The current evidence of dental care and oral health for achieving healthy longevity in an aging society

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*: Can only be accessed at Japan Dental Association's Members-Only Website

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Introduction and summary overview

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[Introduction]

As we face the rapid aging of our population, which is proceeding at a rate never before experienced by humankind, many efforts to deal with this problem have been initiated in various fields of academic research as well as in medical, health, welfare, and community settings. In order to realize a society where elderly people can live life in peace and with dignity, it is essential to develop health and medical care systems that provide high-quality healthcare services.

It is inevitable that in old age, people experience a decline in the functions of daily living and become more susceptible to diseases. The aging of the population is a result of decreasing mortality in adulthood and old age, not to mention the neonatal period and early childhood, which has been achieved through the accumulation by humankind of science, technology, and knowledge. However, population aging has also extended the period during which people require care, and it will continue to increase the amount of healthcare needed at the national and community level.

Under the present circumstances, providing sufficient healthcare to all elderly individuals requires adequate human and social resources, a social security system which includes a healthcare system and rests on a solid financial foundation, and the accumulation of scientific evidence. Moreover, it will be necessary to inform the citizenry, policymakers, and healthcare workers regarding the outcomes of the various measures. Another big political issue is how to extend the healthy period during old age.

On the other hand, dental and oral health is an essential element for the maintenance of QOL throughout one's life. Moreover, research has made it clear that dental and oral health has the potential to maintain and improve systemic health status. Therefore, a social system that allows everyone to receive high-quality dental care and oral health services even during old age is necessary. In addition, collaboration between the medical and dental fields and between professionals in both fields toward the development of a more effective healthcare provision system is needed. To this end, it is necessary to accumulate clearer evidence and take specific actions in order to situate dental care and oral health firmly within the social security system and healthcare policy, which in turn will facilitate its contribution to the realization of healthy longevity.

Against this backdrop, this collection of reviews aims to provide the target audience (i.e., policymakers, healthcare professionals, and researchers) with a summary of the present evidence and issues. To this end, I conducted a literature review for each topic based on the hypotheses (II-1 of this collection of reviews, Figure 10) regarding the conceptual pathway linking dental/oral health and the extension of healthy life expectancy, and then the evidence regarding each topics was analyzed The topics covered in this collection of reviews include the relationship of dental and oral health with (1) age-related changes and aging, (2) life expectancy, (3) NCDs as the main causes of death and the risk factors thereof, (4) diseases that cause conditions requiring long-term care, (5) health promotion activities such as exercise, nutrition, and rest, (6) socioeconomic factors, and (7) the effects of dental care. In addition, the particularly important literature is summarized, in some cases in table form, within the review of each topic. Moreover, the strength of the evidence presented in each study is noted by specifying the study design (e.g., observational study, intervention study, data integration study), so that this collection of reviews can be used as an easy-to-understand resource where policymakers as well as the general public can obtain oral health information. At the end of this collection of reviews, we have also provided a commentary regarding the history of Japan's 8020 campaign and the universal health insurance system that was implemented in 1961.

The reviews contained herein were conducted mainly by using Ichushi (the largest database of medical literature in Japan) for Japanese articles and PubMed for English articles to conduct searches of research reported up through 2014. Excerpts of the main findings from the topic-specific reviews by each author are provided below.

[Summary of findings from each topic-specific review]
1. Age-related changes and aging
[Fukai K, Kambara M, Morito M *et al*.]

With regard to aging in the oral area, chewing and swallowing were examined as representative of oral functions. The results confirmed that all oral functions, including occlusion, chewing (mastication), salivation,

articulation, and swallowing, show a decline while influencing each other. Moreover, reduced oral function was closely related to dementia, systemic diseases, and motor function, as well as the functions of daily living.

