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Healthcare-associated viral and bacterial infections in dentistry

[A.M.G.A. Laheij](#),^{1,*} [J.O. Kistler](#),² [G.N. Belibasakis](#),³ [H. Välimaa](#),^{4,5} [J.J. de Soet](#),¹ and European Oral Microbiology Workshop (EOMW) 2011

¹Department of Preventive Dentistry, Academic Centre for Dentistry Amsterdam, Amsterdam, The Netherlands

²Department of Microbiology, Dental Institute, King's College London, London, United Kingdom

³Section of Oral Microbiology and Immunology, Institute of Oral Biology, Center of Dental Medicine, Faculty of Medicine, University of Zürich, Zürich, Switzerland

⁴Department of Virology, Haartman Institute, University of Helsinki, Helsinki, Finland

⁵Department of Oral and Maxillofacial Surgery and HUSLAB, Helsinki University Hospital, Helsinki, Finland

* **A.M.G.A. Laheij**, Department of Preventive Dentistry, Academic Centre for Dentistry Amsterdam, Gustav Mahlerlaan 3004, 1081 LA Amsterdam, The Netherlands. Tel: +31 20 5980685, Fax: +31 20 5980333. Email: a.lahey@acta.nl

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Abstract

Infection prevention in dentistry is an important topic that has gained more interest in recent years and guidelines for the prevention of cross-transmission are common practice in many countries. However, little is known about the real risks of cross-transmission, specifically in the dental healthcare setting. This paper evaluated the literature to determine the risk of cross-transmission and infection of viruses and bacteria that are of particular relevance in the dental practice environment. Facts from the literature on HSV, VZV, HIV, Hepatitis B, C and D viruses, *Mycobacterium* spp., *Pseudomonas* spp., *Legionella* spp. and multi-resistant bacteria are presented. There is evidence that Hepatitis B virus is a real threat for cross-infection in dentistry. Data for the transmission of, and infection with, other viruses or bacteria in dental practice are scarce. However, a number of cases are probably not acknowledged by patients, healthcare workers and authorities. Furthermore, cross-transmission in dentistry is under-reported in the literature. For the above reasons, the real risks of cross-transmission are likely to be higher. There is therefore a need for prospective longitudinal research in this area, to determine the real risks of cross-infection in dentistry. This will assist the adoption of effective hygiene procedures in dental practice.

Keywords: cross-transmission, cross-infection, dentistry, bacteria, viruses, healthcare-associated infections

The oral cavity is a natural habitat for a large number of microorganisms. This ecological niche can be a reservoir for opportunistic and pathogenic microorganisms that can pose a risk for cross-contamination and infection and may even cause systemic infections. This is of particular importance in the case of routine dental practice, as the risk of exposure to microorganisms in the oral cavity is increased due to the open and invasive nature of the procedures.

It is important to consider that the pathways of contamination can be bidirectional. An infectious microorganism may be transferred from the patient to members of the dental team, but also vice versa, e.g. through the hands of the dental team. Moreover, another infectious association is the transfer of pathogens from patient to patient, without the mediation of the dental staff, but rather through a surface located in the dental practice, or a device or instrument used during dental procedures. This can apply in the case of inadequate sterilization of the dental instruments or disinfection of the dental unit. The possibility also exists that pathogens present in dental unit waterlines (DUWLs) could be spread by aerosols created by dental hand-pieces, presenting a risk for both the patient and members of the dental team.

There are a number of possible means by which transmission of viral and bacterial pathogens can occur in the dental practice. The patient's own saliva and blood are major vectors of cross-transmission. Blood-borne contamination can occur by exposure to the infectious material through non-intact skin and mucosal lesions. The highest infectious risk of this type is associated with accidental punctures by contaminated needles or injuries by sharp instruments. Insufficient cross-contamination control, such as improperly sterilized dental instruments, is also a possible device-borne means of pathogen transmission. Emanation of the pathogens through the spray of the hand-pieces of the dental unit can also be considered an air-borne or water-borne means of transmission, which may affect both the patient and the dental team. Air-borne infections can also occur via an inefficient ventilation system in the dental practice environment, whereby contaminated air may be withheld or recycled. Overall, the risk of any such transmission depends on the dose of the pathogens transmitted, the virulence of the pathogen, as well as the frequency or probability of exposure to the infectious material and the state of the host immune responses.

