by the hospital's designated hazardous waste disposal agency. Establish a protective quality control supervision team within the department, led by the Head Nurse, to conduct daily inspections and supervision of healthcare personnel's operational practices. Promptly identify non-compliant behavior, implement corrections, and maintain records. Hold weekly review meetings to identify issues in protective measures and implement targeted corrective actions.

(3) Optimize operational interventions from an environmental perspective

The operating room shall be equipped with dedicated acid-resistant workbenches featuring hydrofluoric acid-resistant ceramic worktops. These shall incorporate splash-proof edges and be fitted with waste collection trays beneath the worktop, connected to specialized corrosion-resistant waste drainage pipes. Enhance emergency flushing facilities: skin flush taps shall feature constant temperature and pressure design with long handles for accessible full-body rinsing; eye wash stations shall employ dual-nozzle configurations with adjustable spacing, incorporating saline solution reservoirs. Regularly inspect flushing pressure and nozzle patency, undertaking maintenance as required to ensure operational readiness. Install ventilation systems within work areas to maintain air circulation and minimize hydrofluoric acid concentrations. Strengthen management of items within the operating room. Ensure hydrofluoric acid is managed by designated personnel and stored in a dedicated cabinet. The storage cabinet shall be constructed of corrosion-resistant steel, equipped with ventilation, and labelled with hazard warnings to alert medical staff. Store hydrofluoric acid separately from other chemicals such as alcohol and oxidizing agents to prevent chemical reactions caused by mixing ^[5].

(4) Interventions from an emergency response perspective must first establish dedicated contingency plans

Tailored to common hydrofluoric acid exposure scenarios in dental departments, detailed emergency protocols should be developed for skin and ocular contact. These plans must clearly define procedures, assign responsibilities, and refine reporting mechanisms to provide a basis for managing sudden occupational exposures. Conduct quarterly departmental emergency response drills for hydrofluoric acid occupational exposure, simulating diverse exposure scenarios. This enables healthcare personnel to progressively master emergency procedures such as flushing and disinfection through practical experience, thereby enhancing their emergency response capabilities. Summarize drill outcomes to identify deficiencies and propose improvement measures, optimizing the emergency response plan ^[6]. Concurrently, ensure adequate stockpiles of emergency supplies within the department, including common

treatment items such as physiological saline and 2% calcium gluconate gel. Conduct regular checks on the expiry dates of these supplies to facilitate timely replacement or replenishment. Furthermore, the dental department should strengthen coordination with departments such as dermatology and emergency medicine to ensure rapid and effective post-exposure treatment for healthcare personnel, thereby mitigating risks.

2.3. Observation indicators

- (1) Theoretical assessments were conducted on two groups of healthcare personnel regarding their knowledge of occupational exposure to hydrofluoric acid and risk perception. Practical assessments evaluated their protective skills and operational procedures. Each assessment component was scored out of 100 points, with higher scores indicating greater proficiency.
- (2) Assess the implementation of protective measures during hydrofluoric acid handling among both groups of healthcare personnel, scoring from 0 to 10 points, where higher scores indicate stricter adherence. Evaluate the emergency response capability for patient management, with a maximum score of 100 points, where the score is directly proportional to the demonstrated capability.
- (3) Statistical analysis of occupational exposure incidents occurring in both groups during the study period, comparing incidence rates. Survey healthcare personnel regarding their satisfaction with occupational health, calculating and comparing satisfaction levels.

2.4. Statistical analysis

This study employed SPSS 23.0 software as the data analysis tool. Normally distributed quantitative data were presented as mean \pm standard deviation (SD) and analyzed using the *t*-test. Categorical data were expressed as percentages (n, %) and assessed using the chi-square test. *p*-values were used to determine statistical significance, with $p < 0.05$ indicating a significant difference between groups.

3. Results

3.1. Comparison of occupational exposure knowledge mastery, risk perception and protective skill operation scores between the two groups

The scores in the observation group were significantly higher than those in the control group ($p < 0.05$), as shown in Table 1.

Table 1. Comparison of occupational exposure knowledge mastery, risk perception and protective skill operation scores between two groups ($\bar{x} \pm s$, points)

| Group | Example count | Knowledge mastery assessment | Risk perception score | Protective skill operation assessment |
|-------------------|---------------|------------------------------|-----------------------|---------------------------------------|
| Observation group | 30 | 89.56 \pm 6.14 | 92.33 \pm 4.84 | 88.45 \pm 4.29 |
| Control group | 30 | 83.74 \pm 7.21 | 88.57 \pm 5.12 | 84.56 \pm 4.53 |
| <i>t</i> | | 3.366 | 2.923 | 3.415 |
| <i>p</i> | | 0.001 | 0.005 | 0.001 |

3.2. Comparison of emergency response capability scores and implementation of protective measures between the two groups

The observation group demonstrated higher scores for both protective behavior adherence and emergency response capability ($p < 0.05$), as shown in **Table 2**.