Age-related changes in the oral cavity due to aging, the oral health status of the elderly in Japan, dental care among the elderly, the daily life of the elderly, and oral health risks among the elderly were examined. The results revealed that organic changes in the oral cavity affect oral function, and that with aging comes specific changes in terms of oral diseases, oral health behaviors, and lifestyle habits; thus, appropriate measures to address these changes are necessary. If we were to address these changes with conventional strategies on a disease-by-disease basis, changes associated with aging must be quantified using appropriate measurement methods, and tailor-made treatment programs would be developed in accordance with established thresholds. However, age-related changes are often subjective. Thus, resident- or patient-based responses should be emphasized in order to address the problem of how best to go about one's daily life, including daily activities and work, rather than simply looking at everything from the perspective of treating diseases and mental or physical disorders.

2. Life expectancy [Fukai K, Ansai T *et al.*]

The association of dental and oral health with mortality was reviewed. With regard to the relationship between the number of teeth and overall mortality, the results of several cohort studies from different countries have provided evidence that the maintenance of higher numbers of teeth contributes to the extension of life expectancy. Meta-analyses have confirmed that vital prognosis is improved due to the use of dentures after tooth loss. A number of reports have also shown an association between tooth number and cardiovascular disease (CVD).

With regard to the effect of masticatory function and occlusal state on life expectancy, individuals with high masticatory function or a stable occlusal state (i.e., able to chew in the molar region) have better health status and significantly lower mortality risk. An association between masticatory function and CVD mortality has also been reported.

The results of investigations regarding the relationship between oral diseases (e.g., dental caries and periodontal disease) and life expectancy revealed that there is currently insufficient evidence to establish a clear relationship. One report, however, did show that people with regular oral care habits have a longer life span.

3. NCDs as primary causes of death and associated risk factors [Izumi Y, Yoneyama T, Ueno T, Kikutani T, Shimazaki Y *et al.*]

The results of the investigation regarding the association of dental and oral health with main causes of death and NCDs revealed that there exists evidence showing associations with diabetes mellitus, pneumonia, cancer, cardiovascular diseases, and metabolic syndrome, as detailed below. The association of dental and oral health with cerebrovascular diseases, and the effects of maintaining dental and oral health during the perioperative period following cancer surgery will be described in separate sections of this introduction.

Diabetes mellitus affects diseases in the oral cavity, and periodontal diseases in particular are closely associated with diabetes mellitus. For this reason, dentists have a potential role in contributing to the improvement of diabetes mellitus. Moreover, since performing oral health management can potentially result in early detection of diabetes mellitus or provide opportunities to educate patients in the pre-diabetic stage, medical-dental cooperation should be further promoted in the future.

The idea that oral care can help prevent aspiration pneumonia in elderly patients has already gained social support; however, this claim rests primarily on evidence from a single RCT, so further accumulation of evidence from well-planned RCTs is needed. On the other hand, a sufficient level of evidence does exist to support a connection between oral care and the prevention of ventilator-associated pneumonia.

With regard to the association between cancer and oral health, oral adverse events that occur in association with cancer treatment can hinder treatment and sometimes affect patients' vital prognosis. Some evidence suggests that the implementation of proper oral hygiene management before initiating cancer treatment is effective in decreasing the risk of oral adverse events and reducing their severity.

An association between periodontal and cardiovascular diseases has been observed. Moreover, there have been new findings, such as that the risk of cardiovascular disease among people with periodontal disease is higher in people who are 65 years of age or younger, that the association of periodontal disease with acute myocardial infarction is stronger than with chronic coronary heart disease, and that people with periodontal disease accompanied by systemic bacterial infection have a higher risk of coronary heart disease. A few studies have revealed that the treatment of periodontal disease is associated with reduced risk of developing cardiovascular disease or a decrease in serum

antibody titers, but these have not yet been established as causal relationships.

