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Review

Nanometals and Metal Ion Pollution from Dental Materials in Dental Environment

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Abstract: The dental environment is being polluted with metals from dental materials in many ways, mainly due to aerosol-generating procedures; this could affect the long-term well-being of dentists, dental students, and dental personnel. The current dental pollution incorporates metallic nanoparticles, which are highly reactive and quickly become airborne, especially those particles that become unbound in the bulk composition. In addition, liquid mercury or mercury vapors may be released from dental amalgam, causing concerns in the dental community. In our study, we reviewed the behavior of metallic elements present in dental materials, their routes of exposure, and their potentially toxic effects on the dental team. This review found that skin and lung disorders are the most harmful effects of metallic exposure for dentists, dental students, and dental personnel. Therefore, chronic exposure to low concentrations of metals in the dental environment, especially in nanosized forms, should be further investigated to improve the environmental matrix, material choice, and safety protocols.

Keywords: dental materials; nanometals; toxicology

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1. Introduction

The use of restorative materials to replace missing dental structures has been the base of dental care since its beginnings [1]. Despite the recent development of new biomaterials, such as composites and ceramics, the old metallic restorative materials remain used in current dental practices. One reason is that metallic elements confer excellent mechanical properties and durability for fillings, crowns, bridges, and dental implants [2–4]. These metallic restorations are presented mainly as alloys containing several metals, including mercury, silver, tin, copper, gold, nickel, zinc, aluminum, chromium, cobalt, iron, manganese, titanium, palladium, platinum, iridium, ruthenium, beryllium, gallium, indium, molybdenum, beryllium, lithium, strontium, barium, bismuth, and zirconium, as well as rare metals, such as rhodium and osmium [3,5–10], and promising metals such as niobium [11]. The examples of metallic components in dental materials are summarized in Table 1.

With advances in nanotechnology, the risk of toxicity and metal absorption from dental materials has increased. For example, nanometals ranging from 5 to 260 nm were incorporated into dental materials to improve physicochemical properties and antibacterial purposes, but the reactivity of the metal particulates also increased [4,12,13]. Another technological advance was the introduction of computer-assisted design and computer-assisted manufacturing (CAD/CAM) in dental offices. This technology allows ceramic restorations to be milled chairside in a same-day visit. Even though there is no available data to prove the toxicity, it is possible to assume that the presence of airborne nano and microparticles originating from the CAD/CAM milling could also aggravate the air quality of the dental environment.

Table 1. Metallic elements in dental materials.

Element	Atomic Mass	Density (G/Cm^3)	Metal Type	Commonly Present in		
				Prostheses	Restorative Materials + Cements	Implants
Calcium (Ca)	40.08	1.54	Alkaline Earth Metal		X	X
Strontium (Sr)	87.62	2.64	Alkaline Earth Metal		X	
Barium (Ba)	137.33	3.62	Alkaline Earth Metal			X
Magnesium (Mg)	24.30	1.73	Alkaline earth Metal			X
Gold (Au)	196.97	19.32	Transition Metal	X		X
Palladium (Pd)	106.42	12.02	Transition Metal	X	X	
Platinum (Pt)	195.08	21.45	Transition Metal	X		
Iridium (Ir)	192.22	22.65	Transition Metal	X		
Ruthenium (Ru)	101.07	12.48	Transition Metal	X		
Rhodium (Rh)	102.91	12.41	Transition Metal	X		
Copper (Cu)	63.55	8.92	Transition Metal	X	X	
Titanium (Ti)	47.87	4.51	Transition Metal	X	X	X
Beryllium (Be)	9.01	1.85	Transition Metal	X		X
Chromium (Cr)	51.99	7.15	Transition Metal	X	X	X
Iron (Fe)	55.84	7.87	Transition Metal	X		X
Manganese (Mn)	54.93	7.30	Transition Metal	X		
Molybdenum (Mo)	95.95	10.20	Transition Metal	X		
Nickel (Ni)	58.69	8.91	Transition Metals	X		X
Zinc (Zn)	65.4	7.13	Transition Metal		X	
Mercury (Hg)	200.59	13.53	Transition Metal		X	
Osmium (Os)	190.2	22.57	Transition Metal	X		
Vanadium (V)	50.94	6.0	Transition Metal			X
Zirconium (Zr)	91.22	6.52	Transition Metal	X		X
Niobium (Nb)	92.90	8.57	Transition Metal		X	
Tantalum (Ta)	180.94	16.4	Transition metal			X
Silver (Ag)	107.87	10.49	Post-transition Metal	X	X	X
Aluminum (Al)	26.98	2.70	Post-transition Metal	X	X	X
Gallium (Ga)	69.72	5.91	Post-transition Metal	X		
Indium (In)	114.81	7.31	Post-transition Metal	X		
Bismuth (Bi)	208.98	9.80	Post-transition Metal		X	
Tin (Sn)	118.71	7.28	Post-transition Metal	X	X	
Indium (In)	114.82	7.31	Post-transition Metal	X	X	

