

PERSPECTIVE

Open Access



Putting the mouth back in the body – the neglected area of dental and oral travel health

Irmgard L Bauer^{1*}

Abstract

The lack of dental travel health care has been deplored for some time. Travel medicine's remit is to prepare people for travel. People travel with their mouth firmly in their body, yet the mouth's wellbeing does not rate a mention. This article represents the first exploration of a range of topics relevant to an until now neglected, yet potentially highly important, area of health care. A range of dental mishaps can occur while away from home, from simple toothache to accidents, serious emergencies, or restoration failures. Other problems originate in unwise behaviour, including holiday-inspired body modifications.

Unless there is pain, teeth are typically not thought about much. However, examining the practical side of dental hygiene during travels, several overlooked and perhaps surprising topics emerge that – through the travel lens – take on a different and important role: the oral microbiome, toothbrush hygiene, the toilet plume, and traveller diarrhoea. Based on this discussion, recommendations are made for clinical practice, education, and further research.

The historical chasm between dentistry and medicine, despite long-standing calls for change, does not seem to go away and impairs holistic high quality travel health care. Travel medicine can bypass this unproductive division. It has the unique opportunity to be the first medical specialty cooperating closely with dentists to bridge this gap by providing quality travel health care to travellers with all their body parts attached.

Keywords Dental care, Toothbrush contamination, Toilet plume, Traveller's diarrhoea, Dentistry vs. medicine, Oral piercings, Tooth jewellery, Disease prevention, Quality health care

Introduction

The lack of dental travel health care has been deplored for some time [1] and the few available publications on this topic are a quarter of a century old [2–5]. Insurance companies speak to travellers directly through product disclosure statements and tips on their website[e.g., 6, 7], and dental clinics may provide post-treatment travel advice online. Academic articles are of the 'travellers

should' kind; none indicates who is supposed to act on this information and advise the traveller and, therefore, none has an applicable purpose. It is unclear if travel clinics advise international travellers on dental/oral health, as documented evidence appears to be missing or unavailable. Search engines available to the public respond to keywords 'dental' and 'travel' with a myriad of advertisements for dental tourism and are useless for those looking for dental travel health information.

The purpose of this paper is to (1) describe dental and oral issues linked to travel, (2) draw on research in dentistry and its specialties, microbiology, infection control, epidemiology and others, to identify issues important for travel medicine, and (3) discuss the chasm between

*Correspondence:

Irmgard L Bauer

Irmgard.Bauer@jcu.edu.au

¹College of Healthcare Sciences, Academy - Tropical Health and Medicine, James Cook University, Townsville, QLD 4811, Australia



© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

dentistry and medicine with a view to bridge the gap between both for the benefit of comprehensive high quality travel health care. Importantly, this discussion specifically excludes the topic of dental tourism.

Dental health in travellers

The history of dentistry is fascinating [8], yet often of the kind that makes one grateful for access to modern dental technology. However, despite people travelling since the dawn of time, prevention of or attention to dental problems when away from home seem unaddressed. Travel medicine books from the 1500s [9–11] do not mention teeth. A comprehensive compendium on dental health from 1530/46 details anything from helping teething children to treating worms in teeth or stinking gums to conserving healthy teeth, but travel advice is missing [12].

Throughout history it seems dental problems had to be suffered regardless of where one lived, worked, or travelled. One can only assume that travellers possibly included home remedies in their luggage; advice to do so is illusive. Portable were false teeth which, over the centuries, improved in functionality and cosmesis and may have been accompanied by a spare set, in case of breakage. Equally portable were masticators, plier-like implements with metal spikes, to help ‘chew’ meat before passing it into a toothless mouth. Travellers could also avail themselves of market-dentistry, travelling dentists, or a tooth-drawer’s services [13]. Today, regular dental check-ups are recommended to keep teeth in good working order.

Pre-travel dental check-ups. Too much to ask?

Poor dental and oral health not only impacts on the functionality of the mouth and appearance, speech, and self-esteem, it causes or contributes to a range of chronic diseases. Regular dental checks help preventing such negative consequences. However, a visit to the dentist is often delayed or cancelled, even if pain provides much encouragement, due to a range of factors. Unfavourable patterns of dental attendance are caused by dental indifference, embarrassment, dissatisfaction with previous care, but most importantly fear and costs. Dental anxiety may be caused by a perceived lack of control, uncertainty about what to expect, previous adverse experiences or others’ bad experiences [14–19]. Cost is a major barrier to regular dental visits [14, 17–19]. Australia, for example, has a primarily private dental health system. The wealthy can pay the fees; the very poor have access to public services, but the extensive waiting times negate the benefits of treatment; many people in-between cannot afford a consultation and attend only when problems are serious, and extraction is the most cost-effective solution [14]. For various reasons, almost two-thirds of Australian adults avoid or delay a visit, 63% of them due to

cost [20], causing over 87,000 avoidable hospitalisations in 2022–2023 [21]. Other countries may find similar results.

Considering these barriers, and that people go to the dentist to have a problem fixed, it is highly unlikely that travellers pop into a clinic to have a chat about travel advice. The number of travellers who might do so is unknown. The number of dentists who give travel health advice is equally unknown as is the number of travellers who depart despite having a dental problem. Regardless, dental events occur during travel.

Dental issues while travelling

There is relatively little recent information on dental mishaps during travel. Despite half of cruise passengers (mean age 71 years) having attended a pre-travel dental check, complex dental emergencies required on-board dental treatment; defective restorations, pulpal disease, defective prostheses, and caries were the most frequently diagnosed [22]. Dental problems were the third most common health problem for Voluntary Service Overseas (VSO) volunteers [23]. Dental emergencies during wilderness expeditions [24], including high altitude trekking [25], may require evacuations, with altered hygiene practices making existing dental issues worse [25].

Insurance companies are the only source of collated information on the extent of dental events overseas. These data are now highly guarded and only available under legal agreements. Twenty-five years ago, the distribution of dental treatments claimed was conservative (30%), prosthodontic (26%), endodontic (18%), multiple/other (16%), periodontal (8%), and oral and maxillofacial surgery (2%) [2]. Unfortunately, it is impossible to know if current trends are similar.

Millions of travellers fly to their destinations. Many of them experience toothache during flights due to changes in atmospheric pressure (barodontalgia). These pressure variations, previously described during WWII in aerial combat pilots [26], called for a new dentistry specialty: aviation dentistry. Other predicaments were xerostomia (dry mouth), reduced retention of prostheses, and odontocrexia (tooth fracture) [27, 28]. While teeth typically fractured due to previous restorations [29], the fracture of a sound tooth has also been reported [30]. Similar findings apply to another popular tourist activity: scuba diving. While orofacial pain was common in an Australian study, odontocrexia was rare [31]. However, dental barotrauma, barodontalgia and mouthpiece-related damage due to insufficient interdental bite platforms are known [32].

Practical problems affecting dental health and hygiene

People are educated to brush their teeth twice daily, preferably after meals, and floss and/or use interdental

brushes. However, during travel, routine dental hygiene practices can suddenly be curtailed for several reasons, such as limited opportunity or time to clean teeth, or uncondusive environment or circumstances. Other problems may, at least temporarily, be out of the travellers' control, e.g., limited choice of non-cariogenic food, dehydration, injury to teeth or mouth, or damage to restorations. Practical problems, how to avoid them, and how to deal with mishaps, will be discussed later in this paper. Intended damage to teeth, i.e. dental modifications, adds to the long list of potential predicaments and deserves a separate introduction.

Oral and dental modifications

Away from home, free from social constraints and in an adventurous mood, some may return home with stories of partaking in local customs or with a memento of their travels. This can be as harmless as dreadlocked hair. It can also be imprudent or dangerous, agreed to on a whim, fuelled by drug or alcohol-induced impaired decision-making, or on purpose as a sign of self-expression, non-conformity, peer-acceptance or to shock family and friends. Travel medicine has discussed ill-advised behaviour, such as the consumption of substances [33] or getting risky tattoos[e.g., 34] while overseas. Oral cavity modifications obtained while travelling have not attracted the equivalent attention. Dental modifying treatment may also be obtained on a whim while coming across local advertisements for cheap dental work, especially exaggerated veneers ('Turkey Teeth').