The aim of this position paper on healthcare-associated infections in dentistry was primarily to evaluate cross-transmission risks of relevant viral and bacterial infections based on the evidence available in the current literature.

Viruses

Herpes viruses

Herpes viruses are ubiquitous human pathogens which can all be found in the oral environment. Cross-transmission risks in dentistry are mainly related to herpes simplex virus type 1 (HSV-1) and type 2 (HSV-2) and to varicella-zoster virus (VZV). Oral secretions can also be infectious in the sub-clinical phase of herpes virus infections and constitute a risk of cross-transmission.

Herpes simplex virus (HSV) In Europe, the age standardized seropositivity for HSV-1 ranges from 52% in Finland to 84% in Bulgaria and the Czech Republic. For HSV-2 the seroprevalence ranges from 4% in England and Wales to 24% in Bulgaria (1). Seropositivity increases with age. In the US on average 60.3% of the population is infected with HSV-1 (2). The seroprevalence of HSV-1 is 92% and of HSV-2 is 13.2% in rural parts of East China (3). Twenty to forty percent of the seropositive subjects have

recurrent infections in the oral region and asymptomatic shedding is common (4). Manipulation of the oral region, endotracheal intubation and immune-suppression are health or medical care-associated factors known to provoke oral reactivation of HSV-1 (5, 6). Previously, HSV-1 primary infections were commonly acquired in childhood. According to recent literature, however, a large proportion of young adults in Western countries today are not infected with HSV-1 (1).

HSV is highly contagious and is transmitted via exposure of the mucosa or skin to infectious secretions or contents of an infectious HSV blister. In the periphery, HSV-1 is most commonly associated with mucosal infections of the oral region and HSV-2 with genital infections, although both viruses are detected in either anatomical region. In the oral region, HSV-1 primary infection causes gingivostomatitis in 1–10% of patients and labial herpes or intraoral herpetic ulcers are typical symptoms of reactivation (7).

Unless adequate personal protection is worn, the dental team and the patient are at risk of being exposed to HSV via direct contact with herpetic ulcers or infectious splatters from herpetic lesions or saliva (8). This could result in mucosal or skin infections, keratitis or herpetic whitlow. Outside the body HSV is inactivated within hours and is easily inactivated by disinfectants, such as alcohols.

There are only a few reports of HSV cross-infection in the dental practice. The frequency of herpetic whitlow was observed to be higher among practicing dentists compared to the normal population (9). However, reports confirming the transmission of infection from the patient to the dental team infection are available in the literature (8). Also the cross-infection of HSV from dental team to patients has been shown. A dental hygienist with a herpetic whitlow, who did not use gloves routinely, infected 20 out of 46 patients (10).

A large portion of the adult population is infected with HSV-1 and reactivations resulting in subclinical or symptomatic infection are frequent. However, little research is published on the cross-transmission and infection of HSV-1 through the dental practice.

Varicella-zoster virus (VZV) Chickenpox is the manifestation of VZV primary infection. About 90% of unvaccinated children acquire chickenpox before school age (11). In the periphery, VZV reactivation typically manifests as zoster of the skin or mucosa affecting 1–3 dermatomes in an episode. 20–30% of people are estimated to have zoster during lifetime (12). VZV can be also asymptotically shed in saliva. Immune suppressed patients are at increased risk for disseminated disease and in non-immune pregnant women fetal infections are possible.

VZV is a highly contagious virus. It is transmitted through direct contact to the blisters or exposure to infectious droplets from saliva or the respiratory system. Airborne transmission is also possible (13).

Cross-transmission during dental care has not been reported, but VZV is known to cause healthcare-associated infections. After inadvertent exposure in the hospital environment, the transmission rate has been reported to be 4.5–29% (14). Respiratory secretions can already be contagious 2–4 days before varicella rash eruption. In addition to rashes, secretions of a zoster patient may also be contagious (15). VZV DNA has been detected in the environmental contact area of a zoster patient but also in the air-conditioner filter in a zoster patient's room, indicating a possibility of spread by aerosols from zoster patients (15, 16).

There is no evidence of VZV cross-transmission within dental healthcare but reports from other medical fields indicate that VZV infection constitutes a risk for healthcare-associated transmission of VZV in the dental practice as well.

Human immunodeficiency virus (HIV)

In the 2010 UNAIDS report the total number of people infected with HIV worldwide in 2009 was estimated to be 33.3 million (0.8% of the global population). The HIV prevalence ranges from 0.2% in Central and Western Europe to 5% in Sub-Saharan Africa.

