Review

DOI: 10.5582/bst.2022.01046

What does oral care mean to society?

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SUMMARY Oral care is defined in a narrow sense as cleaning of the teeth, oral cavity, and dentures, and in a broad sense as the maintenance of oral functions (feeding, swallowing, chewing, speech, aesthetics, *etc*.), dental treatment, feeding and swallowing training, and articulation training. In the past, it was recognized as simply cleaning the mouth, but the concept of oral care has gradually expanded, and many studies and surveys have been conducted in cooperation with various other professions. As a result, oral health care is involved not only in the prevention of pneumonia, but also in the onset and suppression for severity of diabetes, cardiovascular diseases, some malignant tumors, cerebrovascular diseases, rheumatoid arthritis, dementia, *etc*. It is also a powerful supportive therapy in cancer treatment. In the terminal stages of life, oral health care can help people to maintain their dignity by continuing to consume food orally until the end of their lives, and in times of disaster, oral health care has been found to be as important as attention to deep vein thrombosis. It has also been found to be effective in preventing severe diseases such as COVID-19. And, although it has not been discussed much, it has been found to have medical and economic benefits such as reducing the duration of hospitalization and treatment costs. This article reviews the results of research to date.

Keywords oral care, supportive therapy, perioperative oral management, economic benefit

1. Introduction

Dentistry was originally focused on the treatment of dental caries and periodontal disease. Subsequently, emphasis gradually shifted to prevention, such as the pursuit of effective methods of brushing to remove dental plaque as a method of prevention and treatment of dental caries and periodontal disease, and the development of drugs. However, these efforts were mostly limited to patients visiting dental clinics and did not encompass inpatients, patients whose general condition was deteriorating, or elderly patients with weakened immunity.

That said, cleaning of the oral cavity of inpatients has been performed by nurses for a long time as a part of physical care. At home, too, mouth cleaning called "mouth care" have been used since around the 1980s with the spread of at-home care. However, this was probably based on the same concept as that of cleaning the body of patients who could not take a bath. In addition, the act of cleaning another person's mouth was time-consuming and difficult to perform safely and reliably and was often postponed due to busy schedules and lack of personnel.

The relationship between oral bacteria and other diseases has been discussed in terms of focal infections such as palmoplantar pustulosis. Knowledge was limited: infective endocarditis was known to be associated with oral infection, and periodontitis in diabetic patients tended to become severe. A breakthrough in oral care in hospitals was made in 1999 when Yoneyama *et al*. reported that thorough oral care was effective in preventing aspiration pneumonia (*1*). Since then, the importance of oral care has been highlighted, and oral care has been recognized as an evidence-based practice (*2*).

Oral care is defined in a narrow sense as cleaning of the teeth, mouth, and dentures, and in a broader sense as the maintenance of oral functions (eating, swallowing,

chewing, speech, aesthetics, *etc*.), dental care, eating and swallowing training, and articulation training. The concept of oral care has gradually expanded, and many studies and surveys have been conducted in collaboration with various professions.

The next section will review these studies, and the latter half of this section will look at the health economics of oral care, which have seldom been discussed until now.

2. What are the benefits of oral care?

2.1. Prevention of aspiration pneumonia and ventilator-associated pneumonia

The number of deaths from pneumonia decreased with the introduction of penicillin and other antimicrobials.

However, the number of deaths began to increase in the 1980s with the aging of the Japanese population, and according to the Vital Statistics of the Ministry of Health, Labor, and Welfare (MHLW), pneumonia, including aspiration pneumonia, surpassed stroke as the third leading cause of death in 2011 (*3*).

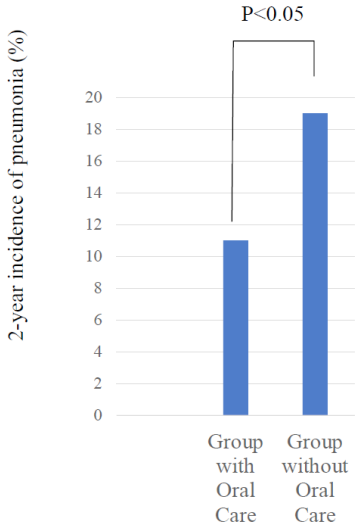

Figure 1. Comparison of the 2-year incidence of pneumonia between the oral care group and the control group. One group (oral care group) was visited once a week by a dentist or dental hygienist for professional oral cleaning, while the other group (control group) received conventional care. Results indicated that the incidence of pneumonia decreased by about 40%.

Oral care is known to facilitate the prevention of aspiration pneumonia in the elderly. In 1999, Yoneyama *et al*. reported on the potential of oral care to prevent aspiration pneumonia in a randomized controlled trial (RCT) in which residents of a special nursing home were randomly assigned to two groups (*1,4*). One group (oral care group) was visited once a week by a dentist or dental hygienist for professional oral cleaning, while the other group (control group) received conventional care. Results indicated that the incidence of pneumonia decreased by about 40% (Figure 1, Table 1). However, the problem is that no meta-analysis yielding reliable evidence has been conducted since that study.

There is a large body of literature suggesting that oral care is effective in the prevention of ventilator-associated pneumonia (VAP). In patients undergoing cardiac surgery, oral rinsing with chlorhexidine has been reported to reduce the incidence of VAP by a factor of 0.56 (95% confidence interval 0.41-0.77) compared to no rinsing (*5*). A study of 12 RCTs by Labeau *et al*. found a similar reduction in the incidence of VAP of 0.72-fold (95% CI 0.55-0.94) (*6*). That said, the effectiveness of rinsing with povidone-iodine and the effectiveness of oral cleaning with a toothbrush at preventing VAP have not been sufficiently proven. The problem is that a chlorhexidine concentration of 0.12% to 0.2% is used for oral rinsing, which is not a concentration that can be used in Japan. The cases of anaphylactic shock caused by chlorhexidine gluconate have been reported (*7*), and thus the undiluted concentration of chlorhexidine gluconate in mouthwashes is limited to 0.05%.