In many cultures, oral decorations have a long history displaying group affiliations, social status or simply beautifications. Today, apart from women's pierced earlobes, other piercings, especially oral modifications, still catch the eye even if they seem to become more common. Dental and oral travel health is interested in two types: oral piercings, and tooth jewellery. Both are intended to 'make your smile glow' [35] or 'make you shine like a star' [36].

Oral piercings

Oral soft tissue is pierced, and a piece of metal (barbell, ring, labret) inserted. Piercings may be located through the tongue, lingual frenulum, upper labial frenulum, the oral rim, cheeks, even the uvula [37]. Several recent systematic reviews [38–42] of diverse studies examined the local and systemic impact of oral piercings with the overall consensus of warnings of serious negative effects, and the advice to remove piercings.

Immediate reactions to piercings may be pain, swelling, uncontrollable bleeding, and infection with later and chronic complications, such as damage to teeth, restorations and gums, tissue overgrowth and recessions [43], increased plaque build-up, tooth fractures, periodontal disease, and nerve damage [44]. There may also be a

galvanic current flow between the jewellery and metal dental restoration as well as mucosal reaction to corroding metal [40]. Systemic and potentially life-threatening complications include adornment aspiration, endocarditis, hepatitis, and Ludwig's angina [45]. Unhygienic piercing techniques increase the risk of infections.

Virtually all literature emphasises that oral hygiene is of particular importance for piercing wearers, a requirement that may be harder to meet when travelling. The same literature also highlights the vast lack of complication awareness, not only by customers [37, 46, 47] but also piercers, where 100% were unaware of tongue and gum anatomy and only 30% explained risk and maintenance to clients [48]. The need for public, client, health professional and piercer education is stressed by many authors, yet who conducts the education remains elusive. Hardcore modifications, such as tooth filing or tongue splitting, are probably rare and medical advice unwelcome.

Tooth jewellery

Tooth beautifications with gems or modifications, such as filing and grooving, have also been part of many ancient cultures but resurfaced more recently with rappers, hip-hop artists, popstars and other 'celebrities'. It is then no wonder that dental jewellery is advertised (by dentists) as 'to be a really [sic] celebrity tantalize your teeth with tooth jewellery or tooth gems, add sparkle to your smile' [36, p.358]. Tooth jewellery is particularly popular in India; internationally, many tattoo parlours and piercers have added this service to their repertoire. Tooth gems are glass crystals mounted on aluminium foil, while dazzlers and twinkles are precious stones mounted on gold. In both cases, the enamel must be etched, and the gem bonded with a flowable composite resin. Tooth grills ('fronts') are removable or permanent metal (precious or otherwise) shields covering the front teeth. Tooth tattoos are removable porcelain crowns with images in different shades of colour placed after tooth reduction. Tooth rings require the drilling of a hole through which the ring is placed, and an optional charm attached. Such rings can also connect two neighbouring teeth. Complications include aspiration, accumulation of cariogenic microbes, and many listed above under piercings [44, 49–51]. Again, hygiene practices are of utmost importance.

Even though practicing good oral hygiene during travel may be challenging, advising to just putting in more effort seems simple enough. However, on close inspection, several spanners are thrown in the works that need further examination.

The oral microbiome – does travel matter?

Antonie van Leeuwenhoek (1632–1723), proud of his clean teeth, found growing between them a ‘*little white matter as thick as wetted flower [flour]*’. Putting his magnifying glass to good use he writes: ‘*and then to my great surprise perceived that the aforesaid matter contained very small Animals, which moved themselves very extravagantly*’ [52, p.568]. The same happened with the ‘matter’ of other people with clean teeth, and no animals could be found in anyone’s ‘spittle’. Brandy or vinegar only killed creatures on the outside of the ‘scurf’ (dental calculus).

Today, we know the animals as microbiome, a complex community of microorganisms without which life would not exist. Everyone’s microbiome is unique, influenced by, e.g., genetics, diet, or the environment [53]. After the gut, the oral cavity houses the second largest and diverse microbiome colonising hard and soft surfaces [54]. The relevance of the gut microbiome in travel has been highlighted recently [55]; an exploration of the oral counterpart in that respect is still outstanding.

Several hundred species of microorganisms, i.e. bacteria, viruses, fungi, and protozoa, form a biofilm [56] consisting of symbiotic commensal microbes which do not harm, and prevent pathogenic species from adhering. If, however, oral pathogens break the biofilm, oral infectious diseases, such as caries, periodontitis, endodontitis, alveolar osteitis or tonsillitis, can occur [54, 57, 58]. Furthermore, an unbalanced oral microbiome has been linked to systemic disease including cardiovascular disease, diabetes, stroke, pneumonia, inflammatory bowel disease, among others [57–59]. Dental calculus (periodically mineralised plaque) acts as a long-term reservoir for microorganisms [59]. While there is a predominant core microbiome, external factors influence a person’s unique variable microbiome [54]. Diet plays an important part. For example, a sugar-rich diet and poor oral hygiene, a situation not uncommon during travel, promote cariogenic microbes such as *Streptococcus mutans* [60]. Interaction with others also likely influences microbiota, for example, prolonged contact with family members, even pets [61]. If there is such a transaction between (long-term?) fellow-travellers is unknown. Intimate kissing plays a role in transferring tens of millions of bacteria per kiss [62], a finding that may be of interest considering the frequency of travel-related sexual encounters. If it matters, we do not know as we have not asked these questions.

What should matter to travel medicine more directly are non-oral (non-resident) bacteria in the oral cavity and their relevance for overall health with a particular focus on Enterobacteriaceae, e.g. *Staphylococcus aureus*, *Escherichia coli*, or *Enterococcus faecalis*, introduced with contaminated food and water or poor personal hygiene [63, 64], also with a long list of systemic consequences.

A link to traveller’s diarrhoea seems suddenly worthy of investigation.

Traveller’s diarrhoea

Traveller’s diarrhoea (TD) is the most common health problem faced by travellers to mainly lower-income destinations with the now added concern of increasing antimicrobial resistance [65]. Recently identified risk factors for TD, including longer travel periods, travel to destinations with less advanced infrastructure and sanitation, backpacking or a travel companion with TD [66], coincide with the earlier identified travel where it may be difficult to keep toothbrushes clean. TD is caused by bacteria (e.g., *Escherichia coli*, *Campylobacter jejuni*, *Salmonella ssp.*, *Shigella ssp.*, *Clostridium ssp.*, or *Staphylococcus aureus*), viruses (e.g., norovirus, rotavirus), parasites (e.g., *Giardia intestinalis*, *Entamoeba histolytica*, *Cryptosporidium*, *Cyclospora cayetanensis*) or unknown factors. Large-scale viral outbreaks on cruise ships [67] typically enter the news; transmissions on planes have been recorded [68, 69]. Fomites (surfaces, toilet bowls) contaminated with vomit and/or faeces present a risk which increases with an infected cabin mate or travel companion.

The considerable literature on TD typically includes advice on avoidance, i.e., avoiding the introduction of pathogens into one’s mouth. This advice includes dietary discretion, general hygiene, and hand and personal hygiene practices. After realising that the well-meant saying ‘boil it, cook it, peel it, or forget it’ did not prevent TD, poor restaurant hygiene may be the most likely culprit for most infections [70]. Water quality rates a particular mention [71, 72]. The advice to avoid brushing teeth with unsafe water is useful, but carrying bottled water is cumbersome. To minimise water use, hygiene may be kept to an unaccustomed minimum. After carefully avoiding pathogen-laden food, water and fingers, a toothbrush enters the mouth without further thought. Is there a link between toothbrushes and TD? We cannot answer this question because no-one has asked it yet.

The toothbrush conundrum

Toothbrush contamination – a threat to travellers?

In 1920, suspicion fell on toothbrushes for aiding oral and systemic illness, leading to the impractical but interesting idea of designing them to hold single-use pieces of cotton or felt [73]. The microbial contamination of toothbrushes has been examined much [74, 75], especially in relation to vulnerable people with cystic fibrosis [76], immunosuppression or organ transplants [77], mechanically ventilated patients [78], and the potential transmission of COVID-19 [79] or hepatitis C [80].

