ABSTRACT
For some decades now, bacteria known as probiotics have been added to various foods because of their beneficial effects for human health. The number of products containing probiotics, viable bacteria with proven health benefits, entering the market is increasing. Traditionally, probiotics have been associated with gut health, and most clinical interest has been focused on their use for prevention or treatment of gastrointestinal infections and diseases; however, during the last decade several investigators have also suggested the use of probiotics for oral health purposes. Although only a few clinical studies have been conducted so far, the results to date suggest that probiotics could be useful in preventing and treating oral infections, including dental caries, periodontal disease and halitosis. This article summarizes the currently available data on the potential benefits of probiotics for oral health.

Keywords: probiotics, oral health, periodontitis.

INTRODUCTION
The belief that probiotic bacteria can influence health dates back to the beginning of the 20th century when the Ukrainian-born Nobel Prize laureate Elie Metchnikoff reported that Bulgarians lived longer than other populations and supposed that this was due to their consumption of fermented milk products containing viable bacteria. The idea was that the harmless bacteria in the fermented products competed with pathogens injurious to health. By definition, probiotics are live microbial feed supplement that beneficially affects the host animal by improving its intestinal microbial balance as documented in clinical trial. These bacteria...
must belong to the natural flora in order to survive the acid environment during transit to the intestines. Probiotic bacteria can act through several paths: they prevent cellular adhesion and invasion of pathogenic bacteria, modify the intestinal environment by a reduction in pH as a result of fermentation products and they interact and modulate the local and systemic inflammatory immune response.\textsuperscript{[3,4]}

For several decades now, bacteria called probiotics have been added to some foods because of their beneficial effects for human health. The bacteria in yogourt and fermented milk products constitute the most important source of probiotics for humans. The vast majority of probiotic bacteria belong to the genera \textit{Lactobacillus}, \textit{Bifidobacterium}, \textit{Propionibacterium} and \textit{Streptococcus}. Several clinical studies have already demonstrated the effectiveness of certain probiotics in the treatment of systemic and infectious diseases.\textsuperscript{[5]} Probiotics may also prove useful in addressing problems arising from the excessive use of antibiotics, specifically the appearance of bacterial resistance. To date, however, the potential beneficial effects of probiotics for oral pathology have had only limited study.

The most commonly used probiotic bacterial strains belong to the genera \textit{Lactobacillus} and \textit{Bifidobacterium}.\textsuperscript{[6]} These bacterial genera are regarded as a part of the normal human microbiota. In the oral cavity, lactobacilli usually comprise fewer than 1% of the total cultivable microbiota, but no species specific to the oral cavity has been found. Species commonly isolated from saliva samples include \textit{L. paracasei}, \textit{L. plantarum}, \textit{L. rhamnosus}, and \textit{L. salivarius}.\textsuperscript{[7]} Culture-based studies suggest that bifidobacteria are among the first anaerobes in the oral cavity.\textsuperscript{[8]} Indeed, both lactobacilli and bifidobacteria can be found in breast milk, suggesting early exposure of the oral cavity to these bacteria.\textsuperscript{[9,10]} Bifidobacterial species isolated from oral samples include \textit{B. bifidum}, \textit{B. dentium}, and \textit{B. longum}.\textsuperscript{[11,12]}

Lactobacilli and bifidobacteria are generally regarded as safe, and, since the early writing of Metchnikoff\textsuperscript{[13]} even more fermented food products have been associated with health benefits. In respect to normal microbiota and oral health, there seem to be differences in the ability of lactobacilli isolated from caries-active or healthy subjects to inhibit \textit{Streptococcus mutans} in vitro.\textsuperscript{[13]} In addition, the species composition of both \textit{Lactobacillus} and \textit{Bifidobacterium} microbiota is different between patients with periodontitis and those who are periodontally healthy.\textsuperscript{[14,15]} On the other hand, both lactobacilli and bifidobacteria are also associated with dental caries.\textsuperscript{[16,17]} In addition, caries-associated lactobacilli and bifidobacteria have been characterized as exogenous and opportunistic colonizers possibly acquired from food.\textsuperscript{[18]}

Several clinical studies have already demonstrated the effectiveness of certain probiotics in the treatment of systemic and infectious diseases such as acute diarrhea and Crohn disease.\textsuperscript{[5]} Other studies have suggested potential applications in the treatment of cardiovascular disease, urogenital infections, oropharyngeal infections and cancers.\textsuperscript{[19,20]}

**Mechanism of Action**

Several mechanisms have been proposed to explain how probiotics work. For example, these bacteria secrete various antimicrobial substances such as organic acids, hydrogen peroxide and bacteriocins.\textsuperscript{[21]} In addition, they compete with pathogenic agents for adhesion sites on the mucosa.\textsuperscript{[22,23]} Probiotics can also modify the surrounding environment by modulating the pH and/or the oxidation–reduction potential, which may compromise the ability of pathogens to become
established. Finally, probiotics may provide beneficial effects by stimulating nonspecific immunity and modulating the humoral and cellular immune response. A combination of probiotic strains is often used to increase these beneficial effects.

**Fig.1 Mechanism of action of probiotics**

**PROBIOTICS AND ORAL HEALTH**
**Probiotics and Dental Caries**

Dental caries is a multifactorial disease of bacterial origin that is characterized by acid demineralization of the tooth enamel. It appears following changes in the homeostasis of the oral ecosystem leading to proliferation of the bacterial biofilm, composed notably of streptococci from the mutans group. To have a beneficial effect in limiting or preventing dental caries, a probiotic must be able to adhere to dental surfaces and integrate into the bacterial communities making up the dental biofilm. It must also compete with and antagonize the cariogenic bacteria and thus prevent their proliferation.