Table 2. Comparison of emergency response capability scores and protective behavior implementation scores among all healthcare personnel ($\bar{x} \pm s$, points)

| Group | Example count | Protective behavior implementation score | Emergency response capability score |
|-------------------|---------------|--|-------------------------------------|
| Observation group | 30 | 9.12 ± 0.83 | 89.66 ± 7.24 |
| Control group | 30 | 6.28 ± 1.21 | 65.15 ± 8.37 |
| <i>t</i> | | 10.601 | 12.131 |
| <i>p</i> | | 0.000 | 0.000 |

3.3. Comparison of healthcare workers' occupational health satisfaction and occupational exposure incidence rates

No occupational exposures occurred among healthcare personnel in the observation group, with occupational health satisfaction reaching 96.67%. This represented a significant difference compared with the control group ($p < 0.05$), as shown in **Table 3**.

Table 3. Comparison of occupational health satisfaction and occupational exposure incidence rates between two groups of healthcare personnel [n (%)]

| Group | Example count | Occupational exposure incidence rate | Occupational health satisfaction |
|-------------------|---------------|--------------------------------------|----------------------------------|
| Observation group | 30 | 0 (0.00) | 29 (96.67) |
| Control group | 30 | 9 (30.00) | 20 (66.67) |
| χ^2 | | 10.588 | 9.017 |
| <i>p</i> | | 0.001 | 0.003 |

4. Discussion

Hydrofluoric acid is extensively employed in clinical dentistry for procedures such as tooth restoration and orthodontic bonding. Possessing potent corrosive properties, it can inflict severe damage to human tissue, with even low-concentration exposure posing significant health risks. During hydrofluoric acid treatments in dental practice, occupational exposure hazards including skin contact, respiratory inhalation, and ocular mucosal irritation exist, compromising the health of healthcare personnel and disrupting clinical operations^[7]. Historically, protective interventions for dental staff during hydrofluoric acid procedures have primarily comprised basic protective equipment and post-exposure emergency protocols. The absence of a systematic protection framework has failed to comprehensively address all occupational exposure risks, resulting in suboptimal protective outcomes and persistent occupational exposure incidents^[8]. Under this multidimensional protective nursing intervention, the present study addressed occupational exposure risks through comprehensive, end-to-end prevention and control across four dimensions: cognition, behavior, environment, and emergency response. This approach yielded

favorable application outcomes.

The findings of this study indicate that the observation group demonstrated higher proficiency in occupational exposure knowledge and risk perception scores, alongside superior protective skill operation scores compared to the control group, with $p < 0.05$. Possessing knowledge of hydrofluoric acid occupational exposure risks and protective measures is a prerequisite for ensuring the implementation of protective work. Multi-dimensional protective nursing interventions, including specialized training for healthcare personnel and diverse health education initiatives, enhance their understanding of hydrofluoric acid hazards and protective measures. This facilitates the establishment of correct protective concepts and strengthens protective awareness^[9]. Within behavioral interventions, establishing standardized hydrofluoric acid handling and protective protocols clarifies requirements at each operational stage. Supervision teams conduct inspections to promptly correct non-compliant practices, thereby enhancing protective capabilities and compliance with safeguards^[10]. Consequently, the observation group demonstrated higher protective behavior compliance scores ($p < 0.05$). Multidimensional protective nursing interventions encompass optimizing the operational environment, improving protective facilities, and strengthening the standardized management of protective equipment to provide healthcare workers with a safe working environment. This requires the use of dedicated acid-resistant workbenches (with hydrofluoric acid-resistant ceramic worktops and splash-proof edges), the provision of emergency rinsing facilities (skin rinsing taps and eye wash stations), and the installation of explosion-proof ventilation equipment to control gas concentrations, thereby reducing occupational exposure risks^[11]. Consequently, the observation group exhibited lower occupational exposure risks and higher occupational health satisfaction, $p < 0.05$. Comparing emergency response scores between groups, the observation group scored lower than the control group, $p < 0.05$. Within emergency response nursing interventions, developing comprehensive contingency plans and organizing emergency drills enhance healthcare workers' emergency response capabilities, thereby minimizing harm from occupational exposure^[12].

5. Conclusion

In summary, the implementation of multidimensional protective nursing interventions in dental departments contributes to enhancing healthcare workers' awareness of occupational exposure to hydrofluoric acid, strengthening protective consciousness and adherence to protective measures. This approach thereby prevents and reduces the occurrence of occupational exposure risks, continuously improves emergency response capabilities, and better safeguards the occupational health of healthcare personnel, demonstrating significant value for widespread application.

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Disclosure statement

The author declares no conflict of interest.

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