In prospective studies the risk of HIV infection after the percutaneous exposure to HIV infected blood was estimated to be 0.3% (17, 18). After mucous membrane exposure the risk is approximately 0.09% (19). The risk of acquiring HIV after exposure to tissues or other body fluids of an HIV infected person is not quantified, but is thought to be substantially lower (18). The risk of an infection correlates with the volume of blood exposure and blood viral counts (20). Transmission of HIV via saliva is considered unlikely due to low salivary viral titers, low numbers of CD4-positive target cells and the presence of anti-HIV antibodies and salivary antiviral factors protecting oral tissues (21).

Until December 2002, there were 344 published cases worldwide in which healthcare workers were infected with HIV as a result of their profession (22). Of these, 106 were documented to result from occupational exposure. For dental professionals eight possible occupationally acquired HIV infections were published, although no cases were confirmed (22). In four cases transmission of HIV from a healthcare worker to a patient was reported; a dentist in Florida, USA (23), a nurse in France (24), an orthopedic surgeon in France (25) and an obstetrician in Spain (26). Transmission of HIV from patient to patient has been reported, particularly as a result of poor infection control in developing countries and in developed countries in recipients of blood and blood products (27). There are no reports of patient to patient transmission of HIV in the dental practice.

The risk of transmission of HIV through the dental practice appears to be low; however, the data may not provide the complete picture. For instance, no occupationally acquired HIV infections were reported in Asia or parts of Africa and South America, yet the prevalence of HIV in some of these areas is high (28). Given that the risk of exposure to HIV is expected to be higher in areas where the prevalence of HIV infection is high, one would have anticipated reported cases of healthcare associated HIV transmission from these areas too.

Hepatitis B virus

The prevalence of chronic Hepatitis B virus (HBV) infections (positive for surface antigen HBsAg) ranges from <2% in Europe and the USA to 8% in Asia. However, the prevalence of people that have experienced an HBV infection at some stage (positive for antibodies to HBc) ranges from 4–15% in low endemic countries to 40–90% in high endemic countries (29).

Before HBV vaccination was available, HBV infection was considered to be an occupational risk for healthcare workers and laboratory personnel (30). Following the introduction of the vaccine in 1983, the percentage of dentists with serological evidence of an HBV infection declined, especially in young dentists (31). However, even after the vaccine became available, healthcare providers remained at risk for HBV infection (32). The risk of an infection with HBV highly depends on the volume of blood and on the Hepatitis B e antigen (HBeAg) status of the source (33). The risk of HBV transmission to a healthcare worker after the percutaneous exposure to HBeAg- and HBsAg-positive blood is approximately 30%. The risk of HBV transmission after the percutaneous exposure to HBsAg-positive, HBeAg-negative blood is 1–6% (34). Besides through percutaneous injuries, HBV infection can also result from (in)direct blood or body fluid exposure through inoculation into cutaneous scratches,

abrasions, burns or on mucosal surfaces (35). HBV has demonstrated the ability to survive and remain infectious in dried blood at room temperature on environmental surfaces for at least 1 week and probably longer (36).

The US Centers for Disease Control (CDC) described 300 patients that were infected through HBV-infected healthcare workers, including dentists and oral surgeons (34). Perry et al. (37) reported that a total of 12 healthcare workers had infected 91 patients with HBV between 1991 and 2005. The percentage of patients infected by the healthcare workers was 2.96%. None of the healthcare workers were dentists or members of the dental team. Recently, patient-to-patient transmission of HBV in an oral surgery practice was demonstrated using molecular techniques (38). In this case an older woman that had oral surgery contracted an acute Hepatitis B virus infection 2 months after her visit to the oral surgeon. The source turned out to be a woman that had oral surgery on the same date, in the same room, with the same hospital staff, 2 hours before the index patient. Other patients that were treated on the same day and the hospital staff that worked on that day were not infected. Interestingly, the CDC did not find breaches in standard infection control practices (38).

Vaccination of healthcare workers for HBV has greatly reduced the risk of transmission of HBV. However, HBV is highly infectious and vaccination for HBV is not standard for healthcare workers throughout the world. Moreover, patient-to-patient transmission of HBV has recently been proven. The risk of transmission of HBV through the dental practice remains an issue.