There appears to be no evidence of adverse effects of one’s own toothbrush at home under normal

circumstances and commonsense hygienic measures. However, this may be different when travelling. The Centers of Disease Control (CDC) [81] and the American Dental Association (ADA) [82] advise on the use and handling of toothbrushes: no sharing, rinsing after use with tap water, storing upright to dry and not using closed containers as they promote bacterial growth. This is helpful but does not account for challenges while travelling. Low-cost accommodation, perhaps with shared bathrooms and limited space to rest toiletries, makes keeping the toothbrush clean difficult. Even in 'better' hotels up to 5-star, cleaning staff may accidentally topple a toothbrush (electric toothbrushes on chargers are even more prone to being knocked over) and grab it to put it back in place. Travellers will never know onto or into what the toothbrush fell, nor if the retrieving hands have been free of faecal microbes or worm eggs. To complicate things, a foe lurks in the bathroom, unrecognised and possibly underestimated: the toilet plume.

The toilet plume – another threat to travellers?

People flush toilets multiple times a day, and many inspect the actions in the bowl to confirm success without further thought. However, flushing contributes to the potential transmission of pathogens via flush-related aerosols and droplets from contaminated bowl sidewalls and bowl water. The first focus was on lidless toilets, provided in public and commercial spaces but especially in hospitals. There, of particular concern was the transmission of *Clostridium difficile*, but also SARS-CoV-2, influenza virus, norovirus, and others [83–90]. However, the risk of pathogen-laden aerosols extends to all toilets, with or without lid. The common assumption that flushing lid-down eliminates the risk of infection is erroneous. Flushing lid-up, allows a pathogen-laden aerosol particle to rise much higher (up to 1.3 m [83]); in contrast, flushing lid-down changes the shape of the plume and results in larger droplets settling down closer to the toilet. Having the lid up or down makes little difference [88, 91], i.e. only size and shape of particles differ. Apart from being inhaled, toilet plume products settle on surrounding surfaces [85]. The above studies did not consider toothbrushes in their design or recommendations. Those that do mention them alert to potential COVID-19 transmission [92], or that the distance from the toilet or storing toothbrushes in cabinets made no difference to aerosol exposure [93]. A comparison of toothbrushes stored for three months in a bathroom with or without attached toilet only added *E. coli* to a wide range of other microbes attached to the bristles [94].

Is this evidence relevant for travellers? Bouts of vomiting or acute diarrhoea splash onto the sides of the toilet bowl and/or under the bowl rim. Salmonella has been viable under the rim for 50 days; *E. coli* survived on

dried-on faeces for eight days [95]. Improper cleaning of accommodation toilets and bathrooms increase the risk not only of inhaled pathogens but fomite contamination, including toothbrushes. Using cleaning equipment (sponges, cloths) from hotel room to hotel room may explain unexplained outbreaks of traveller's diarrhoea or viral infections in hotels or on cruise ships. Bidets are common appliances in certain cultures. Some bidets create a high spray rate and potential aerosols/droplets, but no research could be located. The size of plane or bus toilets compromises hygiene measures and keeps aerosols confined. Travellers, who like to clean their teeth before arrival, and their toothbrushes are exposed to the toilet plume and the potential dilemma of where to rest the toothbrush. The plumbing of toilets on transport, in accommodation, or public destinations is out of travellers' control, as is the fly that lands on toothbrush tufts to feast on food debris, and fluid accumulated between bristles by capillary action – or simply to rest. If all this sounds unsavoury, potential solutions have been tested.

Toothbrush decontamination – any use for travellers?

Humid bathrooms as well as toothbrush caps and containers, popular with travellers, foster microbial growth, among them *Pseudomonas* [96, 97]. Several studies tested decontamination with sprays or solutions of hydrogen peroxide 3% [96], chlorhexidine [97–101], Dettol and Listerine [102]. The 'VIOLight Personal Travel Toothbrush Sanitizer', a travel gadget, failed to convince [96]. Toothbrush handles should be solid (plastic) to avoid microbial growth [74].

Coating toothbrush bristles suggested another way of limiting microbial growth. Without using toothpaste, nano-gold coated bristles were superior to uncoated ones [103]. Silver, chlorhexidine, or charcoal coated brushes had no antimicrobial effect [104, 105], though in a later randomised controlled study, charcoal bristles reduced bacterial contamination [106]. The role of toothpaste in decontamination was either disappointing [107] or, depending on its ingredients, potentially useful [105, 108, 109]. A pre-brush mouthwash may have some antimicrobial effect on the toothbrush used [75].

Germs encountered at home differ from germs encountered during travel. In addition, modern travel medicine accommodates the desire to travel even for people whose medical conditions were previously a contraindication and who may be more vulnerable to infections. Considering the discussion so far, why does travel medicine exclude dental and oral travel health?

The chasm between dentistry and medicine – ‘putting the mouth back in the body’

The long history of the relationship between dentistry and medicine is one of mixed emotions from disdain to grudging cooperation when absolutely necessary, when it all started so well. Herodotus (c484–425BC) reported that in ancient Egypt doctors were specialists for the treatment of one body part, e.g., the eyes, the head, the teeth, the stomach and so on [110]. Though difficult to verify, Hippocrates (c460–370BC) is much quoted as having noticed a link between the extraction of bad teeth and an improvement in health.

In the medieval Christian world, medical literature by physicians included conservative (herbal and magic) and surgical treatment of dental problems [111]. Monks had access to scientific Arabic texts and practiced medicine, surgery, and dentistry, often for material gain. This, and the ensuing neglect of spiritual health, led to several Church Edicts banning clergy from practising [112]. Medicine was now the realm of university-qualified physicians; surgery and dentistry became the domain of barber-surgeons and barbers respectively. The fact that teeth now belonged to people who shaved, bled, applied leeches, and administered enemas did little to raise the esteem of dental practice. In 1728, enraged by prevailing dental charlatanerie, in part caused by physicians not wanting to be associated with unsavoury practices, French physician Pierre Fauchard (1679–1761), the ‘father of modern dentistry’, published the groundbreaking textbook ‘The Surgical Dentist’ [113]. The relationship between oral infections and systemic disease was again highlighted in 1778 by the Royal Surgeon John Hunter, but his warnings were ignored until more reports of health improvement after tooth extractions became available in the 1800s [114].

In the meantime, when the proposal to teach dentistry in medical school was rebuffed in 1839 as not being important enough [115], dentistry became an independent profession firstly in the United States in 1840 with the creation of a dental school, followed by journals and a professional organisation [116]. However, the separation between the mouth as a specialty and the rest of the body remained, perhaps because of this move. Medicine still somewhat prescribed to humoral theory which has no place for teeth requiring mechanical solutions [116]. A hundred years ago, the ‘Gies-Report’ [115], commissioned by the Carnegie Foundation, criticised the low standards in most dental schools – dubbed a ‘specialty of applied mechanics’ – and demanded, similar to medical schools, the inclusion of biomedical sciences through a university course. ‘Failing to recognise each other’s prime objective, to keep people well’(p.5), led to a breakdown in cooperation.

Robert Koch’s (1843–1910) Germ-Theory confirmed what had been observed already, that oral infection could cause systemic disease [114]. In 1887, Dun had praised dentistry as having overcome ‘the barbarous odors which surround their birth’ [117, p.176] referring to its historic split from surgery and its descent into the ‘coarse and heartless way of the barbers’ (p.175) and pointing to the debt medicine owes to dentistry. ‘Unkempt, unthought of’ teeth bring ‘foulness and decay’(p.177) and affect general health. W. Miller’s review of a great many publications, case studies and conference papers in 1891 [118] created extensive lists of ‘disturbances of the human body which have been traced to the actions of germs growing in the mouth’ [119], ‘pathogenic mouth-bacteria’ [120] and ‘prophylactic measures’ [121], the latter focusing on mouthwashes but stressing the ‘proper use of tooth-brush, toothpick, floss silk, etc.’ (p.913). Hunter, in 1900, concurred and lamented the ‘extraordinary neglect with which it [dentistry] is treated alike by physicians and surgeons’ [122, p.215]. The lack of communication between dentists and physicians changed with the advent of the Focal Theory. In 1912, Frank Billings related chronic focal infections mainly of tonsils and teeth to arthritis and nephritis [123], leading to a brief era of cooperation with dentistry in that physicians prescribed the removal, first, of problem teeth, then, as a precaution, all teeth. While this happened, again, numerous calls for collaboration between medicine and dentistry stress ‘the public necessity in the interest of the health of the nation’ [124, p.151] and the hope that ‘the dentists will be, in fact, a specialist in medicine and on equal footing with other medical specialists’ [125, p.394]. However, in the 1940s, the violent and indiscriminate removal of teeth, including healthy teeth for prevention, was questioned, the Focal Theory rejected [114, 126], and the uneasy cooperation ceased. The mouth again belonged to dentists (trade), the body to physicians (profession). Today, scientific and technological advances in both fields ensure the luxury of modern dentistry and acknowledge the link between oral health problems and systemic disease. However, the disconnect between the two fields prevails: ‘the archaic division between dentistry and medicine is detrimental to overall health and needs to end’ [127]. Interprofessional education [128–130] would be one step to reach this goal so that we can put the mouth back in the body, a phrase coined by the late oral scientist Robert Genco [131].