Metal ions from restorations, cements, dental prostheses, implants, and dental appliances may leach into the patient's saliva due to material degradation in the oral cavity [9,14–17]. However, the exposure to metals is even higher for dentists, dental students, dental technicians, and dental assistants than for patients [18]. Dental professionals and students are constantly exposed to aerosols, vapors, and particulates containing metals during dental procedures such as dental materials manipulation, removal, polishing, finishing, trituration, condensation, scaling, and in the adjustments of dental fillings and cement [19–21], prostheses [22], and dental appliances [23–25].

The quality of the dentistry environment is affected when nanoscale metal particles or metal vapors (e.g., mercury) surround the air and surfaces of dental spaces and laboratories [26,27]. Furthermore, the toxicological reliability of metals in dental materials is unclear, especially for their potentially harmful effects on dental professionals in long-term exposure. Therefore, based on the current literature, this paper reviewed the metallic elements in dental materials and the toxicological potential for dentists, dental students, and dental personnel.

2. Toxicological Potential of Metallic Elements Present in Dental Materials

2.1. Routes for the Spread of Metals in Dentistry

How metallic ions are spread in the dental field can be divided into the following: aerosol, droplets, splatter, and vapor. Slow or high-speed dental drills and ultrasonic scaling dental equipment generate metal spreading in the dental environment [28]. Dental drills are used with diamond or carbide burs for dental amalgam removal, adjustments of restorations, prostheses, dental implants, orthodontic appliances, and diamond disks or points for polishing and finishing restorations and scaling, using an ultrasonic scaler with a tip coupled for ultrasonic scaling. These dental treatment procedures release nanometals and micrometals in a suspension of air–water aerosols containing particles ≤ 5 μm in diameter, droplets in the 5–100 μm range, and splatter with sizes ≥ 100 μm into the dental environment [29–33].

Among the metals listed in Table 1, mercury is a unique liquid metal able to volatilize at room temperature. This particular characteristic attracts attention to the risk of exposure to materials containing mercury. In dentistry, dental amalgam restoration comprises approximately 50% wt. of elemental mercury [34,35]. When liquid mercury (Hg) is mixed with a metal alloy, the Hg reacts with intermetallic Ag_3Sn (γ-phase), forming Ag_2Hg_3 (γ1-phase), Sn_8Hg (γ2-phase), and the unreacted alloy Ag_3Sn (γ-phase). The γ-phase and γ1-phase are mechanically strong, but the γ2-phase is soft and unstable, which leads to metal leaching. [36]. Therefore, dental amalgam degradation may be attributed to the γ2-phase. Mercury vapor may be released during mixing, placement, condensation, polishing, finishing, and dental amalgam removal.

According to Warnick D. et al., 2019 [37], amalgam particulates still release significant amounts of mercury vapor after removing the amalgam filling. The literature also shows remaining mercury vaporization in dental instruments, opened capsules, work surfaces and tools, and amalgam residues after procedures with dental amalgam. Bulk mercury may spill from defective amalgamators and mercury dispensers or leak from amalgam capsules [21,26,38].

2.2. Routes of Exposure to Metals in the Dental Environment

The three primary routes of occupational and nonoccupational exposure to metals in dentistry include (1) inhalation, (2) ingestion, and (3) dermal/ocular exposure. Figure 1 illustrates the possible routes of exposure, pathways to organs, and primary target organs of the human body for metallic elements in the dental environment.