The current authors have been teaching about oral care in the ICU of a hospital in Vietnam, and the incidence of VAP has been successfully reduced. In addition, the hospital is also actively engaged in nosocomial infection control, teaching basic countermeasures, providing VAP care bundles, and conducting training in VAP countermeasures. Therefore, the results of these measures may have also contributed to the decrease in the incidence of VAP, and the results of oral care alone cannot be adequately evaluated (Data not shown)

As described above, oral care is thought to play a major role in the prevention of respiratory diseases, but dentistry cannot be said to play an active role in this area. The creation of a social system in which dentistry

Table 1. Comparison of the number of fever cases, pneumonia cases, and pneumonia deaths between the oral care group and the control group

Group	Number of patients	Age Mean ± SD	Male/Female	Baseline ADLs Mean ± SD	Baseline MMSE Mean ± SD	Number of fever cases (%)	Number of pneumonia cases (%)	Deaths due to pneumonia (%)
Oral Care	184	82.0 ± 7.8	36/148	16.3 ± 6.5	13.6 ± 6.9	27** (15)	21* (11)	14** (7)
No Oral Care	182	82.1 ± 7.5	37/145	16.2 ± 6.7	13.9 ± 6.9	54 (29)	34 (19)	30 (16)

MMSE: Mini-Mental State Examination. There were significantly fewer cases of fever and pneumonia in the oral care group than in the control group. There were also significantly fewer deaths from pneumonia. *$p < 0.05$ and **$p < 0.01$ in a test of significant differences between the oral care group and control group.

can play an active role will lead to improvement in the effectiveness of oral care and societal recognition.

2.2. Relationship between diabetes and periodontal disease

Many diabetics have long been known to suffer from periodontal disease, but the mutual causal relationship between periodontal disease and diabetes has become increasingly apparent in recent years.

Watanabe *et al*. reported that oral administration of *Porphyromonas gingivalis* for 22 weeks induced prediabetes in mice with chronic periodontitis (*8*) and that *P. gingivalis* was detected in pancreatic islets (*9*).

An excellent observational study, the Hisayama Study, had all examinees undergo a fasting 75 g oral glucose tolerance test (OGTT). A report on the relationship between the severity of periodontal disease and glucose intolerance using probing pocket depth (PPD) as an index to analyze the relationship between the severity of periodontal disease and the occurrence of glucose intolerance 10 years later (*10*). Results indicated that the odds ratio (OR) for the development of glucose intolerance 10 years later was two to three times higher in the group with severe periodontal disease than in the group with mild periodontal disease. This suggested that the presence of severe periodontal disease may affect the development of glucose intolerance and diabetes itself, possibly because the inflammatory response caused by long-term periodontal disease may affect insulin resistance and insulin secretion itself. However, these studies were all observational studies, and the effect of periodontal disease treatment on the risk of developing diabetes awaits further verification through interventional studies.

Another topic to consider is the relationship between periodontal disease and the treatment of diabetes mellitus. In the Hiroshima Study, high levels of sensitive C-reactive protein (hsCRP) decreased from > 0.25 mg/dL to <0.15 mg/dL and HbA1c improved from > 8.5% to about 6.5% in the high hsCRP group (> 0.05 mg/dL: severe periodontitis group) after 6 months of periodontal treatment (*11*). In contrast, the hsCRP level did not decrease in the low hsCRP group (less than 0.05 mg/dL: group of patients with mild periodontitis) even after 3 months of periodontal treatment, and HbA1c did not change significantly from less than 7% at the time of initial treatment. The same trend was also observed in the high hsCRP group and the low hsCRP group, which received only basic treatment without antimicrobials to treat periodontal disease.

Although meta-analyses have noted improvement in HbA1c, the following problems have been cited: few studies were analyzed, the sample size was too small, comparisons are difficult because of the wide range of periodontal disease and diabetes treatments when the study was conducted, and the alleviation of periodontal disease by periodontal treatment is unclear in some studies. In addition, studies have pointed out that the effects of infections other than those in the oral cavity should be considered when antimicrobials are administered systemically. However, there is a group of patients whose diabetes was alleviated by periodontal treatment according to a systematic review and the results of interventional studies (*12,13*) in Chinese patients, who are similar in size to Japanese patients. In the future, interventional studies should be conducted with a standardized protocol.

In 2018, the American Academy of Periodontology (AAP) and European Federation of Periodontology (EFP) periodontal classifications were revised for the first time in 19 years. The classification aimed to provide a "current assessment (severity, extent, complexity)" of periodontal disease through stage classification and to estimate "future projections (future risk, systemic involvement)" through grading. In addition to the degree of alveolar bone resorption and the depth of periodontal pockets as the main indices, the grading system included HbA1c as a grade modifier and hsCRP as a reference finding. The background for the inclusion of diabetes in the grading system is a US retrospective observational cohort study of more than 300,000 people, which indicated that the medical costs and hospitalizations for type 2 diabetes were significantly lower by about 40% in the group that visited the dentist four or more times a year than in the group that visited the dentist one to three times a year (*14*).

Although periodontal disease was once regarded as an inflammatory disease confined to the periodontium, it is now attracting attention as an "oral systemic link," that is, as a disease associated with systemic diseases.

2.3. Cancer treatment and oral care

During cancer treatment, various adverse events originating in the oral cavity occur at a high frequency, not only increasing patient suffering but also adversely affecting cancer treatment itself.

When a patient is immunosuppressed due to the use of anticancer drugs, dental infections can become severe and progress to systemic infections, which can have a significant impact on prognosis, including death. In addition, a study has reported that the risk of oral infections is increased not only by common bacteria but also by fungi and herpes viruses (*15-18*).