Hepatitis C virus

The prevalence of Hepatitis C virus (HCV) infection ranges from 0.1–1% in Northern Europe, 0.2–1.2% in Central Europe and 2.5–3.5% in Southern Europe (39). However, the prevalence of HCV infection can be as high as 26% in the southern parts of Italy (40). In the eastern part of Europe the prevalence of HCV infection was reported to be 0.9–4.9% of blood donors and 1–10% of healthcare workers (41). High prevalence of HCV outside of Europe is found in Egypt (14.9%), Taiwan (4.4%), Vietnam (2–2.9%) and Pakistan (3%) (42). Here the regional differences are large as well. The prevalence rate of HCV is 30% in the Punjab region in Pakistan.

Relatively little is known about the occupational risk of HCV infection. The average transmission rate of HCV after exposure is about 0.5% (43), much lower than for HBV and slightly higher than for HIV. The risk of transmission of HCV was significantly associated with hollow-bore needle placement in the source patient's artery or vein, deep injury and the sex of the healthcare worker. All cases of HCV transmission occurred after percutaneous exposure to viraemic blood or body fluids and the risk of transmission increased with the HCV viral load (44).

Perry et al. (37) reported a total of 11 HCV-positive healthcare workers that infected 38 patients between 1991 and 2005. The HCV-infected healthcare workers did not include dentists or oral surgeons. One study (45) assessed the risk of HCV infection among dentists in New York. Dentists and especially oral surgeons were at higher risk of having anti-HCV antibodies in their blood than matched blood donors. The higher risk for HCV infection was only attributed to occupational exposure. In the Netherlands, two cases of Hepatitis C virus infection resulting from blood exposure accidents have been documented in healthcare workers (46, 47). Occasionally, cases of acute HCV infection are attributed to blood exposure accidents. In a UK dental practice 1.2% of the staff (none of the dentists) were positive for HCV antibodies. Since the prevalence of HCV in the British population is 0.08–0.55%, the dental healthcare workers have a slightly higher risk of HCV infection compared to the general population (48).

In the general population the prevalence of HCV-infected patients is relatively low. In combination with a low average transmission rate, the risk of HCV transmission in the dental practice appears to be low. Research seems to support this conclusion. However, little is known about the transmission of HCV in comparison to HBV and HIV. Vaccination for HBV does not protect against infection with HCV.

Hepatitis D virus

Hepatitis D virus (HDV) infection can only occur in patients that are HBV co-infected. The incidence of Hepatitis D virus infection is not known, but is thought to be at about 5% of HBV carriers. In the literature, there is a lack of available reports regarding HDV infections in dentistry. One paper reported an outbreak of HDV in the 1980s where dentists were involved (49).

Bacteria

Viruses are mainly associated with a specific disease whilst for many bacteria this is not the case. Often transmission of bacteria does not result in a real infection, especially when opportunistic bacteria are involved. In the following sections, some severe pathogens are discussed that are potentially transmitted in the dental office. Furthermore, special forms of commensal bacteria that are (multi)-resistant to antibiotics are discussed, since they can result in severe and even lethal infections.

Mycobacterium spp.

Mycobacterium tuberculosis causes the disease tuberculosis (TB). Other *Mycobacterium* spp. such as *M. bovis* are also capable of causing the disease. TB continues to be a major health burden in the twenty-first century with an estimated 1.7 million deaths every year (50). In the UK the number of reported cases of TB have been rising in recent years (51). Furthermore, the emergence of multi-drug resistant strains of *M. tuberculosis* (MDR-TB) is a major problem in the successful treatment and control of TB (52). Transmission of *M. tuberculosis* occurs through aerosols generated by coughing, sneezing and speaking. *M. tuberculosis* can remain airborne within small droplets for several hours and susceptible individuals can still become infected (52). It is thought that as few as 1–5 bacilli are required to initiate infection (53). Only about 30% of those exposed to TB are infected, 90% of them latently. In latent infection the bacteria remain viable in the body for many years without causing an active infection but retain the ability to activate under favorable conditions. It is not possible to predict who will develop active TB at some point (54). However, risk factors include immune-compromising situations such as chronic inflammatory diseases, during antitumor necrosis factor therapy, diabetes/obesity or a HIV co-infection (55). Other risk factors include alcoholism, and poor nutrition (54).