Travellers cannot wait for this to happen. Travel medicine needs to step up and advise travellers on dental and oral health, simply because travellers may attend a travel health consultation but won’t visit a dentist for travel advice. In the same way as general health problems can occur during or after travels, and pre-existing conditions influence travel health advice, teeth have the potential to create serious bother while away. The following

recommendations provide a starting point for including dental/oral health into travel health advice and foster a collaboration between medicine and dentistry.

Recommendations

Clinical

Travel medicine is about more than infection avoidance. The constant expansion of travel health topics to safeguard travellers including a growing body of evidence-based knowledge has led to a vast amount of content supposed to be delivered in increasingly short consultations that do not allow comprehensive advice. This does not mean it is impossible. Dental health should be included in travel checklists. Handouts or apps on many travel-related topics can inform travellers after clinicians identified the relevant areas for a particular individual. Clinicians’ credibility is much enhanced by their own travel experiences and ability to apply standard advice to a traveller’s specific circumstances [132, 133]. Professional bodies, such as the International Society of Travel Medicine (ISTM), the Faculty of Travel Medicine, Royal College of Physicians and Surgeons (Glasgow) (FTM RCPSG), or regional travel medicine societies should, in close cooperation with dentists, design handouts or apps that cover content that does not need to take up time during consultations. Failing this, travel clinics should seek out local dentists to prepare such material together. The clinician then only needs to address obvious issues, e.g. noticeable dental concerns, or a person already wearing tattoos and piercings, and mention pre-travel dental check-ups or, for longer trips, recommend a post-travel visit to the hygienist. Medical advice is often not necessarily based on evidence but rather on common sense or personal opinion. Until specific investigations into dental

travel health offer evidence, currently available advice, as found in the literature for this article, will need to suffice and is presented in the following Tables regarding preparation (Table 1), potential practical challenges (Table 2), and potential dental and oral health problems with suggested actions (Table 3).

Education

Travel medicine is scarcely represented in professional qualifications of those who deliver travel health care: doctors, nurses, and pharmacists [134]. On the other hand, dental aspects are missing in travel medicine curricula [25]. There is a need to remedy both shortcomings. Dental problems enter a different dimension when encountered in remote wilderness or high-altitude settings. Not only are hygiene practices severely curtailed, e.g., due to limited facilities or ice-cold water, cold and dry air intake during mouth breathing affects the oral microbiome [25]. Dental repairs may be out of reach. The prudent compilation of a dental emergency kit and dental training of an accompanying expedition physician, even a confident lay person, is crucial. Specific wilderness dentistry for accompanying dentists may avoid life-threatening dental infections and evacuation [24].

Research

A call for research into dental issues of international travellers has, so far, received little response [1]. In the same way as travel medicine does not cooperate with tourism, even though tourists travel in the context of tourism, not medicine [135], there seems equally no interest in cooperating with dentists. This paper has presented evidence from medicine and dentistry, yet these two completely separate lines of research are rarely brought together.

Table 1 Dental health preparation First cell on the right below should not be bold (- visit dentist...). No line under the first item (pre-travel dental check)

Details	What to do
Pre-travel dental check	- Visit dentist, especially for expatriates, long-term travellers (mandatory for workers in remote areas (e.g. Antarctica), expedition members). - Visit dental hygienist, including cleaning; book in advance a clean post-travel.
Packing	- Bring spare toothbrush, enough toothpaste, floss, interdental brushes, care products for dentures or braces. - Pack mouth guard for planned sports.
Dentist’s contact details	- Keep dentist details for contact if necessary.
Local dentists	- Consider language barrier. - Get letter from your own dentist. - Obtain information on, or list of, local dentists from hotel, embassy, travel clinic, insurance.
Dental restorations or repairs	- If possible, avoid travelling right after dental work (esp. after sedation/anaesthesia) - discuss with dentist. - Delay travel for the specified hours/days as per dentist/surgeon advice. - Retention of full/partial dentures changes with altitude and /or dry mouth. - Take spare dentures (store as per instructions for material used). - Carry suitable pain medication. - Be aware that temporary fillings may become dislodged.
Insurance	- Check that policy includes emergency dental work (pre-existing dental conditions are usually excluded)
Prepare and plan for potential challenges	- See Table 2

Table 2 Potential practical challenges

Problems	Examples	What to do
Disrupted routine	- Time difference - No access to bathroom/sink - Toothbrush in inaccessible luggage - Challenging storage of toothbrush	- Consider time difference. - Keep dental care products in hand luggage. - Sugar-free chewing gum. - Toothpaste on finger. - Use salt to rub teeth.
Hasty hygiene	- Cramped plane/bus/train bathroom - People wait in line - No time between meal and transport pickup - 'fuzzy tooth sensation' - Limited facilities - Ice-cold water	- Still try to take time to brush properly - Rinse mouth with clean water (bottled) or cold tea - Toothpaste on finger - Sugar-free chewing gum
Diet	- Dessert, sweets - Alcohol - Sticky desserts, toffee - Soft drinks - Snacks, chips	- Rinse mouth with water - Use straw to minimise contact - Prefer fruit, nuts-
Dehydration/ dry mouth (Xerostomia)	- Dry mouth on plane - Dry mouth at altitude (puffing; mouth breathing) - 'traveller's breath' due to high altitude, fast food	On plane: - Sugar-free chewing gum - Drink plenty of water - Avoid alcohol
Avoidable damage		- Don't use teeth as 'tools' (bottles, nuts) - Wear helmet while using motor scooter or bike and bicycles to avoid facial injuries

Table 3 Potential dental and oral health problems and suggestions

Focus	Problem/Emergency	What to do
Teeth	- Toothache - Chipped, cracked, fractured tooth - Knocked-out tooth - Sensitivity - Cavity - Abscess	- Rinse mouth with water and remove food with floss; cold compress - Keep broken or knocked out tooth in saliva or milk in plastic bag - Don't touch root, clean with saliva or milk, try to re-insert; or keep in cheek - Visit dentist as soon as practicable
Oral cavity	- Bitten lip, tongue, cheek - Bad breath	- Rinse mouth with warm salt water, then cold compress - Sugar-less mints
Restorations	- Lost filling, lost crown - Broken bridge - Broken dentures	- Visit dentist - Visit dental technician
Barodontalgia/ Barotrauma	- Altitude - Scuba diving - After restorations	- Follow instruction by team leader, scuba guide, post-dental intervention advice. - Medical attention if required
Piercings, dental jewellery	- Pain, swelling - Bleeding - Infection - Tooth damage - Nerve damage - Aspiration	- Medical attention - Remove foreign body if possible

Much evidence is presented in stand-alone studies; their designs, influenced by the researchers' field of academia and experience, too varied to compare systematically. Innumerable research topics present themselves that need to be re-visited and examined through the lens of travel medicine in exciting and innovative collaborations with researchers from relevant disciplines. The following section is a starting point with suggested topics important for high-quality travel health care.

The magnitude of dental complaints among travellers is unknown, but that does not mean not advising the

individual consulting a travel health provider. We need to know how many clinicians recommend pre-travel dental check-ups. How many would like to know more about dental travel health, and how and where to obtain the information? How many travellers have asked for advice on dental issues? Dentists could be asked how many travellers visit for travel purposes alone. Also, how many travellers with piercings return for assistance? Local dentists would be an excellent source for the same questions.