In radiotherapy, oral mucositis is inevitable when the oral cavity is included in the radiation field, and the degree of oral mucositis tends to be more severe and prolonged than mucositis caused by drug therapy. Oral mucositis not only causes pain and distress to the patient, but also, in severe cases, can prevent oral intake, leading to malnutrition and dehydration, and can cause systemic infections such as sepsis from secondary infections at the ulcer site (*19-22*). In addition to adversely affecting

the cancer treatment itself, it also adversely affects the patient's everyday life, which involves eating by mouth. The long-term use of bone-modifying drugs such as bisphosphonates and anti-RANKL antibodies, which are used to prevent fractures and alleviate symptoms in patients with bone metastases from cancer, as well as molecularly targeted drugs that inhibit angiogenesis, has been reported to cause medication-related osteonecrosis of the jaw (MRONJ). In a systematic review, the incidence of bisphosphonate osteonecrosis (BON) was 6.1% in all studies, 13.3% in studies with a follow-up, 0.7% in studies without a documented follow-up, and 1.2% in epidemiological studies (*23*).

Osteoradionecrosis (ORN) can easily occur within the radiation field due to invasive surgery such as tooth extraction, tooth-derived infection, or mucosal damage from ill-fitting dentures. In a systematic review of the prevalence of ORN in patients with head and neck cancers, the weighted prevalence of ORN was 7.4% for conventional radiation therapy, 5.1% for intensity-modulated radiation therapy (IMRT), 6.8% for chemoradiation therapy, and 5.3% for intra-tissue radiation therapy (*24*). Moreover, the oral cavity after radiation therapy is associated with decreased saliva. Furthermore, the oral cavity after radiotherapy is more susceptible to caries and more prone tooth loss due to the effects of treatment, such as decreased saliva production and qualitative changes in the oral microbiota (*25*).

Oral management of dental infections should consider the expected degree and duration of myelosuppression, and patients should be examined and treated for the presence of a focus of infection in the oral cavity to the extent that the situation permits before the start of cancer treatment. Moreover, the risk of infection should be controlled during the period of myelosuppression by oral cleaning with a focus on brushing. Periodontal disease has a high risk of causing acute infection during cancer treatment and must be evaluated and managed before treatment begins. These oral management practices have been found to be effective in preventing systemic complications during cancer treatment (*26-29*).

The total incidence of ORN after tooth extraction in the irradiated field was 7%, and the highest risk was observed in the extraction of mandibular molars in the irradiated field in patients with radiation doses exceeding 60 Gy (*30*). This is not only because the act of tooth extraction is bad, but because the patient has chronic inflammation that requires tooth extraction. In other words, since the risk of ORN remains the same even many years after irradiation, preventive measures are important. Teeth with a poor prognosis in the irradiation field should be extracted or treated appropriately at least 2 weeks before the start of treatment. Continuous dental and oral management is also important to avoid tooth extraction as much as possible (*31-33*).

Similarly, MRONJ is not only caused by tooth extraction, but by chronic inflammation that is left untreated. MRONJ is not incurable, and early conservative treatment can alleviate symptoms and inhibit disease progression. A study has proposed that the prodromal stage of MRONJ, when the mucosa is destroyed and the sequestrum is exposed, be called "stage 0," and the study contended that treatment in this stage may improve prognosis (*34*).

For oral management of oral mucositis, there are no preventive medicines or treatments that can completely suppress the onset of the disease. Symptomatic treatment is mainly focused on alleviating pain and other symptoms, reducing the risk of secondary infection, and promoting healing. During cancer treatment, the secretion of saliva decreases, causing dryness in the mouth, and nausea and fatigue make good oral hygiene difficult. However, , the symptoms of mucositis can be alleviated, the severity of the disease can be reduced, and the duration of the disease can be shortened by providing appropriate oral hygiene guidance tailored to the situation and making efforts to keep the oral cavity clean and moist (*35-38*).

2.4. Relationship between oral microbiota and cancer

Research on oral microflora and carcinogenesis is also progressing. In gastrointestinal cancers, *Helicobacter pylori* eradication has been found to reduce the risk of developing gastric cancer, and in colorectal cancers (CRC), many studies have reported on the relationship between *Fusobacterium nucleatum*, a type of periodontal bacterium, and colon cancer. However, the pathway of *F. nucleatum* infection in colon cancer tissues was unknown. Fourteen patients (10 males and 4 females, mean age: 69.4 years) with no history of antimicrobial use within one month were randomly selected from among 84 patients diagnosed with CRC according to colonoscopy. CRC tissues and saliva samples were collected via endoscopy and cultured using Fusobacterium selective medium. A total of 1,351 colonies were isolated and 361 isolates of *F. nucleatum* were detected by a specific primer polymerase chain reaction (PCR). As a result, *F. nucleatum* was detected in both colon cancer tissues and saliva in eight cases. When *F. nucleatum* isolated from these eight cases was analyzed at the strain level using arbitrarily primed PCR (AP-PCR), the same strain was detected in both colon cancer tissue and saliva in six cases (*39*).

A study performed a genetic analysis and comparison of the bacterial flora in 206 saliva and stool samples (103 saliva samples and 103 stool samples) collected from 52 CRC patients and 51 healthy controls. Results indicated that the oral and intestinal microflora contained oral indigenous bacteria (*Peptostreptococcus stomatis*, *Streptococcus anginosus*, *S. koreensis*, and *Solobacterium moorei*) that were suggested to be involved in carcinogenesis and cancer progression. These bacterial species were more prevalent in both

saliva and stool samples from the CRC group than from the control group. *S. moorei* and *P. stomatis* were present in relatively high amounts not only in stool but also in saliva, suggesting that they may originate from the oral cavity. *S. moorei* was detected in significantly higher amounts in both saliva and stool samples from patients with advanced stage CRC than from patients with early-stage CRC (*40*).