Among reports from various countries regarding the association between metabolic syndrome and oral health, there have been a relatively large number of studies conducted in Japan. Individuals with metabolic syndrome have a high risk of periodontal disease, and some studies have shown that metabolic syndrome is more prevalent among those with periodontal disease; however, the majority of this evidence is from cross-sectional studies. Obesity, which plays a central role in metabolic syndrome, is an important risk factor for diabetes mellitus and arteriosclerotic diseases. Many studies have shown that obesity is also associated with periodontal disease, and in particular, a strong association has been found between visceral fat obesity and periodontitis. Since many aspects of the relationship between metabolic syndrome and oral health, such as the direction and underlying mechanisms of the association, remain unclear, more evidence needs to be accumulated in order to further elucidate this association.

With respect to NCD risk factors, smoking, drinking, exercise, and eating habits have each been found to be associated with oral health problems such as periodontal disease. In particular, smoking clearly affects periodontal health. Although it has been suggested that intake of a large amount of alcohol may affect periodontal health, results have varied among studies. People with good exercise habits and those who consume healthy food and nutrients tend to have better periodontal health. Improved lifestyle habits bring about positive effects for not only systemic health but also oral health, but further evidence is required to justify the inclusion of instruction regarding lifestyle habits (other than smoking) into oral health guidance programs and routines.

4. Diseases which cause conditions necessitating long-term care   [Kikutani T, Yamamoto T, Aida J *et al*.]

Predictive factors for the incidence of conditions that necessitate long-term care include old age, cognitive dysfunction, visual impairment, low subjective health, decreased or increased body mass index (BMI), decreased functionality in the extremities, decreased exercise or social interaction, and smoking. In addition to these factors, it has been pointed out that oral health may be related to some of the risk factors associated with the development of a condition requiring long-term care. For example, oral health affects social activities, such as interacting with friends and participating in recreational activities, through conversation, facial appearance and smile, and eating function. For the

elderly, social participation has been shown to prevent the occurrence of conditions that necessitate long-term care, thus it is possible that oral health status plays an important role in terms of its effect on social participation.

As for the specific evidence, healthy oral conditions including denture use have been associated with a low incidence of future occurrence of a condition requiring long-term care. In the future, by further disseminating healthcare interventions aimed at maintaining oral health among the elderly, the incidence of conditions requiring long-term care can be reduced.

The leading disease resulting in long-term care among the Japanese people is cerebrovascular disease. Cerebrovascular disease causes movement disorders that affect not only the extremities but also the orofacial area, and it can even cause the deterioration of oral hygienic status. Investigations of the association between oral health status and cerebrovascular diseases have revealed that young people and people with many missing teeth or high CAL and PPD have an increased risk of stroke, as reported in the context of the association between periodontal disease and stroke. Moreover, the association of periodontal disease is stronger with non-hemorrhagic (ischemic) stroke than with hemorrhagic stroke. However, the current evidence regarding the reduced risk of cerebrovascular events associated with periodontal disease is insufficient to establish causality. It will be necessary to conduct follow-up and/or intervention studies in order to address these issues.

The question of whether oral health is associated with the later onset of dementia or cognitive decline was examined based on original articles reporting cross-sectional and/or intervention studies. The majority of the studies examined have reported significant associations. Oral hygiene, periodontal disease, number of teeth, occlusion, mastication, presence of a primary care dental clinic, and dental visitation have been reported as factors that are likely associated with the onset of dementia and cognitive decline.

The question of whether poor oral status increases the risk of future incidence of falls and femoral neck fracture, as well as which oral conditions have associations with falls and fractures, was investigated. Several cohort studies have demonstrated that loss of occlusal support and non-use of dentures after tooth loss are risk factors for subsequent fall events. Moreover, having periodontal disease and fewer teeth have been shown to increase the risk of subsequent femoral neck fracture.

The relationship between oral health and joint diseases was examined based on the results from intervention studies, case-control studies, cross-sectional studies, and

basic studies. The results suggest an association between periodontal disease and rheumatoid arthritis, and that the prevention and treatment of periodontal disease could improve some of the symptoms of rheumatoid arthritis. However, these improvements were limited, and the effectiveness of such improvements is ambiguous in some of the articles; therefore, further investigative research is necessary.