How many travellers (short-term, long-term, volunteers, expats [excluding mandatory dental checks for

work in remote settings]) go/did go to a dentist pre-travel, why, and why not? Do pre-travel dental checks make a difference? Do travellers with mandatory pre-travel dental checks have fewer dental problems while abroad? How many travellers left home despite current dental problems? How did travel influence routine dental hygiene and how, or not, did travellers adapt to sub-optimal conditions? How did they store/clean their toothbrush? What travel situations made dental hygiene challenging? Was there a need to visit a local dentist for unexpected dental issues?

Toothbrush-related research, contamination, decontamination, and storage should be re-examined from a travelling perspective with practical advice and suggested solutions including product ingredients. The existence of the toilet plume (and perhaps bidet plume) should be investigated much more in various levels of accommodation, and bathroom or toilet layouts, as well as toilets on transportation, i.e., planes, buses, and ships, with a view on practical advice. As refurbishments are out of the question, practical hints for travellers are needed. What solutions exist to protect toothbrushes from contamination, yet avoid bacterial growth in covers and caps? It is unknown if contaminated toothbrushes can cause TD. Can we exclude the role of pathogen-laden toothbrushes in TD? If not, toothbrush hygiene should be added to TD prevention.

For those interested in specific niche areas, an examination of microbiome transaction between sort/long-term fellow travellers, or those engaging in travel sex or sex tourism, could be of consequence as well. The increase from no research to some commonsense investigations may lead, for example, to simple travel advice on types of toothbrushes, toothpaste, and storage to safeguard travel health.

Conclusion

At the moment, travellers' teeth are nobody's business. This is peculiar since they travel with their owners and potentially create problems that may either be preventable or need addressing like any other travel illness. It is highly unlikely that a traveller, even one who has regular dental checks, visits a dentist to get some practical tips for an upcoming trip. Travel health professionals are not dentists, but the mouth is part of the traveller and, therefore, dental and oral health should be part of travel health, even though typical travel ailments are not caused by rotten teeth. Dental travel health is not just about an unpleasant event due to toothache, lost fillings, or emergency treatments in foreign countries. Its impact and relevance could be way more far-reaching than previously assumed.

This paper is the first to discuss dental travel health care, incorporating a diverse range of relevant scientific

literature to alert travel health professionals to the breadth of challenges and provide a background for advice to travellers including, at least, mentioning the need for pre-travel dental checks, dental hygiene, and emergency action. Recommendations are made for clinical practice, education and urgently needed research.

Despite the obvious, yet still unappreciated, link between medicine and dentistry, travel medicine by association is drawn into the persistent and illogical division between the two fields leading to disjointed health care in contrast to longstanding calls for holistic attention. Neither this specialty nor travellers should have to wait for this chasm to close by itself. Travel medicine is in a unique position to be a pioneer in cooperating with dentistry so that travellers can travel with their mouth firmly back in their body.

Abbreviations

ADA	American Dental Association
CDC	Centers for Disease Control and Prevention
FTM RCPSG	Faculty of Travel Medicine, Royal College of Physicians and Surgeons (Glasgow)
ISTM	International Society of Travel Medicine
TD	Traveller's Diarrhoea
VSO	Voluntary Service Overseas

Acknowledgements

Not applicable.

Author contributions

I.B. is the sole author.

Funding

Not applicable.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The author has declared no conflicts of interest.

Received: 13 November 2024 / Accepted: 9 December 2024

Published online: 15 March 2025

References

1. Preet R. Dental health is a neglected topic in travel medicine. *J Travel Med.* 2018;25:tay082. <https://doi.org/10.1093/jtm/tay082>.
2. Leggat P, Leggat F, Kedjarune U. Travel insurance claims made by travellers from Australia for dental conditions. *Int Dent J.* 2001;51:267–72. <https://doi.org/10.1002/j.1875-595X.2001.tb00836.x>.
3. Leggat P, Kedjarune U. Dental health, 'dental tourism' and travellers. *Travel Med Infect Dis.* 2009;7:123–4. <https://doi.org/10.1016/j.tmaid.2009.02.001>.
4. Kedjarune U, Leggat P. Dental Precautions for travelers. *J Travel Med.* 1997;4:38–40. <https://doi.org/10.1111/j.1708-8305.1997.tb00771.x>.