Finally, metabolism of food-grade sugars by the probiotic should result in low acid production. The advantage of incorporating probiotics into dairy products lies in their capacity to neutralize acidic conditions. It has already been reported that cheese prevents demineralization of the enamel and promotes its remineralization. Comelli and colleagues reported that of 23 bacterial strains used in the dairy industry, *Streptococcus thermophilus* and *Lactobacillus lactis ssp. lactis* were the only ones with the capacity to integrate into a biofilm present on a hydroxyapatite surface and to interfere with development of the cariogenic species *Streptococcus sobrinus*. More recently, it was demonstrated that isolates of *W cibaria* had the capacity to inhibit, both in vitro and in vivo, biofilm formation by *S mutans* and to prevent proliferation of this bacterial strains. Recently, Petti and colleagues reported that yogourt containing *S thermophilus* and *L bulgaricus* had
selective bactericidal effects on streptococci of the mutans group. Several clinical studies have demonstrated that regular consumption of yogurt, milk or cheese containing probiotics led to a decrease in the number of cariogenic streptococci in the saliva and a reduction in dental plaque. More specifically, Nikawa and colleagues reported that consumption of yogurt containing *Lactobacillus reuteri* over a period of 2 weeks reduced the concentration of *S. mutans* in the saliva by up to 80%. Comparable results were obtained by incorporating probiotics into chewing gum or lozenges. In 2001, Nase and colleagues published the results of a long-term (7-month) study of 594 children 1 to 6 years of age that evaluated the effects on dental caries of consuming milk supplemented with a strain of *L. rhamnosus*. The authors concluded that children consuming milk containing this probiotic, particularly those 3–4 years of age, had significantly fewer dental caries and lower salivary counts of *S. mutans* than controls. These promising results suggest a potentially beneficial application of probiotics for the prevention of dental caries.

**Periodontal diseases**

The first studies of the use of probiotics for enhancing oral health were for the treatment of periodontal inflammation. Patients with various periodontal diseases, gingivitis, periodontitis, and pregnancy gingivitis, were locally treated with a culture supernatant of a *L acidophilus* strain. Significant recovery was reported for almost every patient. There has been significant interest in using probiotics in treatment of periodontal disease recently, too. The probiotic strains used in these studies include *L reuteri* strains, *L brevis* (CD2), *L casei* Shirotia, *L salivarius* WB21, and *Bacillus subtilis*. *L. reuteri* and *L. brevis* have improved gingival health, as measured by decreased gum bleeding.

The use of probiotic chewing gum containing *L. reuteri* ATCC 55730 and ATCC PTA 5289 also decreased levels of pro-inflammatory cytokines in GCF and the use of *L. brevis* decreased MMP (collagenase) activity and other inflammatory markers in saliva.

*B. subtilis* seemed to reduce the number of periodontal pathogens. Use of tablets containing *L. salivarius* WB21 has been shown to decrease gingival pocket depth, particularly in high-risk groups such as smokers, and also affect the number of periodontopathogens in plaque. Again, although encouraging results have been observed, most studies have been fairly short. Furthermore, in some studies the observed differences were quite small, though statistically significant.

**Oral candida**

Two studies have investigated the effects of probiotic bacteria on oral *Candida* infection in humans. When a test group of elderly people consumed cheese containing *L. rhamnosus* strains GG and LC705 and *Propionibacterium freudenreichii ssp. shermanii* JS for 16 weeks, the number of high oral yeast counts decreased, but no changes were observed in mucosal lesions. In a shorter study with younger subjects, no significant difference was observed between effects of probiotic and those of control cheese on salivary *Candida* counts.

**Halitosis**

Halitosis has many causes (including consumption of particular foods, metabolic disorders, respiratory tract infections), but in most cases it is associated with an imbalance of the commensal microflora of the oral cavity. More specifically, halitosis results from the action of anaerobic bacteria that degrade salivary and food proteins to generate amino acids, which are in turn transformed into volatile sulphur compounds, including hydrogen sulphide and methanethiol. Kang and colleagues reported the capacity of various strains of *W cibaria* to inhibit the production of volatile...
sulphur compounds by *F nucleatum*. They concluded that this beneficial effect resulted from the production of hydrogen peroxide by *W cibaria*, which inhibited the proliferation of *F nucleatum*. A recent study showed that certain bacterial species, including *Atopobium parvulum*, *Eubacterium sulci* and *Solobacterium moorei*, predominate on the dorsal surface of the tongue among people with halitosis. Conversely, another species, *Streptococcus salivarius*, was detected most frequently among people without halitosis and is therefore considered a commensal probiotic of the oral cavity. *S salivarius* is known to produce bacteriocins, which could contribute to reducing the number bacteria that produce volatile sulphur compounds. The use of gum or lozenges containing *S salivarius* K12 (BLIS Technologies Ltd., Dunedin, New Zealand) reduced levels of volatile sulphur compounds among patients diagnosed with halitosis.

**CONCLUSION**

Bacteriotherapy in the form of probiotics seems to be a natural way to maintain health and protect oral tissues from disease, and data suggest that the potential benefits increase with an early childhood start. The research is still in its infancy but a daily intake of probiotic lactobacilli with an inhibitory effect on other bacteria is currently most promising. Milk, milk drinks, or yoghurt containing one or more probiotic strains could be a treatment option in the long-term prevention of childhood caries. However, further double-blind, randomized, placebo-controlled trials that assess carefully selected and defined strains of probiotics using standardized outcomes are needed before any clinical recommendations can be made.

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