High concentrations of periodontal bacteria as well as *S. anginosus* were detected in cancerous tissues from patients with esophageal cancer, and the characteristics of oral bacterial flora and periodontal disease status were investigated for the relationship between oral infectious bacteria and esophageal cancer (*41*). Samples of subgingival dental plaque and unstimulated saliva were collected to evaluate the prevalence and abundance of oral bacteria. In the esophageal cancer group, the prevalence of all bacteria except *F. nucleatum* in dental plaque, the prevalence of *Aggregatibacter actinomycetemcomitans* in saliva, and the prevalence of all bacteria except *F. nucleatum* and the prevalence of all bacteria except *F. nucleatum* and *Prevotella intermedia* in dental plaque, the prevalence of *A. actinomycetemcomitans* in saliva, and the prevalence of *A. actinomycetemcomitans* and *S. anginosus* in dental plaque were significantly higher. *P. gingivalis* and *Aggregatibacter* have also been reported to be associated with a higher risk of pancreatic cancer (*42*).

In the future, examining oral flora through saliva tests and combining those results with responses to questionnaires on lifestyle may lead to the detection, risk detection, and prevention of cancer.

2.5. Cardiovascular disease and oral care

Since Mattila *et al*. reported that oral health was associated with the occurrence of myocardial infarction (*43*) in 1989, the relationship between periodontal disease and ischemic heart disease has attracted attention, but epidemiological studies to date have not necessarily reached a consensus on the existence of a causal relationship. Senba *et al*. conducted a large-scale study in Japan and found that the proportion of patients with periodontal disease who had coronary heart disease was significantly higher than that of those without periodontal disease (male: OR = 1.51, 95% CI: 0.90-2.52, female: OR = 1.48, 95% CI: 0.95 to 2.32) (*44*).

Periodontal disease has been associated with an increased prevalence of ischemic heart disease and associated mortality. In addition, periodontal disease affects systemic inflammation and vascular endothelial cell function. However, designing a study that excludes all confounding factors that may affect both is extremely difficult, and there is insufficient evidence to indicate its association with the onset or progression of ischemic heart disease.

However, recent studies have found that the relative risk of cardiovascular disease increases in patients with periodontal disease when the target population is limited to those under 65 years of age and that periodontal disease associated with systemic bacterial infection increases the risk of coronary artery disease (*45,46*). These findings suggest the need for well-designed follow-up and intervention studies that take these factors into account in the future.

2.6. Cerebrovascular disease and oral care

Cerebrovascular disease is the second leading cause of Japanese people requiring nursing care. Although the percentage of cerebrovascular disease has been declining in past Basic National Life Surveys, it still accounts for 16.6% in the latest figures for 2019 (*47*). Cerebrovascular disease causes motor impairment not only in the limbs but also in the orofacial region, which in turn causes deterioration in oral health. In addition, lifestyle habits that may cause cerebrovascular disease may also worsen oral health, suggesting the existence of common risk factors that affect both. Thus, oral health status and cerebrovascular disease are closely related to each other, and many studies have examined both.

In recent years, research has been focused on *S. mutans*. Cnm-positive *S. mutans*, which express the highly collagen-binding protein Cnm, is known to be involved in intracerebral hemorrhage, and about 20% of the entire population is said to have Cnm-positive *S. mutans*. When *S. mutans* was administered to stroke-prone spontaneously hypertensive rats, intracerebral hemorrhage was extensive, and streptococci infiltrated the extravascular lumen of blood vessels (*48*). Among the four disease types (hypertensive cerebral hemorrhage, lacunar infarction, cardiogenic cerebral embolism, and atherothrombotic cerebral infarction), the rate of detection was highest in cases of hypertensive cerebral hemorrhage, reaching 26%, and the OR for the other disease types was 5.66 (95% CI: 1.34 -23.9) (*49*). In addition, Cnm-positive *S. mutans* carriers had a higher incidence of intracerebral microhemorrhage, including microhemorrhages deep in the brain, suggesting that microhemorrhage has a negative impact on the brain (*50*).

However, studies have not sufficiently demonstrated that treatment of periodontal disease reduces cerebrovascular disease, and the causal relationship is not clear. As was mentioned earlier, designing a trial that excludes all possible confounding factors that may affect both the oral environment and stroke is difficult, making evaluation very difficult as well.

2.7. Rheumatoid arthritis and oral care

A study has suggested that rheumatoid arthritis and periodontitis exist in a mutually causal relationship (*51*). Rheumatoid arthritis (RA) predisposes patients to periodontitis. The aforementioned study investigated

the relationship between rheumatoid arthritis and periodontitis. In addition, Sjogren's syndrome and poor dental behavior can lead to tooth loss.

In contrast, other studies have suggested that periodontitis itself can be an aggravating factor for RA through periodontopathogenic bacteria. *P. gingivalis*, a commensal oral bacterium and one of the causes of periodontal disease, secretes an enzyme (PPAD) that functions similarly to peptidylarginine deiminase (PAD) in the body. Since periodontal patients routinely suffer from bacteremia, not only does *P. gingivalis* invade the synovial fluid, but citrullinated PPAD also invades the synovial fluid. It is thought to cause an autoimmune reaction in the joints, resulting in exacerbation of rheumatoid arthritis (*51*).

Interventional studies have indicated the effects of periodontal treatment in patients with rheumatoid arthritis (*53-55*), and case-control studies using data from the NHANESIII, a large US health survey, have also noted a relationship between periodontal disease and rheumatoid arthritis (*56-58*).

The results of intervention studies, case-control studies, cross-sectional studies, and basic research have indicated that periodontal disease and rheumatoid arthritis are related and that prevention and treatment of periodontal disease alleviates some of the symptoms of rheumatoid arthritis. However, improvement is only one aspect of evaluation, and some studies have not described discrete improvement, so further research is needed.

