Disinfection of Impression Materials: A Comprehensive Review of Disinfection

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ABSTRACT

Impression making is one of the most common procedures that are performed by dentists in day-to-day practice. These impressions can act as vehicles of transmission and carry various types of microorganisms, which further cause diseases like Hepatitis B, C, HIV, Tuberculosis etc. This contamination and cross contamination of microorganisms can be prevented by disinfecting the impressions immediately after removing from the mouth and label them as disinfected. Usually the impressions are placed under running water to remove saliva and blood, but this will eliminate the disease-causing microorganisms, so a standard protocol to disinfect the impressions and casts should be known to dentists and dental personnel. Various methods of impression disinfection like chemical disinfection, Microwave, Autoclave, Ultraviolet radiation have been described in literature having their own advantages, disadvantages and effects on impression material and casts. Recently antimicrobials and nanoparticles have been incorporated into the impression material itself to make it self- disinfecting. This will not only disinfect the impression material from inside but also disinfect the impressions from the time it is inserted in patient's mouth. A broad search on the literature available was performed to provide knowledge about mechanism of action, concentration of usage along with commercial preparations available of different disinfectants. This review article will enhance the knowledge and improve the behavior of dental health care workers about impression disinfection.

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1. Introduction

Dentistry is a branch of surgery that involves exposure of a person or materials to saliva/blood and other potentially infectious materials either directly or indirectly. On an average, 1ml of a healthy person's saliva contains about 750 million microorganisms [1]. Numerous studies have reported the colonization of distinct bacterial communities on different oral structures and tissues, and about 280 bacterial species from the oral cavity have been isolated [2]. Most commonly observed microorganisms in oral cavity of patients wearing prosthetic dental appliances, removable orthodontic appliances include *Staphylococcus, Streptococcus, Lactobacillus, Actinomyces*, and *Candida* species [3]. Health care professionals, especially dealing with oral diseases, are more vulnerable to cross infections during treating patients [4]. Furthermore, dental technicians are also susceptible to these infections as they handle various dental materials which are directly carried from the patient's oral cavity to the dental laboratory. Chidambaranathan AS *et al* (2017) reviewed and compared the various disinfection techniques available in the literature and they reported that 67% of the materials received in laboratories were contaminated with *Streptococci, Staphylococci, Candida* species, *methicillin-resistant S. aureus (MRSA), or P. aeruginosa* [5]. It was reported that dental personnel have a 5–10 fold chance of acquiring Hepatitis-B infection than the general population [6]. numerous studies also stated that Tuberculosis and Hepatitis-B microbes can survive up to 7 days or longer at room temperature [7].

Practicing high standards of infection control and safety measures are essential to control cross contamination and occupational exposures to blood and saliva borne diseases. The British Dental Association (BDA) stated that "Infection control is a core element of dental practice" [8] and certain recommendations are applicable to all levels and fields of dentistry including personnel involved in providing dental care directly or indirectly [9].

2. Dental Impression – A Possible source of cross-contamination

Impression making is an important practice to be carried out in dental treatment, specifically, involving in making a replica of the oral structures. During impression procedure, impression materials often encounter with saliva and blood, which may be infected with infectious diseases such as AIDS, herpes, hepatitis, or tuberculosis [10]. Dental impressions that are exposed to patient's saliva or blood, contaminate stone casts [11] and serve as a source of infection to dental personnel who handle or deal with the impressions or casts [12]. The personnel who works on such contaminated casts can cross-contaminate one patient casts to other and finally to the dentist and other patients. Therefore, Infection control is an essential and imperative issue in the dental practice to prevent the spreading of infection from one patient to another and also to provide protection to the dental health care providers. This article gives an insight on importance disinfection of dental impressions in preventing crosscontamination and also emphasizes the various disinfection modalities recommended for various impression materials.

BDA had recommended to decon-taminate and disinfect the dental impressions before they were sent to the dental laboratory [8] and it has evidently specified that the dentist is solely responsible for disinfection of the impression before it is being sent to the laboratory [9]. In 1998, FDI guidelines suggested that all impression materials, before transferring to laboratory, should be disinfected [13]. American Dental Association (ADA) [14] and Center for Disease Control (CDC) [15] also suggested disinfection of impressions or impression materials to prevent cross-infection and this can be accomplished by either immersion or spraying with disinfectants or other different methods.

