Review Article

Chemical Occupational Hazards in Dentistry: A Comprehensive Review

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Abstract

Dentists are exposed to various types of chemicals while providing care that may be potentially toxic and can pose a serious health hazard in the absence of appropriate precautionary measures. These include hazardous chemical agents used in clinical dentistry include Mercury, powdered natural rubber latex (NRL), disinfectants, methyl methacrylate, metal alloys, silica and nitrous oxide (N_2O). Exposure to these chemicals can result in acute and chronic health effects. Acute effects include skin and eye irritation, respiratory distress, and allergic reactions, while chronic exposure can lead to more serious conditions such as asthma, neurological disorders, and even cancer. This review article aims to identify and categorize the common chemicals used in dental practices and their associated health hazards and to provide safety guidelines and best practices for minimizing exposure to hazardous chemicals in dental settings.

Keywords: Chemical hazard, dentistry, occupational risk

Introduction

Dentists are exposed to various types of chemicals while providing care that may be potentially toxic and can pose a serious health hazard in the absence of appropriate precautionary measures. Most of the dental materials undergo an extensive range of tests both before and after use.[1] Even so, some dental materials in direct contact can be harmful or sometimes they are aerosolized during high-speed cutting and finishing and may thereby be inhaled by dental staff. If the health effects of these chemicals are not known, they can result into health problems taking years to manifest.[2]

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These chemical substances usually act in three ways i.e. local action, inhalation and ingestion. The illness may occur depending on the duration of exposure, quantity of exposure and individual susceptibility.[3] Dental professionals, including dentists, dental hygienists, dental assistants, and laboratory technicians, are regularly exposed to a variety of chemicals that include mercury, powdered natural rubber latex (NRL), disinfectants, methyl methacrylate, metal alloys, silica and nitrous oxide (N_2O).[4]

Exposure to these chemicals can result in acute and chronic health effects. Acute effects include skin and eye irritation, respiratory distress, and allergic reactions, while chronic exposure can lead to more serious conditions such as asthma, neurological disorders, and even cancer.[5]This review article aims to identify and categorize the common chemicals used in dental practices and their associated health hazards, to review the scientific literature on the health effects of these chemicals, and to provide safety guidelines for minimizing exposure to hazardous chemicals in dental settings. Thorough understanding of these hazards and implementing effective safety protocols can help to promote awareness and education among dental professionals, thereby promoting overall occupational health and well-being.

Hazards from chemical used for treatment

Nitrous oxide

Exposure to nitrous oxide in dental offices is usually small, but the exposure is continuous and occurs over the long term. [6] Workers are exposed to N_2O while administering the anaesthetics gas to patients. Several human studies have shown that occupational exposure to N_2O, may cause reduced fertility, congenital malformations (anaesthetic gases slow the rate of cell division and increase the rate of abnormal cell formation and chromosomal aberrations), spontaneous abortions, and neurologic, renal, and liver disease as well as documented decreases in mental performance, audiovisual ability, and mental dexterity in susceptible individuals.[1]

Hazards from chemical used for cleaning and disinfection

Formaldehyde

Liquid and vapour forms of formaldehyde may cause severe abdominal pain, nausea, vomiting and eye irritation and also it is a common cause of allergic contact dermatitis.[7] Formaldehyde is classified as a known human carcinogen by several health organizations, including the International Agency for Research on Cancer (IARC). The individuals allergic to formaldehyde are usually develop eczema on the hands or face as shown in Figure 1. The characteristic features of formaldehyde allergy are anaphylactic reaction or shock and generalized urticaria.[8]

Figure 1. Eczema on hands due to formaldehyde allergy

Alcohol based hand sanitizer (ABHS)

Commonly used sanitizer contains ethanol or isopropyl alcohol that may result in contact irritant dermatitis, which may vary in intensity from mild to concerning, can present as dryness, itching, irritation, pruritis, and skin cracking as shown in Figure 2. Similarly, allergic contact dermatitis can also vary from mild to severe symptoms and may sometimes be accompanied by respiratory distress. Even though less widely reported, contact urticaria syndrome has also been associated with alcohol sanitizer use. It presents as swelling, redness, burning sensation, tingling, and/or itching within minutes (up to an hour) after applying alcohol. This urticarial reaction is localized and is characterized by wheal-and-flare.[9,10] Ethanol-based hand sanitizers can cause alcohol poisoning on swallowing that can induce intoxication and hypoglycaemia. The use of alcohol-

based hand sanitizers is also associated with a small but measurable risk of fires and burns.[9,10]

Figure 2. Contact dermatitis due to ABHS

Detergent

Detergents are also widely utilized in dentistry for cleaning a variety of surfaces but it may contain possible eye, skin, and respiratory irritants. Some products may cause allergic dermatitis or contain sensitizers such as nickel or limonene.[11]