The possibility of *M. tuberculosis* transmission within dental settings has been subject to risk assessments by the CDC. Most dental clinics in the US were considered to fall within a very low risk category (56, 57). Despite the putative low risk, evidence for the transmission of TB in dental practice is present. In the UK a report documented cases of intraoral and pulmonary TB in patients that had been infected by their dental surgeon (58). All of the patients had tooth extractions performed by the dental surgeon who had active pulmonary TB. Furthermore, dental team-to-dental team and possibly patient-to-dental team TB infection was documented (59, 60). Hospital dental staff may be at increased risk of exposure to TB (60, 61).

The risk of TB transmission in the dental practice appears to be low. However, transmission of TB remains possible, primarily through patients from high risk areas in the world or from patients with reactivated TB infections such as the present-day elderly who may have been exposed to TB in their youth.

Pseudomonas spp.

The opportunistic pathogen *Pseudomonas aeruginosa* is frequently recovered from DUWLs where it can form biofilms in the tubing. *Pseudomonas* spp. may pose an important health hazard, particularly for immune-compromised patients. *P. aeruginosa* is associated with many types of infection, including hospital-acquired pneumonia (62), skin infections (63), urinary tract infections (64), burns (65), eye infections (66) and blood stream infections (67). Furthermore, *P. aeruginosa* is increasingly becoming multi-drug resistant, thus negatively affecting patient outcomes (68).

P. aeruginosa was isolated in 25% of studied DUWLs in Canada (69) and in 8% of DUWLs in Switzerland, where the dental chair units older than 5 years were contaminated significantly more often than new units (70). Patients with cystic fibrosis, known to be exceptionally susceptible to *Pseudomonas* spp. infections, were investigated for the presence of *P. aeruginosa* after a dental visit. *P. aeruginosa* was isolated from up to 5% of DUWLs, but only one patient tested positive in sputum for genotypically matched *P. aeruginosa* (71). Others reported two patients with solid tumors that developed gingival abscesses with pyocin-matched *P. aeruginosa* after dental treatment. Furthermore, 78 subjects with no underlying medical condition were transiently colonized for 3–5 weeks with *P. aeruginosa* when treated in a unit with contaminated water (72).

Given that the incidence of *Pseudomonas* spp. in DUWLs is high but that there are limited reported cases of infection following exposure to DUWLs, it is apparent that the risk of infection is very low. Although reports in this area are conflicting (73, 74); DUWL endotoxin from gram-negative bacteria such as *Pseudomonas* spp., has been suggested to complicate the healing processes after periodontal surgery operations (75) and to induce asthma exacerbations (74). Therefore, further studies will be needed to verify this potential health hazard.

Legionella spp.

Legionella spp. can cause a severe form of pneumonia in humans: Legionnaires' disease, and a less severe flu-like disease: Pontiac fever. *Legionella pneumophila*, particularly *L. pneumophila* serogroup 1, is the most common etiological agent of Legionnaires' disease although other species of the *Legionella* genus can also be causal (76). Inhalation of aerosols contaminated with *Legionella* spp. acts as the main route of transmission (77). Legionnaires' disease outbreaks have frequently been associated with contaminated aerosol-producing water systems such as showers, humidifiers and water-cooling towers. *Legionella* spp. can readily multiply in water at temperatures between 25 and 45°C (78), especially in stagnant water and they grow in biofilms. Legionnaires' disease is considered to be an important nosocomial infection, about 11.5% of reported Legionnaires' disease cases in the UK between 1980 and 2009 were hospital-acquired (UK's Health Protection Agency, January 2011). Outbreaks of Legionnaires' disease in hospitals have been predominantly associated with contaminated potable water supplies (79).

Legionella spp. presents a potential risk in the dental clinic where contaminated DUWLs could act as a source of infection to both dental staff and patients. DUWLs harbor microbial biofilms that are seeded by the mains water supply and can provide a suitable environment for the multiplication of *Legionella*

spp. within protozoa (80). Studies of contamination of DUWLs frequently detected *Legionella* spp. among the bacteria present, although their prevalence varies substantially between different studies (81–84). In particular, prevalence rates vary with differing geographic location (80). While the prevalence of *Legionella* spp. in UK DUWLs varies between 0.37 and 1.19%, similar studies in the US show prevalence rates of 68% (83, 85), although differences in methodology could be responsible for these differences. The number of colony forming units (CFU's) of *Legionella* spp. found in DUWLs has been reported to be around 10^2 – 10^5 CFU/ml. The infective dose of *Legionella* spp. is thought to be greater than 10^5 CFU/ml (86).