Disinfectants should function as effective antimicrobial agents without showing adverse effects on the accuracy and the dimensional stability of the impression material. Various disinfectants such as sodium hypochlorite, glutaraldehyde, iodophors, and phenols are advocated for disinfecting impression materials [16]. The better practice to follow is the cleaning of the impression under running water with subsequent disinfection process, and also coordinate with the laboratory by labelling the device to specify disinfected status, as there is a possibility of repeated disinfection of an impression in the dental laboratory. This repeated disinfection may have detri-mental changes in dimensions of the impressions made [16].

Microorganisms can survive on, or even inside, the impressions. However, the number of microorganisms decrease rapidly after impression making, and they are further eliminated by rinsing the impression under running water immediately after removing it from the patient's mouth [7]. Though this was the common practice and recommended procedure for disinfection of the impressions until 1991, numerous studies reported that such practice can only eliminate 40% of bacteria, viruses, and fungi, hence there is potential for infection [17]. Therefore, an appropriate disinfection treatment of impressions is mandatory to eliminate potential risks. Several disinfection methods such as chemical disinfection (immersion method/ spray method), autoclave, microwave, ultraviolet radiation are proposed to disinfect the dental impressions and models [10].

3. Chemical disinfection methods

Chemical disinfection preferably immersion, seems to be the most reliable and practical method, provided it does not adversely alters the dimensional accuracy of the impressions. Immersion disinfection is considered as an effective method as it ensures that all surfaces of the dental impression are exposed to the disinfectant solution. However, this method is not indicated for hydrophilic impression materials like hydrocolloids and polyethers as they can imbibe the disinfectant solution that results in dimensional inaccuracy of the impression [18]. In addition, immersion disinfectants should be discarded after every use (except for glutaraldehyde) [19], and it is a time consuming and expensive method.

The spray method is the other chemical disinfection modality which reduces the chance of dimensional changes or distortion, especially in hydrocolloid and polyether impression materials. However, it may not effectively disinfect the impression as this technique uses less amount of disinfectant solution and it may be inadequate to reach the areas of undercuts. Additionally, chemical disinfectants must be freshly prepared and also possesses poor shelf life [20].

3.1. Solutions used as chemical disinfectants for impression materials

3.1.1. Iodophors

Iodophor was discovered by H. A. Shelanski and M. V. Shelanski. This bactericidal, sporicidal, viricidal, and fungicidal compound is a complex of polyvinyl pyrolidone (PVP, povidone) and elemental iodine. They need more contact time with the impression material to achieve disinfection which may results in the dimensional inaccuracy of impressions. In addition to applications in dentistry, Iodophors are often used for the thermometers, disinfection of blood culture bottles, hydrotherapy tanks, and endoscopes [21].

3.1.2. Glutaraldehyde

Glutaraldehyde is a pungent colorless oil and can be used as disinfectant in liquid and gaseous forms. It is widely used to sterilize medical and dental instruments and also as preservative in industries. Glutaraldehyde possess bactericidal, viricidal, fungicidal, sporicidal, and parasiticidal activity. Their efficiency is increased in the presence of lower concentrations of organic material. They are recommended to be used with suitable protective equipment in a ventilated environment under the supervision of a trained person [21].

3.1.3. Sodium Hypochlorite

Sodium hypochlorite is a chemical with formula of $NaOCl$. It is composed of sodium cation and hypochlorite anion. It is water soluble. It is often used in industries for bleaching, surface purification, odor removal, and disinfection of water. Hypochlorite removes stains from clothes at room temperature. Hypochlorous acid and Sodium hydroxide is formed by adding water to the hypochlorite and it can be further dissociated into hydrochloric acid (HCl) and oxygen (O). The oxygen atom is a very strong oxidator [21]. The concentration of available chlorine and the pH of the solution governs the efficacy of $NaOCl$ as disinfectant. Hypochlorous acid ($HOCl$) is a weak acid and it dissociates to the hypochlorite ion ($-OCl$) and proton (H^+) depending on the pH of solution. Generally, it is considered that $HOCl$ is the dynamic species in the bactericidal activity, while the concentration of $-OCl$ is a key factor that determine the cleaning efficacy. It is assumed that $HOCl$ penetrates into the microbial cell across the cell wall and inhibit the enzyme activity essential for the growth, damage the cell membrane and DNA, and perhaps an injury to membrane transport capacity [22].