Figure 3. Contact dermatitis due to detergent

Low level disinfectant

This group of chemicals include chlorine compounds, quaternary ammonium salts, iodophors and phenolic compounds that are used widely for disinfection in dental clinics. Most of these also act as an eye, skin, and respiratory irritants, particularly when concentrated.[11]

Glutaraldehyde

The most serious adverse health effect documented among employees exposed to glutaraldehyde vapor is occupational asthma, a chronic condition characterized by bronchial hyperresponsiveness. Reactions can be either immediate or delayed, with a latent period ranging from a few weeks to several years from the onset of exposure. In addition, an increased prevalence of irritant symptoms, including itching of the eyes with increased lacrimation (tearing), rhinitis, sore throat, coughing and burning nose have also been reported. Glutaraldehyde also acts as a contact allergen, typically on contact with solutions containing more than 2% glutaraldehyde, giving rise to contact dermatitis, usually on the hands but occasionally on the face.[12]

Orthophthalaldehyde

It is an alternative for glutaraldehyde although, it also comes with certain health hazards and act as respiratory and skin irritant. It may result in dyspnoea and dry cough with a subsequent diagnosis of bronchial asthma. It also results in immediate and late-phase skin reactions that are immunoglobulin (Ig) E-mediated and manifest as serous papules and urticaria of the skin.[13]

Figure 4. Papular urticaria of hands due to Orthophthalaldehyde

Hydrogen peroxide

Hydrogen peroxide is designated as a hazardous substance when present at concentrations above 5%. Direct exposure of skin or eyes to hydrogen peroxide may cause severe irritation or burns (Figure 5) of skin, oral and ocular mucosae, respiratory tract with burning, erythema and oedema, while ingestion may be irritating to the oesophagus and stomach, causing bleeding and sudden distension. Nausea and vomiting were the most common symptoms secondary to ingestion. Hydrogen peroxide is

cytotoxic in nature, the end result of which can be cell death. While hydrogen peroxide may be injurious to tissue directly, secondarily derived oxidants such as hydroxyl radical as well as hypochlorous acid can also contribute to tissue injury.[14]

Figure 5. Chemical burn due to hydrogen peroxide

Ethylene Oxide

Exposures to ethylene oxide may result in eye pain and blurred vision, sore throat, respiratory irritation and lung injury, headache, nausea, dizziness, vomiting, diarrhoea, shortness of breath, convulsions, skin irritation and cyanosis. Chronic exposures to ethylene oxide have mutagenic potential and arelinked with neurotoxicity, peripheral paralysis, muscle weakness, cancer, reproductive disorders, etc. [15]

Hazards from other chemicals

Latex

The population at risk for latex allergy includes healthcare workers due to sweating and multiple gloves changing or latex-fruit syndrome (allergy to various fruits).[16] Natural rubber latex (NRL) gloves dusted with cornstarch powder are the most often used but dental personnel should also note that latex is also present in other equipment like Adhesive bandages and tape, Air or water syringe tips, Amalgam carriers, Anaesthetic masks, Bite blocks, Impression materials, Irrigation tubing, IV tubing and bags, Mixing bowls, Operative masks with rubber ties, Orthodontic rubber bands, Oxygen masks, Polishing discs, Prophy cups, Rubber dams, Suction tips, suction tubing, Syringes, eyewear, clinical gowns and rubber dam.[17]

The gloves and the mask may be a source of allergies – primarily in those persons who use rubber products on a regular basis.[17] The etiology of latex sensitivity is based on a reaction to the plant containing allergenic proteins in natural rubber. Referred to as Type I allergy (Atopy) to natural rubber latex protein, allergic reactions can be severe sometimes fatal due to the repeated exposure to latex products. [17,18]

Turjanamaa et al. [19] established that 2.8-17% of the employees of health service are allergic to latex and 8.8% of dentists were found to be allergic. The American Dental Association (ADA) began investigating the prevalence of Type I latex hypersensitivity in dental personnel in 1994 and results showed that 6.2% of participants were positive for Type I latex hypersensitivity.[20]

Clinical signs of the immediate allergic reactions to latex can include rash, conjunctivitis accompanied by lacrimation and swelling of eyelids, mucous rhinitis, edema, bronchospasms, and allergic shock. In case of latex sensitization it presents as: contact urticaria and dermatitis or atopic dermatitis (Figure 6).[21] Corn-starch or the so-called absorbable dusting powder also plays an important role in latex allergies. The powder does not include detectable proteins but, as some studies demonstrated, the health service employees who had an anaphylactic reaction to the dusting powder were positive in skin tests. [21]Chemical agents involved in the production of gloves process such as benzothiazole, thiuram, and carbamate also have strong allergenic potential.[22]