2.8. Dementia, nursing care, and oral care

As the world's population ages, dementia is becoming a major problem because of the need for nursing care. Many cross-sectional studies have indicated that people with dementia have poor oral health (*59,60*). These cross-sectional studies suggested that patients had dementia, which resulted in poor oral health due to inadequate oral care. In recent years, however, a study has reported that oral health affects the subsequent development of dementia and cognitive decline (*61*).

In a study by Dominy *et al*, gingipains, which are a proteolytic enzyme produced by *P. gingivalis*, were found in the hippocampus of patients with Alzheimer's disease (AD), and inhibition of gingipains suppressed amyloid β protein (Aβ) production, reduced neuroinflammation, and inhibited hippocampal neuron loss (*62*). In addition, the study found that (*i*) *P. gingivalis* is present in saliva and cerebrospinal fluid of patients with AD, (*ii*) local injection of gingipains into the hippocampus of mice causes neurodegeneration, which is inhibited by administration of gingipain inhibitors, (*iii*) Aβ42 increases in the brains of mice infected with *P. gingivalis*, and this increase is inhibited by administration of gingipain inhibitors, (*iv*) *P. gingivalis* proliferation in the brains of mice is inhibited by administration of gingipain inhibitors, and (*v*) gingipain inhibitors do not cause drug resistance. Therefore, there are possible pathways by which these periodontal diseases lead to the onset of dementia and decline in cognitive function.

In addition, tooth loss may cause degenerative changes in cognitive areas of the brain due to decreased chewing ability and decreased stimulation of the brain by chewing (*63*). In addition, decreased chewing ability may decrease the number of raw vegetables consumed, resulting in deficiencies in nutrients such as vitamins (*64*). These vitamin and other nutritional deficiencies are risk factors for the development of dementia.

Dental treatment for the increasing number of patients with dementia requires the detection of dementia in an early stage, a response to that condition in cooperation with the family physician, and provision of appropriate oral function management depending on the patient's condition. Therefore, dentists need to improve their ability to deal with dementia.

2.9. End-stage medical care and oral care

In patients with so-called terminal cancer, the condition of the oral cavity often deteriorates due to decreased saliva secretion, resulting in damage to the oral mucosa and taste disorders, as well as dental caries, periodontal disease, and denture incompatibility (*65*). In addition to medical treatment of systemic and psychological symptoms, efforts also need to be made to maintain the basic function of eating and to prevent systemic diseases such as pneumonia, and oral care can play a role in supporting patients with cancer so that they retain their human dignity until the end.

2.10. Disaster medical care and oral care

After the Great East Japan Earthquake, the number of suspected cases of "disaster-related deaths," in which symptoms developed or worsened in the wake of a disaster leading to death, increased (*66*). Of the 615 additional recipients of disaster condolence money compiled by the city of Kobe by January 1996, one year after the Great Hanshin-Awaji Earthquake, 89.6% were age 60 or older. By cause of death, 37.9% had cardiovascular disease (28.8% had heart disease and 9.1% had brain disease), 35.0% had respiratory disease (26.2% had pneumonia and 8.8% had some other respiratory disease), 3.6% had gastrointestinal disease, 2.0% had hematopoietic disease, 0.7% committed suicide, and 21.0% had exacerbation of a pre-existing condition (*67*).

The reasons for the prominence of cardiovascular and respiratory diseases are the poor diet and living conditions in shelters after an earthquake, the dust, and the lowered immunity due to the prolonged stay in shelters, as well as the inability to brush one's teeth and maintain good oral hygiene due to the extreme lack of water. In addition, extreme lack of water, poor oral hygiene due to the inability to brush one's teeth,

and difficulty removing dentures at night due to lack of privacy are said to be related to the increase in oral bacteria and subclinical aspiration, in which oral bacteria are swallowed along with saliva during sleep. In addition, many patients die from aspiration pneumonia as a result of worsening of chronic diseases such as hypertension, diabetes, and cerebrovascular disease due to the difficulty in taking prescriptions and regular medications and the inability to exercise and control one's diet.

Unlike deep vein thrombosis (DVT), the recognition that aspiration pneumonia caused by inadequate oral care can directly affect life or death has not yet fully entered the consciousness of doctors, nurses, public health nurses, and other medical professionals, as well as the government. Even if it is recognized, medical personnel are busy immediately after a disaster and tend to overlook or postpone the importance of aspiration pneumonia, just like brushing one's teeth. While there are many measures to prevent pneumonia, such as pneumonia and influenza vaccinations, management of chronic diseases, and early improvement of diet and living conditions, the importance of oral care must also be recognized.

2.11. COVID-19 and oral care

The novel coronavirus (SARS-CoV-2) infects people by binding to the angiotensin-converting enzyme (ACE) 2 receptor (*68*). ACE2 is expressed predominantly in the gastrointestinal tract, kidneys, and heart. Although pneumonia is a problem with COVID-19, ACE2 is expressed less in the lungs than in the gastrointestinal tract and is more abundant in salivary glands than in the lungs (*69*).

A comparison of the sensitivity and specificity of RT-PCR at detecting the nucleic acids of SARS-CoV-2 in saliva and nasopharyngeal/nasal swabs noted no significant differences between the two, and saliva was comparable to nasopharyngeal/nasal swabs (*70,71*). Saliva is equivalent to nasopharyngeal swabs, the gold standard for virus detection, suggesting the presence of infectious viruses in saliva.

In addition, SARS-CoV-2 damages the epithelial cells and weakens the defense mechanisms of the lungs, causing secondary bacterial pneumonia due to aspiration of oral bacteria. Thorough oral hygiene is important to prevent the salivary glands from becoming reservoirs of SARS-CoV-2 and to prevent secondary bacterial pneumonia.