5. Health promotion such as exercise, nutrition, and rest
[Miyazaki H, Hanada N, Ando Y, Naito M *et al*.]

With regard to motor function, the association of dental/oral health with physical fitness and activities of daily living (ADL) was examined. The existing research shows that balance, lower limb muscle strength, and upper limb muscle strength are associated with occlusal support and chewing ability, and that deterioration of occlusal status causes deterioration of balance and lower limb muscle strength over time. However, the interpretation of these results requires that consideration be given to dental treatment interventions as well as sampling bias. Moreover, the relationship between oral health status and ADL is believed to be indirect, i.e., nutritional state and physical strength serve as mediators, meaning that the maintenance of oral health status or recovery of oral function likely prevents reduced ADL through these mediators.

The results of the review of the relationship between dental/oral health and nutrition revealed that tooth loss is associated with a decrease in food consumption, mainly that of vegetables and fruits, and nutrient intake, mainly vitamins with anti-oxidation effects. In addition, tooth loss is associated with obesity or weight loss. This association is affected by factors such as age, sex, and race. Especially among the elderly, associations with a decrease in total energy intake and malnutrition have been observed. Edentulous individuals with full dentures have inferior nutrition intake compared to non-edentulous individuals, but such an association is not observed among those with adequate denture fit who have received regular maintenance. Self-rated oral pain is associated with malnutrition. However, no improvement effects on nutrition intake have been observed as a result of dental prosthesis treatment alone. Improvements in healthy dietary intake and nutritional status, which require behavior modification, are difficult to achieve without nutritional guidance. Based on these findings, it is likely that regular dental maintenance which results in tooth loss prevention and maintenance of denture fit will decrease the risk of NCDs, prevent malnutrition among the elderly, and prevent reduced ADL,

ultimately leading to the extension of healthy life expectancy. There is, however, a methodological challenge that must be overcome in future research; namely, that it is difficult to assess causality because observational studies regarding the association between dental/oral health and nutrition have usually relied on a cross-sectional design. Therefore, studies with a higher level of reliability (e.g., cohort studies) need to be conducted in order to accumulate a strong body of evidence that would clarify the nature of this association. It would also be desirable to conduct research that assesses the effects of improved nutrition through collaboration with other professionals, such as nutritionists, in the context of an intervention study.

Concerning the association between oral health and rest, communication, and QOL, the research indicates that oral health and health-related QOL are significantly correlated, and that the maintenance and promotion of oral health contributes to improved QOL. Furthermore, stress and sleep, which are associated with communication and rest, are also associated with oral status. While few reports exist on these factors, rest and communication are thought to be related to survival, ADL, social participation, and QOL, thereby indirectly affecting healthy longevity. The association of stress and amount of sleep with mortality risk has been reported, so research on how oral health is related to these factors would have great public health significance. Therefore, further accumulation of evidence in this area is encouraged.

6. Social determinants
[Aida J *et al*.]

Social determinants of health are "causes of the cause" that inevitably affect the health and behavior of people. A review of systematic reviews and meta-analyses regarding social determinants and dental health inequalities was conducted to examine the existing evidence, both globally and in Japan. It was found that higher income and education level were associated with better oral health conditions and behaviors, confirming the existence of health inequalities. Even among the studies conducted in Japan, where dental treatment is covered by the universal health insurance system, similar health inequalities were observed. Health inequalities arise due to inequalities not only in disease treatment, but also in disease incidence. Accordingly, inequalities are known to exist even if the cost of medical examination is free. Concerted efforts must be made if inequalities in the occurrence and treatment of dental diseases are to be reduced. It is difficult to implement measures that will improve the condition of patients who do not readily change their health behaviors even after

repeated health guidance, or those who do not even come to a medical checkup. In order to improve the health of our entire society, including people who are unwilling to make any effort, it is necessary to come up with an approach that takes into account the health-related social determinants that exist in the background. Clarification of the social determinants that impact health, and then the realization of an environment that promotes the health of everyone in society, are essential.