Figure 6. Contact dermatitis due to NRL gloves

Mercury

Although amalgam containing mercury is no longer as widely used as it once was, it is nevertheless frequently encountered in dental procedures and remains a hazard for the dental staff. Hypersensitivity to mercury or its salt causes an inflammatory and sometimes vesiculating reaction when it is in contact with skin.[23]According to decreasing toxicity of mercury it is classified as organomercury, mercury vapour, and inorganic mercury.[24] The mercury body burden of dental personnel has often shown higher levels than the general population posing a greater risk of exposure to mercury for dentist.[25] Urine mercury level is used for determining long time exposure to mercury. The level at which symptoms of subtle, non-specific chronic mercury intoxication are recognized at concentrations above 25–50 mg Hg/l urine. Because of the diffuse nature of symptoms diagnosis of chronic mercury intoxication is always based on history of exposure. Weakness, fatigue, loss of appetite, gastrointestinal disturbances, diarrhoea, desquamative dermatitis and renal disturbances (nephritis) are described as symptoms occurring after long time exposure to low level exposure.[26] The active component (methyl and ethyl mercury) has a particular affinity for brain tissue. Classical symptoms after high exposures are tremors of fingers, limbs and tongue, insomnia, headache, progressive, tremulous illegible handwriting with slurred speech and erethism.[24] Another method to evaluate occupational exposure is to measure the air mercury level at the workplace. WHO has decided an exposure limit of 50 mg Hg/m3 air. Oral manifestation may include metallic taste, hypersalivation, gingivitis or stomatitis.[27]

Acrylic Resin

Dental polymer materials based on methyl methacrylate (MMA), seem to appear to affect several body systems, including the skin, the respiratory tract, and the neurological system in dental personnel. Monomers used in dentistry present severe cytotoxicity (monocytes, granulocytes and endothelial cells).[28] The free monomers during polymerization may cause a wide range of adverse health effects such as irritation to skin, eyes or mucous membranes, allergic dermatitis, and paraesthesia in the fingers. Additionally, disturbances of the central nervous system such as headache, pain in the extremities, nausea, loss of appetite, fatigue, sleep disturbances, irritability, loss of memory, and changes in blood parameters may also be noted.[29] Allergic respiratory problem due to dental materials is also an important occupational hazard as it can lead to dyspnoea, wheezing, coughing, rhinorrhoea and it can trigger or aggravate occupational asthma. [30] It has been shown that MMA affects the integrity of latex examination gloves, which not only allows MMA to penetrate the skin, but also allows significant virus leakage.[31]

Dental alloys

Metallic dusts or fumes of dental alloys that are generated during the casting and finishing of the metal are potentially toxic to the dentist and other dental laboratory workers. Both the International Agency for Research on Cancer (IARC) and the National Institute of Occupational Safety and Health (NIOSH) consider chromium (VI) compounds as carcinogens.[32] Hard-metal pneumoconiosis, caused by cobalt dust, is a severe and progressive type of pneumoconiosis that result in interstitial fibrosis with diffused reticulonodular infiltration of lungs (Figure 7). In addition, molybdenum exposure can cause biochemical changes.[33,34]Studies have reported that patients with pneumoconiosis had considerable amount of chromium-cobalt particle in the lung tissue and the patient subsequently developed adenocarcinoma of the lung.[35] Both NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH) classify beryllium as a potential carcinogen[36]and may lead to acute chemical pneumonitis, and chronic beryllium granulomatosis.[33,34] The major health risks of nickel and its compounds are related to the increased risk of respiratory cancers primarily in the lung and nasal sinuses, as well as chronic irritation of the upper respiratory tracts, pneumoconiosis, bronchial asthma, and allergic contact dermatitis.[33,34] IARC classifies metallic nickel as possibly carcinogenic to humans while NIOSH considers all compounds of nickel as potential human carcinogens.[32]

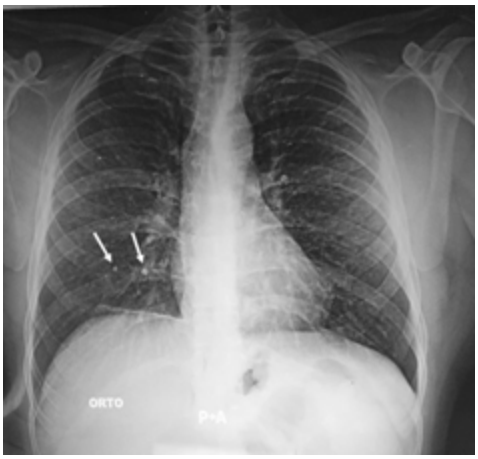

Figure 7. Chest X-ray of patient with pneumoconiosis showing small rounded and irregular radio-opacities

Silica

Inhalation of dust containing free silica or silicon dioxideleads to silicosis. It is a devastating interstitial lung disease characterized by diffuse pulmonary fibrosis (Figure 8).Patients generally report with pulmonary and systemic symptoms, including dyspnoea, pleurisy, cough, fevers, fatigue, and weight loss. Physical examination frequently reveals hypoxia.[37]