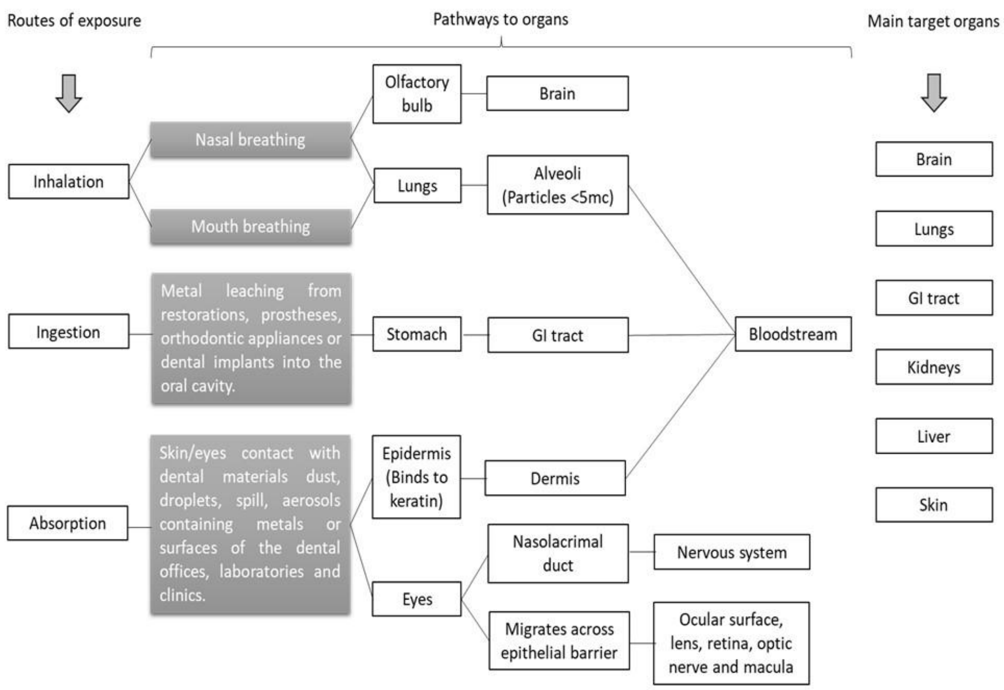

Figure 1. Routes of exposure, pathways to organs, and primary target organs of the human body for metallic elements in the dental materials and dental environment.

For dentists, dental students, and dental personnel, inhalation and dermal/ocular absorption are the main routes of exposure to metallic elements in the dental environment. Ingestion is a route of exposure to metallic elements that often occurs in dental patients. The ingestion of metal ions happens due to dental material degradation in the oral cavity [9,14–17].

After inhalation and the dermal/ocular absorption pathway, metal ions reach several organs. Some metal elements (e.g., Cu, Cr, Fe, Mn, Mg, and Zn) are essential for the physiological functions of the human body, while others (e.g., Li, Cr, Sr, Ag, Ba, and Hg) are nonessential [39]. The metallic elements are nonbiodegradable. When the metal ions are in excess, they are widely distributed in different organs, and bioaccumulation in the human system is a concern.

Metals have a long half-life due to the chemical properties of the elements, especially nonessential elements. In general, metals in excess may be trapped in vital organs by covalent chemical bonds with organic groups, which generate intracellular granules in an insoluble form to be excreted through the organism's feces or for long-term storage that may cause toxic effects [40]. For example, mercury binds to sulphydryl protein groups in the central nervous system (CNS).

2.3. Potential Metal Toxicity in the Dental Environment

A dental environment can include a dental clinic, preclinical teaching laboratories, dental laboratories, and hospital dental departments. The metal exposure in these environments is affected by the type of dental procedure and properties of the environment matrix (air quality and room temperature). However, the properties of the metallic ions (pH, redox potential, and the possible formation of complex metallic compounds) are essential factors in determining the potential toxicity [41]. In addition, other important factors can affect the exposure–response relationship, such as the route and time of exposure, biological factors, skin permeability, and the diet of exposed individuals [42–44]. Therefore, dentists, dental students, and dental personnel should evaluate the already reported toxic effects of metal exposure in the dental environment (Table 2) and consider the potential risks of the metallic elements to which they are exposed (Table 3).

Table 2. Summary of adverse health effects on dentists, dental students, and dental personnel associated with metal exposure.