7. Effects of dental care

[Ueno T, Morito M, Izumi Y, Yamamoto T, Tsuneishi M *et al*.]

Reducing perioperative complications in surgery has important implications not only in terms of improved treatment prognosis but also from the perspective of medical economics. Some postoperative complications occur in the oral environment (hygiene status, dental disease, etc.). Therefore, oral management during the perioperative period helps to reduce the risk of infectious complications such as pneumonia, and it contributes to postoperative recovery by supporting the reinitiation of oral intake after surgery. To date, studies have reported evidence regarding risk reduction for the following specific postoperative complications: 1) postoperative pneumonia, 2) complications during endotracheal intubation (tooth fracture and loss, etc.), 3) infection during cardiovascular surgery, 4) infection during organ transplant surgery, and 5) postoperative complications associated with oropharyngeal and esophageal surgery (respiratory complications, wound infection).

With regard to the effect of dental care on improvement of oral function, our review found evidence for the recovery of mastication due to dental prosthesis treatment after tooth loss, significant contribution of improved chewing ability to systemic problems, and possible improvements resulting from the provision of professional care in patients whose oral function has been reduced to the extent that chewing capacity is hindered.

Many reports have provided evidence that proper continuation of maintenance aimed at preventing the worsening of dental diseases such as dental caries and periodontal disease can help prevent tooth loss. In these studies, the necessary dental treatment is performed before initiating maintenance, and even during the maintenance period it is necessary to carry out early disease detection and treatment procedures. Long-term preservation of teeth can be achieved through proper dental treatment and continued maintenance. Some reports have indicated that putting a complete veneer crown on teeth that have been

subjected to root canal treatment decreases the rate of tooth loss. However, overall the abovementioned results show that dental treatment alone does not ensure a sufficient prevention of tooth loss unless maintenance is continued as well.

The degree of effectiveness of health guidance and dental health education, particularly regarding participant behavior modification and oral status improvement, was examined. In addition, paying particular attention to the relationships between risk factors which are common to dental diseases and systemic chronic diseases, a literature search was conducted to examine the possibility of dental health education contributing to the common risk factor approach. Furthermore, in the context of preventive measures in dental health education, the findings regarding the effect of dental caries prevention from the topical application of fluoride were summarized. This analysis revealed that dental health education is effective in promoting knowledge acquisition and attitude change in participants, and somewhat effective in preventing or improving dental caries, plaque deposition, and periodontal disease. However, many of the studies have verified only short-term effects (i.e., those under six months or less), so the long-term effects are still uncertain. Dental healthcare workers should keep in mind that dental health education is likely effective only for a short-term period of up to 6 months, and they should conduct dental health guidance accordingly. Based on the fact that dental caries and periodontal disease have the characteristics of lifestyle-related diseases and that health education has short-term effects, it is important to encourage patients to visit a dentist regularly, at least every six months, and at to provide them with dental health guidance during each visit. In order to efficiently carry out dental health education in the field of clinical and public health, there is a need to consider the cost-effectiveness of various types of dental health education. Among the common risk factors (nutrition, cleanliness, smoking, drinking, stress, and injury), smoking is one for which dental health instruction support is effective. In relation to dental health education and prevention, topical fluoride applications such as fluoride-containing dentifrices and fluoride mouth rinsing have been shown to be effective in preventing dental caries in the primary teeth as well as permanent teeth of young people.