3.1.4. Benzalkonium Chloride (0.25%)

This is a quaternary ammonium (QA) chloride salt in which the nitrogen is substituted by a benzyl group, two methyl groups, and even alkyl chains. It has antibacterial, antiseptic, detergent, and surfactant action. However, Benzalkonium chloride (BC) is not effective against fungi, viruses, and bacterial spores. QA disinfectants possesses a strong positive charge which combines well with negatively charged surfaces. This makes the QA as good cleaning agent. QA compounds show low toxicity, but prolonged contact may irritate the tissues. Usually they are used for environmental sanitation like floors, furniture, and walls [21].

3.1.5. Isopropyl Alcohol

Isopropyl alcohol is a 2-propanol with the formula of C_3H_8O or C_3H_7OH. It is a colorless chemical compound with strong odor. It is commonly used as a topical antiseptic, and also to disinfect the surface of medical devices. It is suggested that the alcohol-based solutions should be stored in a cool, and well-ventilated area as they are highly flammable. Alcohol irritates the tissues and evaporates rapidly [21].

3.1.6. Ethyl Alcohol

Ethyl alcohol is more bactericidal than bacteriostatic, also tuberculocidal, fungicidal, and virucidal against enveloped viruses. Alcohols are not effective against bacterial spores and non-enveloped viruses. They denature the bacterial proteins, thereby inactivating the microorganisms. The ideal bactericidal concentration in water is 60% to 90%, and the bactericidal activity decreases on diluting the concentration below 50%. Ethanol has shown clear bacterial growth inhibition, especially when used in high concentrations against *S. mutans* and *S. aureus* [23].

3.1.7. Chlorhexidine

Chlorhexidine (CHX) is a positively charged molecule that binds with the negatively charged sites of the cell wall and destabilizes it. Hence, it interferes with osmosis of the cell wall. The CHX then attacks the cytoplasmic membrane and leaks the components that lead to cell death. In high concentrations, CHX causes the cytoplasm to congeal or solidify. The bacterial intake of CHX is very rapid (<20 seconds) [26]. No antifungal activity of CHX has been observed in the agar diffusion test in low concentrations, but 2% CHX showed antimicrobial activity against *S. aureus*, *E. coli*, and *B. subtilis*, but not *C. albicans* [24].

3.1.8. Ozone water

Ozone, is a gaseous inorganic molecule with the chemical formula of O_3. It is less stable than O_2 and easily breaks down to normal dioxygen in the lower atmosphere. Ozone is formed by the action of atmospheric electrical discharges and ultraviolet (UV) light from dioxygen. It exists in low concentrations (0.6 ppm) in the atmosphere. It is a potent oxidizing and antimicrobial agent. Ozone is an unstable compound that decomposes very quickly (half-life 40 minutes at 20°C). Ozone affects the cell membrane, vital proteins, unsaturated lipids, and the intracellular enzymes of microorganisms and may also cause DNA degradation [25].

3.2. Levels of disinfection with chemical disinfectants

Chemical disinfectants can be classified into three categories based on their efficiency against vegetative bacteria, tubercle bacilli, fungal spores, and viruses. The level of disinfection for various impression materials with different disinfecting agents is detailed in Table 1. *High-level disinfectants* are capable of inactivating bacterial spores and all other microbial forms, which is an essential criterion for high-level disinfectants. Commonly used high-level disinfectants include Ethylene oxide gas or Glutaraldehyde solutions. *Intermediate level disinfectants* accomplish destroying microbes like tubercle bacilli, however, they do not have any effect on spores. Formaldehyde, Chlorine compounds, Iodophors, Alcohols, and Phenols are widely used Intermediate level disinfectants. The chemical agents that show narrow antibacterial activity are considered as *Low-level disinfectants*. These are undesirable for disinfection of impressions [26]. Quaternary ammonium compounds, Simple Phenols, and Detergents are classified as Low-level disinfectants.