5. American Dental Association. Dental care while traveling. *J Am Dent Assoc.* 2006;928. <https://doi.org/10.14219/jada.archive.2006.0298>.
6. Bupa Dental. 5 ways travel can affect your dental health. <https://www.bupadental.com.au/blog/gum-health/5-ways-travel-can-affect-your-dental-health>. Accessed 24 Oct 2022.
7. Bupa Dental. Emergency dentist. <https://www.bupadental.com.au/treatment/s/dental-emergencies>. Accessed 26 Mar 2024.
8. Guerini V. A history of dentistry. From the most ancient times until the end of the eighteenth century. Philadelphia: Lea & Febinger; 1909. <https://www.gutenberg.org/files/51991/51991-h/51991-h.htm>. (accessed 4.7.2024).
9. Gratarolo G. De regimine iter agentium vel equitum, vel peditum, vel navi, vel curru seu rheda, etc. viatoribus et peregrinatoribus quibusque utilissimi libri duo, nunc primum editi. Basileae: Nicolaus Brylinger; 1561.
10. Bauer I. Travel medicine in Basel – 450 years before CISTM18. *Travel Med Inf Dis.* 2024;59:102720. <https://doi.org/10.1016/j.tmaid.2024.102720>.
11. Pictorius G. Raiss Büchlin. Strassburg: Knoblauch; 1557.
12. Artzney. Büchlein / wider allerlei krankheyt und gebrechen der tzeen getzogen auss dem Galeno/ Avicenna / Mesue / Cornelio Celso und andern mehr der Artzney Doctorn / seher nützlich zu lesen. In: Sachse M, Artzney Büchlein. Chapter IX; 1530/1546.
13. Woodforde J. The strange story of false teeth. London: Routledge & Kegan Paul; 1968.
14. Ellershaw A, Spencer A. Dental attendance patterns and oral health status. *Dental Statistics and Research Series. Volume 57.* Australian Institute of Health and Welfare: Canberra; 2011.
15. Armfield J. The avoidance and delaying of dental visits in Australia. *Aust Dent J.* 2012;57:243–7. <https://doi.org/10.1111/j.1834-7819.2012.01697.x>.
16. Beaton L, Freeman R, Humphris G. Why are people afraid of the dentist? Observations and explanations. *Med Princ Pract.* 2014;23:295–301. <https://doi.org/10.1159/000357223>.
17. Cope A, Wood F, Francis N, Chestnutt I. Patients' reasons for consulting a GP when experiencing a dental problem: a qualitative study. *Br J Gen Pract.* 2018;68:e877–83. <https://doi.org/10.3399/bjgp18X699749>.
18. Van der Zande M, Exley C, Wilson S, Harris R. Disentangling a web of causation: An ethnographic study of interlinked patient barriers to planned dental visiting, and strategies to overcome them. *Com Dent Oral Epidemiol.* 2021;49:144–57. <https://doi.org/10.1111/cdoe.12586>.
19. Calladine H, Currie C, Penlington C. A survey of patients' concerns about visiting the dentist and how dentists can help. *J Oral Rehab.* 2022;49:414–21. <https://doi.org/10.1111/joor.13305>.
20. Australian Dental Association. Media release 2.8.2024. Cost of living affects dental habits. <https://ada.org.au/resources/media-releases> (accessed 5.8.2024).
21. Australian Institute of Health and Welfare. Oral health and dental care in Australia. 4.10.2024. <https://www.aihw.gov.au/reports/dental-oral-health/oral-health-and-dental-care-in-australia/contents/about> (accessed 27.10.2024).
22. Sobotta B, John M, Nitschke I. Cruise medicine: the dental perspective on health care for passengers during a world cruise. *J Travel Med.* 2008;15:19–24. <https://doi.org/10.1111/j.1708-8305.2007.00162.x>.
23. Bhatta P, Simkhada P, van Teijlingen E, Maybin S. A questionnaire study of Voluntary Service Overseas (VSO) volunteers: health risk and problems encountered. *J Travel Med.* 2009;16:332–7. <https://doi.org/10.1111/j.1708-8305.2009.00342.x>.
24. Deeb G, Johnson A. Wilderness dentistry. In: Auerbach P, Cushing T, Harris N, editors. *Auerbach's wilderness medicine.* 7th ed. Philadelphia: Elsevier; 2017. pp. 1128–45.e1.
25. Küpper T, Hettlich M, Horz H-P, et al. Dental problems and emergencies of trekkers—epidemiology and prevention. *High Altitude Med Biol.* 2014;15:39–45. <https://doi.org/10.1089/ham.2013.1108>.
26. Levy B. Aviation dentistry. *Am J Orthodont Oral Surg.* 1943;29:B92–5. [https://doi.org/10.1016/S0096-6347\(43\)90064-X](https://doi.org/10.1016/S0096-6347(43)90064-X).
27. Lakshmi S, Sakthi D. Aviation dentistry. *J Clin Diagn Res.* 2014;8:288–90. <https://doi.org/10.7860/JCDR/2014/7232.4189>.
28. Shetty K, Sindhu R, Manipal S, et al. Aviation dentistry: is it an unexplored field of dentistry? A cross-sectional study. *J Aerosp Technol Manag.* 2020;12:e2420. <https://doi.org/10.5028/jatm.v12.1120>.
29. Zadik Y, Einy S, Pokroy R, et al. Dental fractures on acute exposure to high altitude. *Aviat Space Environ Med.* 2006;77:654–7.
30. Gunepin M, Derache F, Audoual T. Fracture of a sound tooth in a pilot under hypobaric conditions. *Aviat Space Environ Med.* 2010;81:691–3. <https://doi.org/10.3357/ASEM.2754.2010>.
31. Jagger R, Shah C, Weerapperuma I, Jagger D. The prevalence of orofacial pain and tooth fracture (odontocrexia) associated with SCUBA diving. *Prim Dent Care.* 2009;16:75–8. <https://doi.org/10.1308/135576109787909463>.
32. Zadik Y, Drucker S. Diving dentistry: a review of the dental implications of scuba diving. *Austral Dent J.* 2011;56:265–71. <https://doi.org/10.1111/j.1834-7819.2011.01340.x>.
33. Bauer I, Ayahuasca. A risk for travellers? *Travel Med Infect Dis.* 2018;21:74–6. <https://doi.org/10.1016/j.tmaid.2018.01.002>.
34. Kerkemeyer K, Darby J, Green J. Mycobacterium abscessus infection of a new tattoo in an Australian traveller returning from Bali, Indonesia. *J Travel Med.* 2020;27:taaa014. <https://doi.org/10.1093/jtm/taaa014>.
35. Colgate. A gum piercing: what you need to know. 10.1.2023. <https://www.colgate.com/en-us/oral-health/threats-to-dental-health/what-you-need-to-know-about-getting-a-gum-piercing#> (accessed 29.2.2024).
36. Patil A. Tooth jewellery: a simple way to add sparkle to your smile Introduction. *Indian J Dent Adv.* 2010;2:356–8.
37. Oberholzer T, George R. Awareness of complications of oral piercing in a group of adolescents and young South African adults. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;110:744–7. <https://doi.org/10.1016/j.tripleo.2010.07.012>.
38. Difloe-Geisert J, Müller J, Weiger R, Walter C. Impact of oral piercings on periodontal health – a systematic review. *Int J Dent Hyg.* 2024;22:24–34. <https://doi.org/10.1111/idh.12734>.
39. Mosaddad S, Talebi S, Hemmat M, et al. Oral complications associated with the piercing of oral and perioral tissues and the corresponding degree of awareness among public and professionals: a systematic review. *Diagnostics.* 2023;13:3371. <https://doi.org/10.3390/diagnostics13213371>.
40. Masood M, Walsh L, Zafar S. Oral complications associated with metal ion release from oral piercings: a systematic review. *Europ Arch Paed Dent.* 2023;24:677–90. <https://doi.org/10.1007/s40368-023-00831-0>.
41. Malcangi G, Patano A, Palmieri G, et al. Oral piercing: a pretty risk—a scoping review of local and systemic complications of this current widespread fashion. *Int J Environ Res Public Health.* 2023;20:5744. <https://doi.org/10.3390/ijerph20095744>.
42. Passos P, Pintor A, Marañón-Vásquez G, et al. Oral manifestations arising from oral piercings: a systematic review and meta-analyses. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2022;134:327–41. <https://doi.org/10.1016/j.oooo.2022.04.051>.
43. Srebrna A, Sutkowska P, Szwarz K, et al. The impact of piercing on various aspects of oral health. *J Pre Clin Res.* 2021;15:204–7. <https://doi.org/10.26444/jpcrr/145032>.
44. American Academy of Pediatric Dentistry. Policy on intraoral/perioral piercing and oral jewelry/accessories. *The Reference Manual of Pediatric Dentistry.* Chicago, Ill: American Academy of Pediatric Dentistry; 2023. pp. 143–4.
45. Bridwell R, Gottlieb M, Koyfman A, Long B. Diagnosis and management of Ludwig's angina: an evidence-based review. *Am J Emerg Med.* 2021;41:1–5. <https://doi.org/10.1016/j.ajem.2020.12.030>.
46. Vozza I, Fusco F, Corridore D, Ottolenghi L. Awareness of complications and maintenance mode of oral piercing in a group of adolescents and young Italian adults with intraoral piercing. *Med Oral Patol Oral Cir Bucal.* 2015;20:e413–8. <https://doi.org/10.4317/medoral.20487>.
47. Covello F, Salerno C, Giovannini V, et al. Piercing and oral health: a study on the knowledge of risks and complications. *Int J Environ Res Public Health.* 2020;17:613. <https://doi.org/10.3390/ijerph17020613>.
48. Vozza I, Fusco F, Bove E, et al. Awareness of risks related to oral piercing in Italian piercers. Pilot study in Lazio region. *Annali di Stomatologia.* 2014;5:128–30. <https://doi.org/10.59987/ads.2014.4.128-130>.
49. Bhatia S, Gupta N, Gupta D, et al. Tooth jewellery: fashion and dentistry go hand in hand. *Indian J Dent Adv.* 2015;7:263–7. <https://doi.org/10.5866/2015.7.10263>.
50. Kaur H. Tooth adornments, gems, and grills. *Int J Oral Health Sci.* 2022;12:50–3. https://doi.org/10.4103/ijohs.ijohs_26_22.
51. Kim H, Karanxha L, Park S. Non-destructive management of white spot lesions by using tooth jewelry. *Restor Dent Endod.* 2012;37:236–9. <https://doi.org/10.5395/rde.2012.37.4.236>.
52. Leewenhoeck A. An abstract of a letter from Mr. Anthony Leewenhoeck at Delft, dated Sep. 17. 1683. Containing some microscopical observations, about animals in the scurf of the teeth, the substance call'd worms in the nose, the cuticula consisting of scales. *Philosophical Trans.* 1684;14:568–74. <https://doi.org/10.1098/rstl.1684.0030>.