In Japan, dental care has been provided mainly in outpatient settings, so the reality has been that elderly individuals age 75 years old and older often lack access to sufficient dental care. The review of studies on the effects of dental care provided to elderly individuals at home or in a facility in the form of home-visit care services revealed that

the regular provision of such care by dental professionals contributed not only to a decreased bacteria count, but also to improvements in pneumonia incidence, fever length, and cognitive function. However, underlying diseases and oral status differ among elderly individuals requiring long-term care at home or in a facility, and no systematic study regarding on the effect of home-visit dental services alone could be found.

[Conclusions]

Many of the research results showing associations between dental/oral health and systemic health provide strong, reliable evidence. This evidence comes from cohort studies, meta-analyses, and observational studies that examine the causality of the relationship by allocating the subjects and adjusting the data for confounding factors by using methods which incorporate propensity scores (propensity score analysis). With regard to the associations between dental/oral health and life expectancy as well as healthy life expectancy, as shown in this collection of reviews, evidence has already been obtained for some of the individual pathways. However, the mechanisms through which dental and oral health affects systemic health has not yet been clarified. One possible mechanism involves the infections and inflammation that arise due to oral diseases, such as periodontal disease, causing systemic health problems. Another possibility is that there is a relationship between reduced oral function and dietary behavior and/or nutritional state. While the goal of oral health management is to maintain the health of the teeth and the oral cavity, the role of dental care is to recover lost functionality as well as to prevent the progression of dental diseases. Evidence regarding the effect of dental care on improvements of oral function and systemic health should be further accumulated and clarified by conducting well-designed studies.

Medical economic analysis on the efficient use of healthcare resources is necessary in order to clearly position dental care and oral health as essential health measures aimed at extending healthy life expectancy. This collection of reviews did not address this point. In the future, the effect of dental and oral health on the extension of healthy longevity needs to be analyzed by estimating its efficiency in terms of healthcare cost reduction, while at the same time accumulating evidence of its effectiveness.

Moreover, with regard to the prevention of NCDs and disease progression, which represent central issues in the current enforcement of healthcare policy, enacting measures that target risk factors which are common to both medical and dental health is an important and efficient approach.

However, among lifestyle-related risk factors associated with NCDs, such as smoking, drinking, exercise, and eating habits, smoking is currently the only one where there is sufficient evidence regarding its association with oral health; in other words, ther is not yet enough evidence to justify actively incorporating these factors into clinical and health guidance. In addition to smoking, evidence should be further accumulated regarding the associations between oral health and lifestyle habits such as drinking, exercise, and dietary habits. Furthermore, the practice of common risk diagnosis and handling needs to be systematized across fields.

As shown in this collection of reviews, specific measures to realize healthy longevity in society include (1) extension of life expectancy and prevention of death in early life (prevention of diseases that are main causes of death), (2) prevention of conditions that necessitate long-term care, (3) prevention of a decline in daily living activities, and (4) lifelong health promotion from the viewpoint of a life course approach. The development and implementation of specific practical models, the enactment of health policy to the extent possible, and the accumulation of evidence that demonstrates causal relationships and medical economic effects are required.

1. Oral health and aging
1) Oral health in an aging society

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[Abstract]

The unavoidable reality of population aging is affecting our society on a global scale. Biological aging makes elderly people more susceptible to disease and leads to a decline in the bodily functions needed for daily living. Dental and oral health itself is essential for the lifelong maintenance of quality of life (QOL), and research has furthermore established that dental and oral health contributes to the maintenance and improvement of general health. A social system in which anyone can receive high-quality dental care and oral health services during old age needs to be established. To ensure that dental care and oral health maximally contributes to attaining healthy longevity, it is essential to accumulate clear evidence and take the specific actions needed to ensure that dental care and oral health has a secure and established position within an effective and efficient social security system and healthcare policy.