Recently a case was published of a patient that was infected with *L. pneumophila* serogroup 1 which originated from a dental office in Italy (87). After hospitalization because of the pulmonary problems, the patient died from this infection. By using molecular typing methods, it was clearly shown that the source of the *Legionella* infection was the DUWL in a dental practice, where both the tap water and the unit water were contaminated. It is remarkable that only one patient acquired this *Legionella*. Even Pontiac fever was not found within the other patients in this office. This is the first time that Legionnaires' disease resulting from visits to, or treatment in, a dental clinic was documented. To date, there are no known cases of Pontiac fever in patients, resulting from visits to, or treatment in, a dental clinic. This would indicate that the risk to patients posed by *Legionella* spp. from DUWLs is low. However the risk is not absent and infection can have dramatic consequences. In addition, cases of Pontiac fever that appear 1 week after a dental visit may not be recognized as such and the link between disease and dental treatment is not acknowledged.

There is a single documented fatal case of Legionnaire's disease in a US dentist. In this case the infection was attributed to exposure of the dentist to DUWL aerosols containing *Legionella* spp. (81). *L. pneumophila* and *L. longbeachae* were detected in the dentist's lung tissue and in the DUWLs, however, the dentist's domestic water supplies also had very low levels of *Legionella* spp. The evidence in this case was not conclusive. Studies have found dental staff to have higher serum levels of antibodies specific to *Legionella* spp. than members of the general public (88, 89). This is indicative of an increased occupational exposure to *Legionella* spp. through contaminated aerosols.

Despite this, no other cases of Legionnaires' disease or Pontiac fever shown to result from occupational exposure have been documented in dental staff. However, the lack of investigation into the DUWLs of the dental clinics in other cases of Legionnaire's disease or Pontiac fever in dental staff could have led to under-reporting.

Multi-resistant bacteria

Multi-resistant bacteria pose a major health risk and are increasing the cost of healthcare worldwide (90). Multi-resistant bacteria are mainly transmitted by direct contact or indirectly via contaminated surfaces. Increased risk of colonization by multi-resistant bacteria is associated with long hospital stays, living in a nursing home, institutional and international patient transfers, surgical procedures and the presence of invasive devices, severe medical conditions, immune suppression and antimicrobial therapy (91, 92). Currently, the most problematic healthcare-associated multi-resistant species are methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum β -lactamase (ESBL)-producing *Enterobacteriaceae* and carbapenemase-producing gram-negative bacteria (93).

S. aureus asymptotically colonizes the oropharynx or the skin of 20–30% of people and it has been isolated from various oral infections (94). *S. aureus* is a commensal bacterium, but is also responsible for skin infections, septicaemia, endocarditis, osteomyelitis, pneumonia and toxic shock syndrome (95). Among hospitalized patients receiving treatment for oral conditions, oral cancer patients have been reported to be at increased risk for MRSA colonization (96–98). Carriage rate is influenced by the age and the overall disease status of the host (99). MRSA is resistant to all β -lactam antibiotics including methicillin, cloxacillin, dicloxacillin, cephalosporins and carbapenems and may also display resistance to some other antibiotics.

During the past 10 years, community-acquired MRSA (CA-MRSA) infections have been increasing (100). Studies on the oral or nasopharyngeal MRSA colonization rate report a prevalence of up to 26%, depending on the population (101). In a recent literature review, MRSA carriage in healthcare workers was found to be 4.6%, which is above the rate of the normal population (102). In most studies, MRSA carriage in dental healthcare workers has not been above the level of the normal adult population (101). In the greater Houston metropolitan area 4.2% of dentists and 1.5% of dental hygienists were positive for MRSA (103) whereas only 1.5% of the non-institutionalized US citizens are colonized with MRSA (104). Others showed that 21% of dental students were found to be carrying MRSA in their nose (105). MRSA carriage in dental staff could pose a risk for transmission of MRSA to the patients or co-workers. In the UK, a dentist carrying MRSA was proven to have transmitted MRSA to two patients having oral surgery (106). During 1 year of surveillance in a dental hospital clinic, 8 (out of 140) patients were colonized or infected with MRSA after treatment. The air–water syringe and the chair arm of the dental chair were contaminated with MRSA. The antibiograms revealed that the isolated MRSA strains were similar between patients and the contaminated chair and it was concluded that the patients were colonized or infected by (parts of) the dental chair (107). Furthermore, MRSA has been isolated in dental clinics outside of the hospital environment (108). Moreover, devices such as dental impression guns were reported to be contaminated with MRSA in routine use (109). Dental impressions and gypsum casts were also shown to be heavily colonized by MRSA (110).