Element	Adverse Health Effects Associated with Metal Exposure in the Dental Environment	References
Hg	Risk of neurological and sensory symptoms (memory loss, fatigue, attention deficits, neurobehavioral problems, reduced cognitive flexibility, reduced psychomotor speed, and sleep problems)	G. Bjørklund et al., 2019 [45]
	Risk of fertility issues, congenital deficits or abnormalities, and spontaneous abortion	G. Bjørklund et al., 2019 [46]
	Pathogenetic role in neurological disorders, particularly in pregnant women	G. Bjørklund et al., 2017 [47]
	Increased risk of tremor	J. Anglen et al., 2015 [48]
	Risk of reduction in systolic blood pressure	Goodrich et al., 2013 [49]
	Risk of reduction in Th1-type proinflammatory markers in serum	L. Björkman et al., 2012 [50]
	Risk of miscarriage	Lindbohm et al., 2007 [51]
	A deficit in psychomotor performance (hand steadiness)	A.C. Bittner et al., 1998 [52]
	Behavioral deficits, tension, fatigue, and confusion	D. Echeverria et al., 1995 [53]
	Risk of problems in visual memory, verbal memory, visuomotor coordination speed, visuomotor coordination and concentration, optical scanning, and motor speed	C.H. Ngim et al., 1992 [54]

Table 2. *Cont.*

Element	Adverse Health Effects Associated with Metal Exposure in the Dental Environment	References
	Risk of reproductive issues, renal function changes, allergies, immunotoxicological effects, and glioblastoma (brain cancer)	G. Bjørklund et al., 1991 [55]
	Risk of headaches, fatigue, malaise, weakness, irritability, depression, loss of memory, the feeling of hopelessness, tremor, decreased reflexes, loss of fine motor control, visual disturbances, lens and retina pigmentation, digestive disturbances, diarrhea, poor appetite, nausea, stomatitis, metallic taste, sore mouth, an increase in nasal secretion and saliva, burning tongue, red palms, and eczema	J.G. Bauer et al., 1985 [56]
	Risk of polyneuropathies, mild visuographic dysfunction, and symptom-distress	Shapiro et al., 1982 [57]
Ni	Allergy	E.M. Warshaw et al., 2022 [58]
	Allergy	T. Werfel et al., 2018 [59]
	Contact allergy	K. Wrangsjö et al., 2001 [60]
	Hand eczema and allergy	L.M. Wallenhammar et al., 2000 [61]
	Hand dermatitis	J.G. Hill et al., 1998 [62]
	Allergy, contact dermatitis, and hand eczema	T. Rustemeyer et al., 1996 [63]
	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]
Ag	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]
Cu	Contact dermatitis	K. Wrangsjö et al., 2001 [60]
Cr	Toxic to RAW264.7 cells (monocyte/macrophage cell line)	W. Wang et al., 2020 [65]
	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]
	Risk of lung disorders	A.I. Seldén et al., 1995 [66]
Co	Allergy	L.M. Wallenhammar et al., 2000 [61]
	Contact allergy	K. Wrangsjö et al., 2001 [60]
	Allergy, contact dermatitis, and hand eczema	T. Rustemeyer et al., 1996 [63]
	Toxic to RAW264.7 cells (monocyte/macrophage cell line)	W. Wang et al., 2020 [65]
	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]
	Risk of lung disorders	A.I. Seldén et al., 1995 [66]
Pd	Contact dermatitis	T. Werfel et al., 2018 [59]
	Allergy, contact dermatitis, and hand eczema	T. Rustemeyer et al., 1996 [63]
Sn	Contact Dermatitis	T. Werfel et al., 2018 [59]
Al	Toxic to RAW264.7 cells (monocyte/macrophage cell line)	W. Wang et al., 2020 [65]
	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]
Mo	Toxic to RAW264.7 cells (monocyte/macrophage cell line)	W. Wang et al., 2020 [65]
	Risk of lung disorders	A.I. Seldén et al., 1995 [66]
In	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]
Ti	Risk of pneumoconiosis	M. Okamoto et al., 2017 [64]

Table 3. The potentially toxic effects of metallic elements on humans.