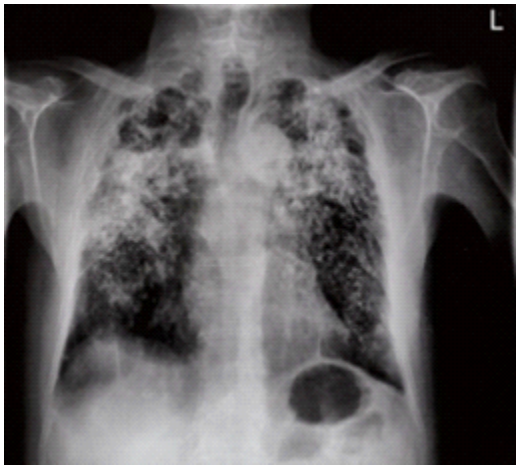

Figure 8. Chest X-ray of patient with silicosis showing large numbers of rounded, solitary nodules or bigger, confluent opacities

Hazard due to chemical used in radiology

Developing solutions and fixing solutions may cause health effects. Glutaraldehyde is primarily used as a hardening agent causes skin sensitization and allergic contact. Sulphur dioxide released during the mixing process of chemical components causes bronchospasm.[32]

Recommendations for Minimizing Exposure and Enhancing Safety:[38]

1. **Administrative controls:**
    - Implement standard operating procedures (SOPs) and adhering to the established safety guidelines for the use and handling of hazardous chemicals.
    - Conduct regular training and education sessions on chemical safety and emergency response procedures and increasing awareness about the health risks associated with chemical exposure and the importance of following safety protocols.
    - Provision of appropriate emergency response equipment to reduce the impact of the exposure and medical follow-up for workers who have had a chemical exposure.
    - Implement regular health surveillance programs to monitor the health of dental professionals.
    - Conduct periodic assessments of workplace safety to identify and mitigate potential hazards.
2. **Use of Personal Protective Equipment (PPE)**:
    - Ensure the use of appropriate PPE (gloves, masks, protective eyewear, and gowns).
3. **Engineering Controls**:
    - Elimination of a hazardous chemical and substitute with an alternative (using digital impression techniques to minimize the use of impression materials)
    - Maintain properventilation systems to reduce the concentration of airborne chemicals.
    - Use local exhaust ventilation (LEV) systems to remove hazardous fumes.

Discussion

Chemical occupational hazards in dentistry are a global concern, affecting dental professionals' health

and safety. There are various health risks associated with the chemical exposure in dentistry that can be broadly categorized into two groups: Acute effects (Skin irritation, contact dermatitis, respiratory distress including asthma and bronchitis, eye irritation and conjunctivitis) and Chronic effects (Long-term respiratory issues such as chronic obstructive pulmonary disease (COPD), neurological disorders due to prolonged exposure to neurotoxic substances like mercury, increased risk of cancer, particularly with prolonged exposure to formaldehyde and other carcinogenic substances).[39]According to the World Health Organization (WHO), approximately 75% of dental professionals report experiencing some form of occupational health issue related to chemical exposure. In the United States, the Occupational Safety and Health Administration (OSHA) has highlighted that dental professionals are at a high risk of exposure to hazardous chemicals, with adverse health effects being commonly reported.[32] In Europe, a study conducted by the European Agency for Safety and Health at Work (EU-OSHA) revealed that nearly 70% of dental professionals experience skin and respiratory problems due to chemical exposure. Similar trends are observed in Australia and Canada, where occupational health and safety agencies emphasize the importance of minimizing exposure to hazardous chemicals in dental practices. [40]In India, the prevalence of chemical occupational hazards in dentistry is significant, though it is often underreported due to lack of awareness and regulatory oversight. A study conducted indicates that around 60% of dental professionals reported experiencing health issues related to chemical exposure.[41] The lack of stringent regulations and standardized safety protocols in many dental practices across India contributes to higher exposure risks.[42] Therefore, there is a pressing need for better awareness, training, and implementation of safety measures to protect dental professionals in India.

Conclusion

Ensuring the safety of dental professionals from chemical occupational hazards is paramount for maintaining a healthy and productive workforce. The prevalence of these hazards is high, and their impact is particularly pronounced in countries like India, where regulatory oversight may be less stringent. By implementing comprehensive safety guidelines, promoting the use of safer alternatives, and ensuring regular training and education, dental practices can significantly reduce the risks associated with chemical exposure. Through heightened awareness and adherence to safety protocols, the dental profession can create a safer working environment, ultimately leading to improved occupational health outcomes. A concerted effort is needed to enhance occupational safety in dentistry, ultimately protecting the health and well-being of dental professionals globally.

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