3. Health economics of oral care

3.1. Perioperative oral function management (POM) in Japan

In Japan, POM was added to dental insurance in the April 2012 revision of medical fees (*72*). Although the practice had been in place for some time, this was the start of a full-scale effort to provide oral care at medical facilities throughout Japan.

POM includes oral hygiene instruction, oral care (moisturizing and cleaning), removal of the tongue coating, professional oral care by a dental hygienist, treatment by a dentist to remove sources of infection (periodontal disease and tooth decay) in the teeth and mouth, and adjustment of dentures. As a result of the widespread recognition of the importance of POM, the April 2014 revision of points for coverage by medical insurance includes the following. When surgery is performed to remove a malignant tumor from the face, oral cavity, neck, chest, or abdomen or cardiac or vascular surgery (excluding that on arteries or veins) is performed under general anesthesia within one month after POM by medical doctors, additional points were assigned to surgery after POM, which led to enhanced medical and dental cooperation. As of April 2018, the scope of coverage has been expanded to include the prevention of postoperative complications such as complications caused by oral bacteria in patients with dental diseases or poor oral hygiene (surgical site infection and local infection), local infection caused by decreased immunity due to invasive surgery or drug administration, aspiration pneumonia caused by endotracheal intubation during artificial respiration, aspiration pneumonia caused by feeding dysfunction due to stroke, and infections related to postoperative nutritional disorders. The scope of coverage has been expanded to include the prevention of complications. Covered surgeries have also been expanded to include malignant tumors of the head and neck, respiratory, and digestive systems, cardiovascular surgery, orthopedic surgery such as hip replacement, organ transplantation, hematopoietic stem cell transplantation, and surgery for stroke (*73*).

3.2. Validation of POM using big data

How has including POM in the Japanese social insurance system, as was mentioned in the previous section, affected the prevention of postoperative complications? There is an interesting analysis using big data.

Kurasawa *et al*. conducted a multicenter study to investigate the risk factors for the development of pneumonia in postoperative patients and the effectiveness of POM at preventing pneumonia (*74*). Eight hospitals in the region were surveyed over a 4-year period from April 2010 to March 2014. Of 346,563 patients without pneumonia at the time of admission (sample population), 25,554 patients with cancer who underwent surgery (the target population) were selected and evaluated. The incidence of pneumonia in these patients was determined and significant predictors of pneumonia were identified using multiple logistic regression analysis. When the incidence of pneumonia before and after the introduction of POM was compared, the incidence of pneumonia

after cancer surgery decreased from 2.0% to 0.8% in the target population. Results indicated that the OR for the development of pneumonia after the introduction of POM was 0.44, indicating that the risk of pneumonia decreased.

Ishimaru *et al*. conducted a retrospective cohort study on the effectiveness with which oral care prevented the development of pneumonia in patients after surgery for a malignant tumor based on an analysis of the National Database of Health Insurance Claims and Specified Health Examinations (NDB) (*75*). They conducted a retrospective cohort study on the effectiveness with which oral care prevented the incidence of head and neck cancer, esophageal cancer, gastric cancer, CRC, lung cancer, and liver cancer from May 2012 to December 2015. Patients who underwent resection surgery for head and neck, esophageal, gastric, colorectal, lung, and liver cancers between May 2012 and December 2015 were examined. The primary outcomes were pneumonia and all-cause mortality within 30 days after surgery. Patient background served as a propensity score (PS), and background items including comorbidities that affected the intervention effect were included as covariates in the analytical model to adjust for effects in the intervention group.

In that study, the oral hygiene group was assumed to include a mixture of patients with good oral hygiene, who are thought to have a low incidence of postoperative pneumonia, and patients with poor oral hygiene, who are thought to have undergone surgery without adequate oral hygiene because of the brief period before surgery. Therefore, the influence of these factors on results needed to be examined. Of 509,179 patients studied, they reported that 81,632 (16.0%) received preoperative oral care by dentists, 15,724 (3%) developed postoperative pneumonia, and 1,734 (0.34%) died within 30 days after surgery. Preoperative oral care by dentists was significantly associated with a reduction in postoperative pneumonia (3.28 *vs*. 3.76%, risk difference: -0.48%, 95% CI: -0.64 to 0.32) and a reduction in all-cause mortality within 30 days after surgery (0.30 *vs*. 0.42%, risk difference: -0.12%, 95% CI: -0.17 to 0.07).

In other words, analyses based on big data, have demonstrated the effectiveness of preoperative oral management in cancer surgery in terms of preventing postoperative pneumonia. However, POM does not cover patients on dialysis, patients taking steroids, non-surgical heart failure, stroke, an examination for a fever of unknown origin, and confirmation before bisphosphonate administration. Therefore, evidence that these conditions can also be alleviated by POM needs to be collected.

3.3. POM systems

Although POM is practiced in general practitioners' clinics, according to data on social medical practice from June 2020, it is mostly practiced in dental departments of hospitals (*76*). A hospital would have to perform POM for a huge number of patients, and POM for all of them would take up human resources, putting pressure on other practices such as dental care.

Therefore, Sekiya *et al*. attempted to institute the practice at a hospital's perioperative medical center (*77*). The center is a one-stop department for the management of patients admitted to the hospital and who will be undergoing surgery involving general anesthesia. Such departments have now been created in many hospitals in Japan. In 2012, the year following the establishment of the department, an "oral triage" system was instituted in which dental hygienists screen the oral cavity and select patients who require preoperative oral hygiene and functional management. In other words, only those patients who need dental intervention after screening receive oral hygiene treatment under this system. The rate of dental intervention was stable at around 20%. Moreover, the system has the advantage that oral hygiene procedures can be performed by similarly trained staff in the same department at a standardized frequency and in a standardized manner. A total of 37,557 patients who underwent surgery at that hospital from April 2010 to March 2019 (2 years before and 7 years after the system implementation) were evaluated, and the sustainability and effectiveness of the system implementation were examined in 7,715 patients undergoing cancer surgery. Oral management was performed at a rate of 20% and the incidence of postoperative pneumonia was significantly reduced (adjusted OR = 0.50, $p = 0.03$), so the system successfully eliminated the reservoir of oral infections within a sufficient treatment period of two weeks. Instituted at a perioperative medical center, the system proved to be a sustainable and evolving method of perioperative oral management. This system may be a useful strategy with which to manage surgical patients with minimal human resources.