Element	Potential Toxic Effects of Metal Elements on Humans	References
Hg	Risk of lung and eye irritation, diarrhea, rashes, and vomiting Risk of DNA damage Risk of reproductive problems (congenital disabilities miscarriages, and sperm damage in men) Risk of neurological disorders, learning disabilities, speech defects, memory loss, tremors and muscle incoordination, deafness, vision complications, and personality changes, Risk of paralysis, insanity, coma, and death Risk of congenital disabilities through a toxic effect on an embryo or fetus	[40,67–71]
Ni	Allergic reactions Risk of respiratory problems (asthma, lung embolisms, and respiratory failure) Risk of heart disorders Ni inhalation may cause: Risk of cancer	[40,68,69,72–75]
Ag	Contact with silver liquid may cause: Risk of allergic dermatitis, skin irritation, and argyria Risk of corneal injury Silver inhalation may cause: Risk of dizziness, headaches, drowsiness, confusion, and staggering Risk of respiratory issues Risk of unconsciousness, coma, and death Silver ingestion may cause: Risk of nausea and vomiting, diarrhea, and stomach discomfort Risk of narcosis, brain damage, and cardiac abnormalities	[40,67–69,76]
Cu	Risk of flu-like symptoms Risk of diarrhea, vomiting, eye irritation, dizziness, and oral mucosa irritation Risk of acute gastroenteritis Oral intake will cause hepatic and, Risk of hepatocellular degeneration, kidney disease, insomnia, anxiety, agitation, and necrosis Risk of Wilson's disease (symptoms: lack of appetite, fatigue, jaundice, Kayser–Fleisher rings, speech impairment, difficulty in swallowing, uncontrolled poisoning, brain damage, demyelination, and hepatic cirrhosis) Risk of death	[40,68,69,77,78]
Cr	Cr ingestion may cause: Risk of nausea and vomiting, fever, diarrhea, gastrointestinal ulceration, vertigo, toxic nephritis, liver damage, and coma Cr (VI) inhalation or repeated skin contact may cause: Risk of allergic contact dermatitis and eczema, gingivitis, irritation of mucous membranes, bronchitis, and liver and kidney disease, Risk of respiratory issues (sinusitis, pneumonia, and lung cancer) Risk of chrome holes in the forearms, hands, fingers, and nose Risk of cancer Risk of death	[40,67,72,79–81]
Co	Risk of skin and respiratory issues allergic dermatitis Co-inhalation may cause: Risk of congestion, wheezing, asthma, respiratory irritation, lung function reduction, edema, pneumonia, fibrosis, and lung hemorrhage Risk of nausea, vomiting, diarrhea, renal congestion, and cardiac and liver disorders	[40,72,82–84]
Zn	Risk of nausea and vomiting, fatigue, anemia, neutropenia, stomach cramps, epigastric pain, copper deficiency, decrease in high-density lipoprotein (HDL) cholesterol, pancreatic complications, and impaired immune function	[40,68,69,85,86]

Table 3. *Cont.*

Element	Potential Toxic Effects of Metal Elements on Humans	References
Mn	Risk of weakness, lethargy, decreased blood pressure, dullness, tremors, akathisia, dystonia, anxiety, motor disorders, and lack of facial expression Risk of neurological disorders and behavioral changes Risk of manganism Risk of mimicry of Parkinson's disease Mn inhalation may cause: Risk of reproductive problems (sperm damage and loss of sex drive) and pneumonia	[40,68,69,72,87–92]
Pd	Risk of allergy or contact dermatitis Risk of eyes and oral mucosa irritation (stomatitis or mucositis) and oral lichen planus	[93,94]
Al	Risk of liver and kidney dysfunction Risk of lung damage and pulmonary fibrosis Risk of leukocytosis, osteomalacia, hypoparathyroidism, and colitis Risk of central nervous system damage Risk of amyotrophic lateral sclerosis, Alzheimer's disease, Parkinsonism dementia complex (ALS–PDC), and listlessness	[40,72,95,96]
Mo	Risk of headache, fatigue, weakness, appetite reduction, hypochromic microcytic anemia, and anorexia Risk of listlessness, chest pain, myalgia, and arthralgia, Risk of testicular atrophy Risk of copper deficiency	[40,68,69,97,98]
In	Risk of interstitial pneumonia and pulmonary and systemic diseases	[99,100]
Ti	Risk of intermittent coughing and respiratory diseases (bronchial asthma, chronic sinusitis, chronic bronchitis, chronic obstructive lung disease, chronic rhinitis, nasal septum deviation, nasal polyposis, recurrent pneumonia, recurrent pleural effusion, and acute pulmonary edema) Risk of yellow nail syndrome Risk of inflammation reactions and hypersensitivity Risk of systemic disease, cardiac failure, and death	[101–105]
Sn	Risk of interstitial pneumonia	[99]