For effective disinfection, the contact time between impression and disinfectant must be at least equal to the time for tuberculocidal activity as recommended by the manufacturer of the germicide. It is essential to rinse the impression immediately after disinfection to remove residual disinfectant from the surface of impression. Kotsiomiti *et al.,* (2008) conducted a review on

Level of Disinfection	Disinfecting Agent	Impression Material
High Level Disinfection	Glutaraldehyde	Irreversible Hydrocolloids Zinc-oxide Eugenol Paste Polysulphide Polyether Silicones
Intermediate Level Disinfection	Sodium hypochlorite Complex phenolics Iodophors Chlorhexidine Alcohols	Irreversible Hydrocolloids Zinc-oxide Eugenol paste Polysulphide Polyether Polysilicones Impression Compound
Low Level Disinfection	Quaternary Ammonium compounds Simple phenols Detergents	Not recommended for disinfection of impressions

Table 1. Levels of disinfection for various impression materials with different disinfectants

accuracy and stability of impression materials subjected to chemical disinfection and suggested that the disinfection modalities should be restricted to methods that show least distortion on impressions and on the chemical nature of the impression material. Hydrocolloids should be disinfected for a limited time period. Immersion is more secure than spraying and self-disinfecting materials are efficacious, but better accompanied by immersion. Polyethers, on the other hand, can be effectively disinfected by spraying. Although this seems to be the preferred method for disinfection of these water-friendly materials. Modern polyethers seem to withstand immersion, even long-term. Little information could be traced considering the stability of hydrophilic silicones upon prolonged immersion disinfection. Until more sound evidence is available, long-term exposure of them in the disinfectants should be applied cautiously, as they may have an enhanced absorption potential. Hydrophobic elastomeric materials can be safely immersed in disinfectants and left for a long period [27].

4. Microwave disinfection methods

Microwave disinfection is an effective and versatile method, which is quick, easy, and inexpensive method. This method can be easily performed by dentists, assistants, and technicians. Thermal and non-thermal are the mode of actions used with microwave disinfection. Thermal effect is conversion of microwave energy into heat by prolonged kinetic motion of polar molecules, where as non-thermal effect is by direct interaction of electromagnetic field with the biologic molecule, creating effects that cannot be caused by thermal action alone [28]. Microwaves are responsible for antimicrobial action by disrupting the cell membrane integrity and cell metabolism of microbes [29].

5. Autoclave disinfection methods

Steam autoclave is a device used to sterilize equipment, surgical instruments in medicine and dentistry by subjecting them to high saturated steam pressure at 121°C or more for 15 to 20 minutes. An autoclave also works at 115°C/10 psi, 121°C/15 psi, and 34°C/30 psi. The standard settings can kill most bacteria, spores, viruses, and fungi at 134°C, which can be achieved in 3 minutes. The color change indicates that the object inside the package or under the tape, has been autoclaved. Addition or condensation silicone materials could be sterilized producing less than 0.5%-dimensional change at 134°C, without showing relevant changes in tear strength [30].

Ethylene oxide gas autoclave is the other method used for disinfection of dental impressions. Holtan et al, (1991) showed that ethylene oxide gas sterilization allowed inclusion of gasses into the vinyl poly siloxane (VPS) impression, and these gasses would release later that results in producing bubbles in dies if poured instantly. This can be avoided by pouring the dies after 24 hours. They also suggested that steam autoclaving was a suitable method, specifically, if the impressions were made for the fabrication of removable prostheses [31]. Olin et al., (1994) reported that the use of ethylene oxide gas autoclaving of heavy- and light-body addition silicone impression material in custom trays showed significant structural changes (>0.5% change) due to the distortion of the trays or incapability of preventing expansion of the impression material [32].

6. UV light as disinfectant

The effectiveness of UV rays in disinfection depends upon the time, intensity, humidity, and access to the microorganism. Since dental prostheses provide a number of sites for housing microorganisms, UV light must be reflected from many directions. UV light exposure has shown to drastically reduce *C.albicans* colonies as compared to direct-current low discharge. It has been observed that a higher-watt UV light tube decreases the colony count in less time. The maximum killing efficiency with UV light exposure has been obtained with 24 watts (3750 $\mu w/cm^2$). The higher wattage required less time to decrease the colony count of *C. albicans* to zero [33]. Samra *et al.*, (2018) recommended the Ultraviolet method as more suitable for disinfecting impressions without compromising their dimensional stability [34]. Various impression materials and their disinfection choices are mentioned in Table 2.

7. Disinfection of casts and models

Disinfection of casts and models is also an ideal practice to prevent the cross-contamination. However, the casts that were once properly disinfected can be re-contaminated during subsequent clinical and laboratory procedures. Many methods have been experimented for disinfecting the casts and models. These methods include spraying of disinfectant on the cast, immersion of cast in disinfectant solution, incorporation of disinfectants into dental casts[35] and also by using microwave oven [36].