53. The Human Microbiome Project Consortium. Structure, function and diversity of the healthy human microbiome. *Nature*. 2012;486:207–14. <https://doi.org/10.1038/nature11234>.
54. Deo P, Deshmukh R. Oral microbiome: unveiling the fundamentals. *J Oral Maxillofac Pathol*. 2019;23:122–8. https://doi.org/10.4103/jomfp.JOMFP_304_18.
55. Henares D, Monsalvez V, Brotons P, et al. Human gut microbiota composition associated with international travels. *Travel Med Infect Dis*. 2024;102747. <https://doi.org/10.1016/j.tmaid.2024.102747>.
56. Slavkin H. Biofilms, microbial ecology and Antoni van Leeuwenhoek. *J Am Dent Assoc*. 1997;128:492–5. <https://doi.org/10.14219/jada.archive.1997.0238>.
57. Dewhirst F, Chen T, Isard J, et al. The human oral microbiome. *J Bacteriol*. 2010;192:5002–17. <https://doi.org/10.1128/jb.00542-10>.
58. Sharma N, Bhatia S, Sodhi A, Batra N. Oral microbiome and health. *AIMS Microbiol*. 2018;4:42–66. <https://doi.org/10.3934/microbiol.2018.1.42>.
59. Warinner C, Speller C, Collins M. A new era in palaeomicrobiology: prospects for ancient dental calculus as a long-term record of the human oral microbiome. *Phil Trans R Soc*. 2015;370:20130376. <https://doi.org/10.1098/rstb.2013.0376>.
60. Cai J, Kim D. Chapter Two - Biofilm ecology associated with dental caries: understanding of microbial interactions in oral communities leads to development of therapeutic strategies targeting cariogenic biofilms. *Adv Appl Microbiol*. 2023;122:27–75. <https://doi.org/10.1016/bs.aambs.2023.02.001>.
61. Song S, Lauber C, Costello E, et al. Cohabiting family members share microbiota with one another and with their dogs. *Comp Study eLife*. 2013;2:e00458. <https://doi.org/10.7554/eLife.00458>.
62. Kort R, Caspers M, van de Graaf A, et al. Shaping the oral microbiota through intimate kissing. *Microbiome*. 2014;2:41. <https://doi.org/10.1186/2049-2618-2-41>.
63. Thurnheer T, Balibasakis G. Integration of non-oral bacteria into in vitro oral biofilms. *Virulence*. 2015;6:258–64. <https://doi.org/10.4161/21505594.2014.967608>.
64. Zaatout N. Presence of non-oral bacteria in the oral cavity. *Arch Microbiol*. 2021;203:2747–60. <https://doi.org/10.1007/s00203-021-02300-y>.
65. López-Vélez R, Lebens M, Bundy L, et al. Bacterial travellers' diarrhoea: a narrative review of literature published over the past 10 years. *Travel Med Infect Dis*. 2022;47:102293. <https://doi.org/10.1016/j.tmaid.2022.102293>.
66. Carroll S, Castellanos M, Stevenson R, Henning L. Incidence and risk factors for travellers' diarrhoea among short-term international adult travellers from high-income countries: a systematic review with meta-analysis of cohort studies. *J Travel Med*. 2024;taae008. <https://doi.org/10.1093/jtm/taae008>.
67. Chimonas M, Vaughan G, Andre Z, et al. Passenger behaviors associated with norovirus infection on board a cruise ship—Alaska, May to June 2004. *J Travel Med*. 2008;15:177–83. <https://doi.org/10.1111/j.1708-8305.2008.00200.x>.
68. Widdowson M, Glass R, Monroe S. Probable transmission of norovirus on an airplane. *JAMA*. 2005;293:1855–60. <https://doi.org/10.1001/jama.293.15.1859>.
69. Holmes J, Simmons G. Gastrointestinal illness associated with a long-haul flight. *Epidemiol Infect*. 2009;137:441–7. <https://doi.org/10.1017/S0950268808001027>.
70. O'Connor B. Travelers' diarrhea. Centers for Disease Control and Prevention. Yellow Book 2024. New York: Oxford University Press; 2023. pp. 85–91.
71. Leung A, Leung A, Wong A, Hon K. Travelers' diarrhea: a clinical review. *Recent Pat Inflamm Allergy Drug Discov*. 2019;13:38–48. <https://doi.org/10.2174/1872213X13666190514105054>.
72. Giddings S, Stevens M, Leung D. Traveler's diarrhea. *Med Clin North Am*. 2016;100:317–30. <https://doi.org/10.1016/j.mcna.2015.08.017>.
73. Cobb C. The tooth brush as a cause of repeated infections of the mouth. *Boston Med Surg J*. 1920;183:263–4. <https://doi.org/10.1056/NEJM192008261830905>.
74. Bunetel L, Tricot-Doleux S, Agnani G, Bonnaure-Mallet M. In vitro evaluation of the retention of three species of pathogenic microorganisms by three different types of toothbrush. *Oral Microbiol Immunol*. 2000;15:313–6. <https://doi.org/10.1034/j.1399-302x.2000.150508.x>.
75. Verran J, Leahy-Gilmartin A. Investigations into the microbial contamination of toothbrushes. *Microbios*. 1996;85:231–8.
76. Mantovani R, Sandri A, Boaretti M, et al. Toothbrushes may convey bacteria to the cystic fibrosis lower airways. *J Oral Microbiol*. 2019;11:167036. <https://doi.org/10.1080/20002297.2019.1647036>.
77. Khan S, Syed F, Khalis T, et al. An updated systematic review on toothbrush contamination: an overlooked oral health concern among general population. *Int J Dent Hyg*. 2024;22:95–105. <https://doi.org/10.1111/ijdh.12740>.
78. Unahalekhaka A, Butpan P, Wongsan R, et al. Contamination of antimicrobial-resistant bacteria on toothbrushes used with mechanically ventilated patients: A cross sectional study. *Intensive Crit Care Nurs*. 2022;68:103120. <https://doi.org/10.1016/j.iccn.2021.103120>.
79. González-Olmo M, Delgado-Ramos B, Ruiz-Guillén A, et al. Oral hygiene habits and possible transmission of COVID-19 among cohabitants. *BMC Oral Health*. 2020;20:286. <https://doi.org/10.1186/s12903-020-01274-5>.
80. Lock G, Dirscherl M, Obermeier F. Hepatitis C – contamination of toothbrushes: myth or reality? *J Viral Hepat*. 2006;13:571–3. <https://doi.org/10.1111/j.1365-2893.2006.00735.x>.
81. Centers of Disease Control (CDC). Use & handling of toothbrushes. <https://www.cdc.gov/oralhealth/infectioncontrol/faqs/toothbrush-handling.html#:~:text=Do%20not%20share%20toothbrushes,it%20in%20an%20upright%20position> (accessed 26.2.2024).
82. American Dental Association. Toothbrush care, cleaning and replacement. *J Am Dent Assoc*. 2006;137:415. <https://doi.org/10.14219/jada.archive.2006.0193>.
83. Crimaldi J, True A, Linden K, et al. Commercial toilets emit energetic and rapidly spreading aerosol plumes. *Nature*. 2022;12(20493). <https://doi.org/10.1038/s41598-022-24686-5>.
84. Johnson D, Mead K, Lynch R, Hirst D. Lifting the lid on toilet plume aerosol: a literature review with suggestions for future research. *Am J Infect Control*. 2013;41:254–8. <https://doi.org/10.1016/j.ajic.2012.04.330>.
85. Barker J, Jones M. The potential spread of infection caused by aerosol contamination of surfaces after flushing a domestic toilet. *J Appl Microbiol*. 2005;99:339–47. <https://doi.org/10.1111/j.1365-2672.2005.02610.x>.
86. Verani M, Bigazzi R, Carducci A. Viral contamination of aerosol and surfaces through toilet use in health care and other settings. *Am J Infect Control*. 2014;42:758–62. <https://doi.org/10.1016/j.ajic.2014.03.026>.
87. Li P, Zhang T, Zhang Y. Measuring the flushing-generated flow and aerosols in lavatory of commercial aircraft. *Build Environ*. 2022;214:108948. <https://doi.org/10.1016/j.buildenv.2022.108948>.
88. Goforth M, Boone S, Clark J, et al. Impacts of lid closure during toilet flushing and of toilet bowl cleaning on viral contamination of surfaces in United States restrooms. *Am J Infect Control*. 2024;52:141–6. <https://doi.org/10.1016/j.ajic.2023.11.020>.
89. Monette M. Flush and run. *CMAJ*. 2012;184:E581–2. <https://doi.org/10.1503/cmaj.109-4196>.
90. Best E, Sandoe E, Wilcox M. Potential for aerosolization of *Clostridium difficile* after flushing toilets: the role of toilet lids in reducing environmental contamination risk. *J Hosp Infect*. 2012;80:1–5. <https://doi.org/10.1016/j.jhin.2011.08.010>.
91. Fennelly M, Hellebust S, Sodeau J, Prentice M. Real-time monitoring of aerosols generated from toilet flushing. *Access Microbiol*. 2020;2. <https://doi.org/10.1099/acmi.fis2019.p00192>.
92. Patel J. A plausible transmission mode. *Br Dent J*. 2020;228:735. <https://doi.org/10.1038/s41415-020-1698-0>.
93. Montero E, Isom I, Filts J, et al. The effects of proximity on aerosol distribution of bacteria on toothbrushes. *J Calif Dent Hyg Assoc*. 2012;27:17–21.
94. Karibasappa G, Nagesh L, Sujatha B. Assessment of microbial contamination of toothbrush head: an in vitro study. *Indian J Dent Res*. 2011;22:2–5. <https://doi.org/10.4103/0970-9290.79965>.
95. Abney S, Bright K, McKinney J, et al. Toilet hygiene—review and research needs. *J Appl Microbiol*. 2021;131:2705–14. <https://doi.org/10.1111/jam.15121>.
96. Beneduce C, Baxter K, Bowman J, et al. Germicidal activity of antimicrobials and VIOlight® Personal Travel Toothbrush Sanitizer: an in vitro study. *J Dent*. 2010;38:621–5. <https://doi.org/10.1016/j.jdent.2009.08.011>.
97. Mehta A, Sequeira P, Bhat G. Bacterial contamination and decontamination of toothbrushes after use. *NY State Dent J*. 2007;73:20–2.
98. Filho P, Macari S, Faria G, et al. Microbial contamination of toothbrushes and their decontamination. *Pediatr Dent*. 2000;22:381–4.
99. Sato S, Pedrazzi V, Guimarães E, et al. Antimicrobial spray for toothbrush disinfection: an in vivo evaluation. *Quintessence Int*. 2005;36:812–6.
100. Kuhn L, Werner C, Aiache D, et al. Microbiological contamination of toothbrushes and identification of a decontamination protocol using chlorhexidine spray. *Revista Odonto Ciencia*. 2011;27:213–7. <https://doi.org/10.1590/S1980-65232012000300007>.
101. Álvarez G, Soler-Ollé A, Isabal S, et al. Bacterial decontamination of toothbrushes by immersion in a mouthwash containing 0.05% chlorhexidine and 0.05% cetylpyridinium chloride: A randomized controlled trial. *Int J Dent Hyg*. 2023;21:357–64. <https://doi.org/10.1111/ijdh.12652>.