Notice the potential of metal spreading increases in dental procedures involving high-speed handpiece or ultrasound scaler usage. According to J. Matys et al., 2020 [106], these instruments generate intensive dental aerosol during dental procedures. In dental clinics and preclinical laboratories, where a group of dentists or students perform dental practices in the same room, the risk of metal exposure should be evaluated as the metal spread will be more intense in this environment. Thus, a specific room for dental procedures involving dental amalgam is suggested to prevent mercury vapor spread.

Metallic ion mobility, related to dental material composition, is particularly concerning from a potential toxicological point of view. Unbound nanoparticles in the bulk composition are more reactive and can become quickly airborne [107]. Furthermore, airborne metal particles are highly insoluble at a physiological pH, which can increase the risk of lung toxicity for metal dust from dental materials in dentists, dental students, and dental personnel [108].

The independent experiments of Checchi L et al., 2005 [108], using bicarbonate dust in variable dimensions (~1–300 µm), showed that a certified personal respirator could be more effective than high-quality surgical masks in dental settings. Currently, the release of nanomaterials into the dental market has increased. For this reason, a study in the U.S.A. that monitored indoor particulates in dental offices in California found that 67% of the particulates had an average particle size of <100 nm in size and there were 37 % of PM0.3–PM10 [109].

More research about barrier efficiency against ultrafine metal particulates is necessary to protect dentists, dental students, and dental personnel in dental clinics and preclinical laboratories. Recently, Liu et al., 2019 [27] found that almost all of the particles produced by tooth drilling and grinding were ≤1 μm. The central vacuum systems and protective surgical masks have limited efficacy against these suspended particulate matters.

Thus, dental procedures should not be underestimated in terms of the risk of metal spreading into the environment and adverse effects on human health. For better conduct of metal spread prevention, dental clinics, and preclinical laboratories should define a guideline detailing a risk procedure for metal spread, a specific treatment area (enclosed or nonenclosed operatory), the necessity of essential equipment (use or nonuse air filtration and evacuation), and the type of personal protective equipment (PPE) for the operator, patient, and others present in the same room, as suggested in Table 4.

Table 4. Guideline of risk of procedure for metal spread.

Low-Risk Procedure	Moderate Risk Procedure	High-Risk Procedure
• Dental procedures without handpieces or ultrasound scaler usage • Dental procedures without dental amalgam • Use an enclosed operatory	• Dental procedures using low-speed handpieces when dental materials containing metal are involved • Dental procedures not involving dental amalgam • Use an enclosed operatory with air filtration and an evacuation unit	• Dental procedures using high-speed handpieces or ultrasound scaler usage • Dental procedures with dental amalgam and the cleaning of instruments after clinical the session • Use a closed operatory with air filtration and an evacuation unit

3. General Recommendations

Several measures have been proposed to reduce and eliminate occupational and nonoccupational hazards in the form of exposure to metallic ions from dental materials in dentists to dental students and dental personnel [37,110–113]. The main measures could be listed as the following:

3.1. Air Quality Precautions

- Use adequately designed ventilation systems, including local exhaust ventilation.
- Use air filtration equipment for dental procedures involving dental amalgam and make sure the filters are appropriate.
- Perform air monitoring periodically to ensure that the occupational (dental workers) and nonoccupational (dental students) exposure limit is not exceeded.

3.2. Good Hygiene Practices

- Clean hands vigorously to create friction in an appropriate sink. Use soap for your hands and a nailbrush to clean your fingernails. Afterward, rinse well to remove all of the soap and dry your hands thoroughly using a paper towel.
- Hand hygiene should be performed immediately before starting a clinical session, before putting on gloves, and following the removal of gloves. Hand hygiene should also be performed at anytime hands are contaminated with visible metal dust or liquid mercury.
- Wearing jewelry is not recommended as it can chemically bond with other metals released during dental procedures.
- Observe periodically if the working team or dental students follow good hygiene practices for quality control.