3.4. Benefits of POM in terms of reducing health care costs

Few studies have examined POM in terms of medical costs. The Japan Dental Association presented data on an interventional study at Chiba University Hospital at the 84th meeting of the Medical Insurance Committee of the Social Security Council in November 2014 as "a case study of the effects of oral function management and medical and dental collaboration functioning effectively (*78*).

Patients undergoing surgery by the Department of Oral and Maxillofacial Surgery, the Department of Gastroenterological Surgery, and the Department of Cardiovascular Surgery, patients receiving radiotherapy in the Department of Oral and Maxillofacial Surgery, and patients receiving chemotherapy for malignant tumors in the Department of Pediatrics and the Department of Hematology during the 9 years and 10 months from

January 2004 to October 2013 were included. The term "management of oral functions" here refers not only to cleaning, but also to keeping oral functions as normal as possible through specialized treatment of periodontal pockets, caries, root canals, the root apex, the jaw, the salivary glands, and other specialized areas. The "unmanaged group" is the group that received general oral care such as mouth rinsing, which was mainly performed by nurses in the past, while the "managed group" refers to the group that was examined by dentists and that received specialized oral function management performed by dentists and dental hygienists.

First, the length of hospitalization for surgical patients was as follows: 77.9 days for the managed group (n = 210) undergoing dental surgery compared to 102.4 days for the unmanaged group (n = 271), 42 days for the unmanaged group (n = 52) undergoing gastrointestinal surgery compared to 29 days for the managed group (n = 108), and 38 days for the unmanaged group (n = 53) undergoing cardiovascular surgery compared 29 days for the managed group (n = 110). Hospitalization was significantly shorter for the managed group (84.2 days, n = 55) receiving chemotherapy for a malignancy in Pediatrics compared to the unmanaged group (135.3 days, n = 64) and for the managed group (96 days, n = 103) in Hematology compared to the unmanaged group (108 days, n = 60). A significant reduction in the duration of hospitalization was observed in all departments. The effect of oral function management on the length of hospitalization for patients undergoing radiotherapy for oral malignancies was also found to be shorter in the managed group (75.2 days, n = 54) compared to the unmanaged group (84 days, n = 33), and fewer days were required for recovery in the managed group (25.6 days, n = 54) compared to the unmanaged group (31.5 days, n = 33). Fewer days were required for recovery in the managed group (25.6 days, n = 54) compared to the unmanaged group (31.5 days, n = 33). These results suggest that a significant reduction in the recovery period after the completion of radiotherapy contributes to a shorter hospitalization. The duration of postoperative antimicrobial therapy for patients with oral malignancies was significantly shorter in the managed group (n = 210, 5.6 days) than in the unmanaged group (n = 271, 9.9 days). Cardiovascular surgery is considered to have the fewest external factors such as infections affecting postoperative recovery. In In cardiovascular surgery, the duration of postoperative antimicrobial therapy was significantly shorter in the managed group (n = 110) than in the unmanaged group (n = 53) 1, 7, 14, and 21 days after surgery.

The same study also presents the medical costs of Asahi General Hospital. For a laparoscopic gastrectomy, the average hospitalization was 6.6 ± 0.94 days in the managed group (n = 20) and 11.1 ± 11.2 days in the unmanaged group (n = 58), and the average medical costs were 1,483,901 yen in the managed group (n = 20) and 1,678,465 yen in the unmanaged group (n = 58). For an open gastrectomy, the average hospitalization was 11.7 ± 10.5 days in the group with oral health care (n = 57) and 16.0 ± 16.1 days in the group without oral health care (n = 57). The average medical costs were 1,627,496 yen in the managed group (n = 57) and 1,758,704 yen in the unmanaged group (n = 57). Thus, POM significantly shortened the duration of required hospitalization and it reduced medical costs.

Sekiya *et al*. confirmed that the average treatment costs for patients who did not develop pneumonia after hospitalization were 1,295,762 (± 1,007,162) (yen/person), and the average treatment costs for patients who developed pneumonia after hospitalization were 2,962,771 (± 1,964,419) (yen/person) (*79*). Therefore, the treatment costs for patients who developed pneumonia after hospitalization were calculated to differ by 1,667,009 (yen/person). POM was estimated to have prevented pneumonia in 161 patients. The total costs would have been 268,388,449 yen (1,667,009 × 161). In contrast, POM cost 18,020,320 yen, so medical costs for 13,668 patients would have differed by an estimated 250,368,129 yen (approximately 250 million yen). These results suggest that oral function management leads to early postoperative recovery and that the effects of oral function management are not limited to mere prevention but also include therapeutic benefits and reduced medical costs.

3.5. Increased revenue to dentistry from POM

Of the 2,082 facilities belonging to the Japan Hospital Association, only 739 have dental and oral surgery. In many hospitals, dentistry has been eliminated or reduced for financial reasons. However, changes have occurred since 2012, when insurance points were assigned for POM.

One change is that hospitals are recognizing the importance of POM as a supportive care, and another is that POM is a powerful tool for dentistry to increase patients and revenue.

The current authors' department was asked to perform POM in about 5 cases per month in 2012, just after the introduction of POM. However, the department is now receiving as many as 300 requests per month as a result of the increase in the number of target diseases and awareness of POM, the establishment of the Admission and Discharge Support Center in 2017, and the simplification of procedures to request POM (Figure 2). The department receives a fee for preparation and a preoperative and postoperative reimbursement for each request, which has resulted in an increase in the number of patients seen and an increase in revenue. In addition, dentists and dental hygienists with fewer years of experience can be actively involved in the practice and task shifting.