102. Pradeep S, Nandini G, Hiranmayi S, et al. A prospective study on assessment of microbial contamination of toothbrushes and methods of their decontamination. *Cureus*. 2022;14:e30155. <https://doi.org/10.7759/cureus.30155>.
103. Durgesh P, Sridharan S, Prabhu S, Rao R, et al. Microbial contamination and plaque scores of nanogold-coated toothbrush. *Int J Dent Hyg*. 2020;18:278–84. <https://doi.org/10.1111/idh.12433>.
104. Ramachandra S, Dicksit D, Gundavarapu K. Oral health: charcoal brushes. *Br Dent J*. 2014;217:3. <https://doi.org/10.1038/sj.bdj.2014.557>.
105. Quirynen M, De Soete M, Pauwels M et al. Can toothpaste or a toothbrush with antibacterial tufts prevent toothbrush contamination? *J Periodontol* 2003;74:312–22. <https://doi.org/10.1902/jop.2003.74.3.312>.
106. AlDhawi R, AlNaq N, Tashkandi O, et al. Antimicrobial efficacy of charcoal vs. non-charcoal toothbrushes. A randomized controlled study. *J Int Soc Prevent Comm Dent*. 2020;10:719–23. https://doi.org/10.4103/jispcd.JISPCD_290_20.
107. Warren D, Goldschmidt M, Thompson M, et al. The effects of toothpastes on the residual microbial contamination of toothbrushes. *J Am Dent Assoc*. 2001;132:1241–5. <https://doi.org/10.14219/jada.archive.2001.0366>.
108. Efstratiou M, Papaioannou W, Nakou M, et al. Contamination of a toothbrush with antibacterial properties by oral microorganisms. *J Dent*. 2007;35:331–7. <https://doi.org/10.1016/j.jdent.2006.10.007>.
109. Addy M. Toothbrushing against coronavirus. *Brit Dent J*. 2020;228:487.
110. Greeff C. Dentists and dentistry in ancient Egypt. *J Semit*. 2014;23:90–133.
111. Anderson T. Dental treatment in medieval England. *Brit Dent J*. 2004;197:419–25. <https://doi.org/10.1038/sj.bdj.4811723>.
112. Hammond E. Physicians in medieval English religious houses. *Bull Hist Med*. 1958;32:105–20.
113. Fauchard P. *Le chirurgien dentiste (The surgical dentist)*. Volume 1. Paris: Jean Mariette; 1728. <https://play.google.com/books/reader?id=BjBSAAAACAAJ&pg=GBS.PP8.&hl=en> (accessed 26.9.2024).
114. Vieira C, Caramelli B. The history of dentistry and medicine relationship: could the mouth finally return to the body? *Oral Dis*. 2009;15:538–46. <https://doi.org/10.1111/j.1601-0825.2009.01589.x>.
115. Gies W. Dental education in the United States and Canada bulletin number nineteen (The Gies Report). The Carnegie Foundation for the Advancement of Teaching; 1926.
116. Schwartz L. The historical relations of American dentistry and medicine. *Bull Hist Med*. 1954;28:542–9.
117. Dun W. The relation of dentistry and medicine. *Dent Regist* 1887; 41:175–9.
118. Miller W. The human mouth as a focus of infection. *Lancet*. 1891;138:340–2.
119. Miller W. The human mouth as a focus of infection Part I. *Dent Cosmos*. 1891;33:689–713.
120. Miller W. The human mouth as a focus of infection Part II. *Dent Cosmos*. 1891;33:789–804.
121. Miller W. The human mouth as a focus of infection Part III. *Dent Cosmos*. 1891;33:913–191.
122. Hunter W. Oral sepsis as a cause of disease. *Br Med J*. 1900;2:215. <https://doi.org/10.1136/bmj.2.2065.215>.
123. Billings F. Chronic focal infections and their etiologic relations to arthritis and nephritis. *Arch Intern Med*. 1912;9:484–98. <https://doi.org/10.1001/archinte.1912.00060160087007>.
124. Cecil R, Miner L. The interrelation of medicine and dentistry. *J Dent Res*. 1930;10:137–71.
125. Kerr W. What the physician should know about dental problems. *Ann Int Med*. 1936;10:386–94. <https://doi.org/10.7326/0003-4819-10-3-386>.
126. O'Reilly P, Claffey N. A history of oral sepsis as a cause of disease. *Periodont*. 2000;23:13–8. <https://doi.org/10.1034/j.1600-0757.2000.2230102.x>.
127. Molayem S. Dentists and doctors need to play on the same team. *Nature Outlook*. 2021; 27 October. <https://doi.org/10.1038/d41586-021-02919-3>.
128. Rasmussen C, McMillan K, McMillan D, et al. Education solutions to the medical-dental divide. *AMA J Ethics*. 2022;24:E27–32. <https://doi.org/10.1001/amajethics.2022.27>.
129. Cervino G. Milestones of dentistry: advent of anesthetics in oral surgery. *Dent J*. 2019;7:112. <https://doi.org/10.3390/dj7040112>.
130. Sen Gupta T, Stuart J. Medicine and dentistry: Shall ever the twain meet? *Aus J Gen Pract*. 2020;49:544–8. <https://doi.org/10.31128/AJGP-06-20-5482>.
131. Otto M. Putting the mouth back in the body. 6.3.2018. <https://www.saturdayeveningpost.com/2018/03/putting-mouth-back-body/> (accessed 29.2.2024).
132. Bauer I. Educational issues and concerns in travel health advice: Is all the effort a waste of time? *J Travel Med*. 2005;12:45–52. <https://doi.org/10.2310/7060.2005.00008>.
133. Bauer I. Do travel health researchers need to get out more? *Travel Med Infect Dis*. 2015;13:426–7. <https://doi.org/10.1016/j.tmaid.2015.08.003>.
134. Hess K, Seed S, Clark E, Lombardo T. Multidisciplinary travel health education: current status and rationale for standardized competencies. *J Travel Med*. 2024;taae130. <https://doi.org/10.1093/jtm/taae130>.
135. Bauer I. Looking over the fence – How travel medicine can benefit from tourism research. *J Travel Med*. 2015;22:206–7. <https://doi.org/10.1111/jtm.12197>.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.