3.3. Personal Protective Equipment (PPE)

- Dentists, dental students, dental personnel, and patients should wear protective clothing (ideally an impermeable full-body covering for procedures with dental amalgam).
- Use a dental dam sealed correctly in the patient's mouth with a saliva ejector to remove contaminated saliva or liquid debris from the oral cavity.
- The protective mask or respirator should be selected according to the type of metal involved in the dental material or procedure, and as guided by the local, national, or

international regulatory agency of occupational and nonoccupational health and safety recommendations. Each agency has its guidelines recommending different types of masks or respirators. The barrier choice should be based on the air monitoring results of the dental clinic or laboratory, respecting the threshold limit value (TLV), permissible exposure limit (PEL), recommended exposure limit (REL), minimal risk level (MRL), or reference concentration (RfC) of the agency. The most common agencies used in North America are the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), the United States Environmental Protection Agency, and the California Environmental Protection Agency. The mask or respirator should cover the mouth and nose completely.

- Regarding protective eyewear, prescription safety glasses, safety glasses over corrective lenses, or loupes with side shields should be used during all preclinical and clinical procedures.
- Bouffant, impermeable dedicated footwear (covering the entire foot) and a face shield are also recommended.
- The patient's skin and clothing should be protected, providing a whole-body, impermeable barrier, and a complete head/face/neck barrier under/around the dam should also be used.
- Use high-volume suction and continually add water spray to the site where the amalgam is removed.

3.4. Health and Educational Surveillance

- Perform medical monitoring of metals levels in the working team or dental students.
- Periodically observe if the working team or dental students are following the local quality control guidelines.
- Review the local guidelines periodically or when updated.

3.5. Substitution with Less Harmful Products

- It is reasonable to choose metal-free materials when appropriate. The use of alternative materials to dental amalgams has been encouraged in Europe to reduce environmental and human exposure to mercury [113]. Composite resins and metal-free glass ionomer cement are excellent alternative materials for dental restorations.
- Metal-free crowns (porcelain-based ceramic, quartz, glass, or resin, through zirconium and lithium disilicate) are suggested instead of metallic crowns (made of gold, platinum, copper, nickel, or chromium) when indicated.
- The cobalt–chromium (Co–Cr) alloy is indicated for fabricating metallic frameworks of removable partial dentures instead of Ni–Cr alloy to reduce allergic reactions. The additional use of allergenic metals should be reduced if possible.

3.6. Cleaning Dental Instruments and Surfaces

- For dental procedures involving dental amalgam, use mercury decontaminant to clean instruments, countertops, and surfaces after the clinical session.
- For dental procedures involving other metal types, clean instruments with water, soap, and a brush.
- Clean spills of mercury using commercial mercury spill clean-up kits. Afterward, check mercury vapor levels in the dental operatory.
- Clean handpieces according to the manufacturer's instructions. For handpieces contaminated with mercury, it is recommended to wipe the handpieces with mercury decontaminant before starting the manufacturer's instructions.

The literature outlines occupational adverse effects of metal exposure for dental workers, including dentists and dental personnel. However, there is a lack of discussion regarding dental student exposures to hazardous metals. Dental students perform daily dental procedures in preclinical laboratories and dental clinics. Extra hours of their regular practices are common in preclinical laboratories. However, the limits of exposure to metallic elements for this population have not been established since they are not considered dental workers.

This review was carried out with a critical eye to expand the safety and health of the dental community, including dental students. Therefore, for dentists, dental students, and dental personnel, we highlight the importance of following the procedural risk guidelines to reduce the spread of metals and also general recommendations for clinical sections.

4. Conclusions

Metallic pollution from dental materials in dental environments has become more prevalent and dangerous with the advance of nanotechnology. Nanometals increase the risk of toxicity and absorption. This review found that skin and lung disorders are the most harmful effects associated with exposure to metallic elements by dentists, dental students, and dental personnel. Therefore, guidelines for reducing risk in dental procedures are encouraged to reduce the daily metal intake through inhalation and dermal/ocular absorption in dentistry.

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