Bacteria in the family *Enterobacteriaceae* can acquire the ability to produce the enzyme extended-spectrum β -lactamases (ESBL) making them multi-resistant to penicillins, second and third generation cephalosporins and monobactams (111).

Carbapenemase-producing gram-negative bacteria such as *Klebsiella pneumoniae* carbapenemase (KPC) are the most recent and serious threat of healthcare-associated infections since they are resistant to all β -lactam antibiotics and they display co-resistance to other antibiotics. They have spread particularly via international hospital transfers from epidemic areas. In addition, *Enterobacteriaceae* harboring New Delhi metallo- β -lactamase-1 (NDM-1) have been repeatedly introduced in Europe via patient transfers (92).

In healthy individuals oral colonization by *Enterobacteriaceae* or *Pseudomonas* spp. is usually transient (112). Even transiently colonizing bacteria can be part of the flora of oral cavity related abscesses and source of cross-transmission (113). ESBL-producers were detected in oropharyngeal samples of 40% of the inhabitants in an Italian long-term-care facility (114) and in the throat of patients in intensive care units (115, 116). There are no published reports available on the possible association of ESBL- or carbapenemase-producers and oral infections nor evidence for transmission of these bacteria through the dental practice.

Hence, MRSA has been shown to be transmitted in dental care. However, evidence for the transmission of ESBL- and carbapenemase-producers does not exist yet, although transmission in the dental practice is possible.

General considerations and concluding remarks

This paper aimed to report and discuss the current literature on the transmission of relevant viruses and bacteria in dentistry. All viruses and bacteria discussed above can be, and most have been, proven to be transmitted to the patient or the dental team in the dental practice. It appears that the transmission of, and infection with, Hepatitis B virus poses the greatest risk for both patients and the dental team, based on the incidence and risk of transmission. Literature on the transmission of the other bacteria and viruses is scarce and it seems that the risk for transmission resulting in an infection with these microorganisms is low. It should be noted, however, that transmission of pathogens may result in an asymptomatic infection that can last weeks or even months until symptoms appear (Table 1). In addition, it is likely that some patients that visit the dental practice are not aware of their infectious status and may carry an asymptomatic infection. There is a lack of prospective longitudinal studies that investigate the incidence of healthcare-associated infections in patients after dental treatment.

Table 1

Incubation period of microorganisms associated with healthcare infections in dentistry

Microorganism	Incubation period
Herpes simplex virus	Up to 2 weeks
Varicella zoster virus	2–3 weeks
Hepatitis B/C/D virus	Up to 6 months
HIV/AIDS	Months–years
<i>Mycobacterium tuberculosis</i>	Up to 6 months
<i>Pseudomonas</i> spp.	3–10 days
<i>Legionella</i> spp.	2–19 days
<i>Staphylococcus aureus</i>	4–10 days

Another important point to keep in mind is that the likelihood of healthcare-associated infections, particularly in dentistry, of being detected, reported, documented and published is small (37). Therefore, healthcare-associated infections are under-reported in literature from the developed world (27, 117). In developing countries the risk of transmission of several microorganisms, for instance the blood borne viruses, is high since a large section of the population is infected. However, literature on the subject from these countries is scarce.

Based on the number of reported cases, most of which were of blood borne viruses, the actual risk for developing an infectious disease through the dental practice appears to be low. However, the real transmission rate of the viruses and bacteria that are discussed in this paper is probably higher. As long as accurate data are absent, the dental team should be fully aware of the risk of dissemination of potentially hazardous microorganisms and ensure that efficient cross-infection control procedures are well in place (118). Every member of the team must follow the standard procedures required to prevent the transmission of microorganisms. Besides preventing disease by vaccination, these include hand hygiene, personal barrier protection, instrument disinfection and sterilization protocols, surface decontamination strategies, approaches to maintain the quality of DUWLs, as well as the emergency procedures in case of accidents that would increase the risk of cross-transmission. These procedures substantially lower the risk of the transmission of microorganisms. Every patient should be treated as potentially infectious. The dental team should be acquainted with the biological principles behind these procedures. The cross-infection control regulations should undergo regular monitoring and need to be subjected to revision whenever necessary.

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The authors declare no conflicts of interest.

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