4. The future of POM

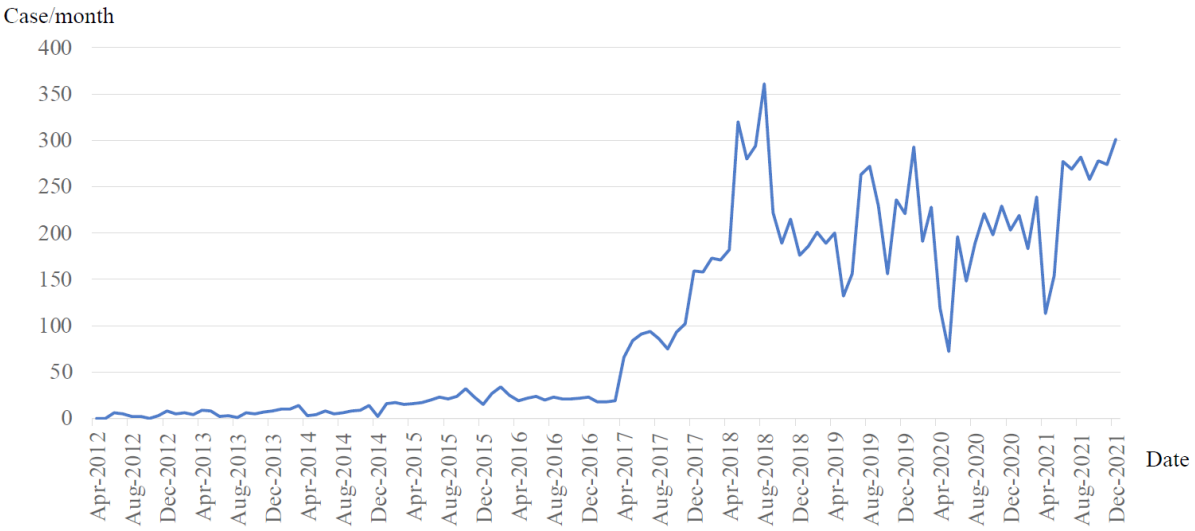

Figure 2. POM performed monthly by the Department of Oral and Maxillofacial Surgery, Center Hospital, National Center for Global Health and Medicine. The Department of Oral Surgery, National Center for Global Health and Medicine was requested to perform POM about 5 times per month in 2012, just after the introduction of POM. However, due to an increase in the number of target diseases and increased awareness of POM, as well as the creation of the Admission and Discharge Support Center in 2017 to simplify the procedures for requesting POM, as many as 300 requests are now being receiving each month (that said, the number decreased temporarily due to the COVID-19 pandemic).

As indicated in the previous section, POM has been found to have had a significant impact on health, far beyond the role it was initially envisioned to play. From a health economics perspective, POM has also been linked to reduced medical costs and increased dental revenue. Therefore, there are increasing attempts to set up oral care teams in hospitals with medical and dental facilities and to implement POM in cooperation with general practicing dentists as well as dentists in hospitals. In the future, medical reimbursement may be added to "team medicine" like palliative care, respiratory care, and pressure ulcer management.

Japan already has a superannuated population, and the number of elderly people is estimated to peak at 39 million in 2042. Therefore, the MHLW is promoting the establishment of a community-based comprehensive support system by 2025 in order to help the elderly maintain their dignity and live independently so that they can continue to live their own lives in their communities as much as possible (*80*).

What can dentistry offer? In addition to so-called dental treatment, such as the treatment of decayed teeth and periodontal disease, dentistry has a role to play in combating dementia, at-home care, delaying the need for nursing care, and nursing care facilities, but the main focus of care is to facilitate eating by mouth.

Oral functions such as chewing and swallowing, eating conditions, and eating posture can be properly evaluated by a multidisciplinary team observing care recipients at mealtime. Additional perspectives can be incorporated professionals in multiple disciplines exchanging opinions. This should enhance eating support, contribute to the intake of required nutrients, lead to weight gain, and prevent aspiration pneumonia. These attempts can be considered as part of oral care in a broader sense.

There is a movement to promote oral care as an academic discipline. The Japanese Society for Oral Care consists of professionals from various disciplines, including dentists, doctors, pharmacists, nurses, dental hygienists, speech pathologists, midwives, care workers, nutritionists, public health nurses, physical therapists, teachers, childcare workers, and home helpers, and it conducts academic research on oral health care. It also aims to promote health maintenance and publicize the results of that research. Moreover, the Society aims to make a significant contribution to improving the QOL of people by facilitating communication and by preventing aspiration pneumonia in the elderly, as well as promoting drinking, eating, and talking.

The Society devices practices, it conducts training, surveys, and research, and it facilitates the exchange of information among health, medical, and welfare professionals from many academic organizations to provide oral health care to the healthy, sick, disabled, homebound, hospitalized, infants, and elderly people.

The International Society of Oral Care was established in 2021 with the aim of contributing to oral health-related science on a global scale.

In conclusion, the field of oral health care has evolved greatly from the days of "cleaning the mouth" to the present, and new and surprising findings are successively being announced. The hope is that new findings will continue to be obtained and that practices will continue to be refined in the future.

Acknowledgements

The authors wish to sincerely thank the doctors of the

Study Group of Hospital Dentistry in the Metropolitan Area (SGHDM Japan) for their valuable advice and comments.

Funding: None.

Conflict of Interest: The authors have no conflicts of interest to disclose.

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Received February 6, 2022; Revised February 14, 2022; Accepted February 17, 2022.

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Released online in J-STAGE as advance publication February 21, 2022.