Various studies reported that the immersion of cast in 0.525% NaOCl show no adverse effect on dimensional accuracy, surface detail reproduction and compressive strength of casts. Microwave irradiation is also an indicated method for cast disinfection [37]. However, autoclaving of the dental cast may results in reproduction of poor surface details, and immersion of the cast in chemical disinfectant dissolves gypsum, thereby decreasing the compressive strength. Microwave oven disinfection is therefore a potentially convenient solution [38]. In an in-vitro study, it was shown that the microwave irradiation significantly decreased the strength of dental casts after one hour of pouring, and did not show much effect after 24 hours. Therefore, it is worth waiting for 24 hours when using microwave irradiation for disinfection gypsum casts [39].

8. Recent trends in disinfecting impression materials

Recently, attempts have been made to incorporate antimicrobial agents into impression materials to avoid the conventional disinfection procedures as mentioned previously [7, 40-43]. Though these efforts were proved to be efficient in preventing the cross-contamination, an increased risk of dermal and mucosal irritation was observed in the patients when they were repeatedly exposed to certain compounds present in these impression materials [44].

Numerous experiments were performed on the alginate impression material as it is inexpensive and most commonly used to make different oral appliances. The disinfectant material added to the alginate must be effective with no adverse effects on the properties, accuracy and stability of the impression. Water solu-

Impression Material	**Disinfecting Agent**
Alginate	Iodophors and diluted sodium hypochlorite
Compound	Iodophors and diluted sodium hypochlorite
Polyether	Iodophors and diluted sodium hypochlorite, complex phenolics
Polysulphide	Iodophors and diluted sodium hypochlorite, complex phenolics
Silicone	Iodophors and diluted sodium hypochlorite, complex phenolics
Agar	Iodophors and diluted sodium hypochlorite
Zinc-oxide Eugenol Paste	Iodophors

Table 2. Impression materials and disinfection choices.

ble antimicrobial compounds such as quaternary ammonium compounds, bisguanidine compounds, quinoline compounds, dialkyl quaternary compounds, didecyldimethyl ammonium chloride, substituted phenols, chlorhexidine, and combination of these materials are typically employed [7]. Alginate microcapsules have been made by either blending the disinfectants physically or by coating onto the alginate powder. The disinfectant agent would be released on mixing these microcapsules with the liquid.

Similarly, disinfectants can also be added to the mixing liquid. Among these, CHX was the most widely used and efficient disinfectant without affecting properties and handling of alginates [45,46]. The addition of various concentrations of NaF to alginate powder produced a significant reduction of contamination with no significant effect on dimensional stability and details. In addition, the tear strength was significantly increased. However, it was also reported that the addition of NaF decreased the wettability of the impression. Among these methods, NaF solution is considered as a suitable disinfectant liquid for mixing with alginate impression material, as it did not significantly affect the properties of the material. It was shown that the properties of alginate were altered greatly at the higher concentrations of NaF. The optimum concentration was shown minimum effect on the properties of alginate impression material [47].

Numerous researchers have developed self-disinfecting impression materials by incorporating different antimicrobial nanoparticles in to impression materials. Numerous studies have reported that the addition of nanosilver is more effective against *S. aureus, Lactobacillus acidophilus*, *Actinomyces viscosus*, and *Pseudomonas aeruginosa* [41, 42, 48]. Particle size and concentration of the silver nanoparticles in alginate impression materials plays a significant role on antimicrobial activity. It was suggested that the silver nanoparticles with the average particle size of 80–100 nm impart superior antimicrobial property to the alginate hydrocolloid in a concentration-dependent manner than the finer nanoparticle size [41,42]. It was also reported that the addition of greater than 1.0wt% of silver nanoparticles affected the flow, gelation time and strength of alginate impression materials [41,42]. Antimicrobial efficacy of Zinc oxide and Copper oxide nanoparticles was also experimented by numerous researchers and these nanoparticles were also proved to be effective self-disinfecting agents for alginate impression materials with no significant negative effect on physical and mechanical properties [49].

9. Conclusion

Infection control is very important aspect in prevention of cross infection and safety of patients, Dentists and dental personnel. Impression disinfection can prevent spread of infection from dental clinic to dental laboratory technician, other patients and dental auxiliaries. It is the responsibility of the dentist to make appropriate choice of disinfection method for different impression materials.

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