[Introduction]

The demographic shift associated with an altered disease structure and increased average life expectancy is a global phenomenon seen not only in industrialized nations but also in developing countries. Humans have always desired longer lives, and now larger populations and longevity have become a reality due to the accumulation of scientific and medical knowledge and the resulting progress in technology and treatment around the world. However, it is an unavoidable fact that with increased longevity comes a decline in the bodily functions needed for daily living, and that aging makes people more susceptible to disease. For this reason, there are challenges to be addressed in order achieve a society in which all elderly people can live with dignity and security. Such challenges include improving the long-term care system, providing social security as well as effective medicine and healthcare, securing financial resources for these services, and accumulating the research needed for extending health. The aging society of the twenty-first century is therefore now facing the dual realities of longevity on the one hand and the burdens it brings with it on the other[1,2].

Dental and oral functions such as eating and communication are essential for maintaining a person's QOL. For this reason, it is essential that we create and maintain a social system in which people can receive dental care and oral health services over their entire lifetime, irrespective of the region or country in which they live. Moreover, scientific evidence has been accumulating that shows the effectiveness of dental and oral health in preventing illnesses in other organs besides the oral cavity and in maintaining general health. It is therefore generally accepted that dental care and oral health can play a role in solving the problems that our aging society is facing and that achieving this requires maintaining an established position for dental care and oral health within each country's health policies[3,4].

In this paper we attempt to describe the current status of global population aging, not only in industrialized countries such as Japan but also in developing countries, and to postulate a conceptual pathway linking oral care to enhanced general health.

[Objective]

This paper aims to review the literature on population aging and the determinants of health and life expectancy, and to propose a conceptual framework for the role dental care and oral health should play in extending healthy life expectancy.

[Methods]

The results of previous research on human life expectancy, social security systems, dental/oral and general health investigations, and statistical data provided by public institutions were analyzed.

[Results]

1. Changes in the world population and longevity

The world population increased nearly threefold from 2.526 billion in 1950 to 7.162 billion in 2013, and is projected to reach 8.083 billion in 2025 and 9.551 billion in 2050. As shown in Figure 1, the majority of people will be
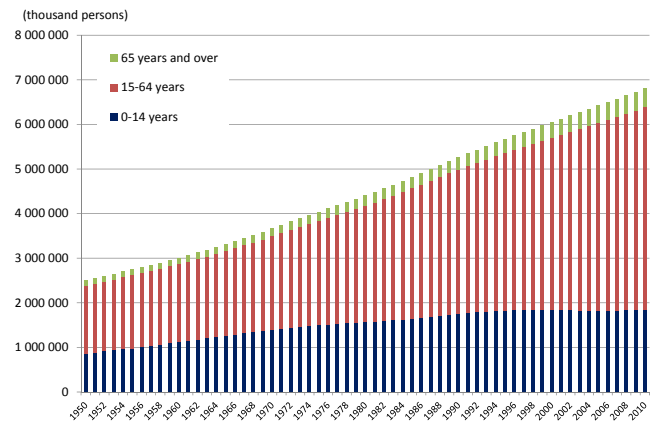
living in developing countries[5].

A look at the history of population aging reveals that average life expectancy was around 40 years up to the eighteenth century. As a result of decreases in infection-related deaths, the life expectancy rose to 50 years by the twentieth century, and then rose further to about 80 years from the middle of the twentieth century to the present day[6]. The percentage of people aged 65 years and over, as shown in Figures 2 and 3, increased in developed countries from 7.7% in 1950 to 16.1% in 2010, and also in developing countries from 3.8% to 5.8%[5]. Population aging is occurring in all regions of the world and in countries at various levels of development, and it is progressing at a faster rate in the developing countries.

2. Causes of death and determinants of life expectancy

While acute diseases such as infections and diarrheal diseases are the top causes of death in low-income countries, chronic diseases such as ischemic heart disease, stroke, and cancer are the main causes of death in high-income countries[7]. Developing countries are subject in particular to three types of diseases: chronic diseases, emerging infections, and acute infections (triple burden). As a country's economy improves, the mortality of pregnant women and newborns declines. Beyond this point, contributing factors for the further extension of life expectancy are the prevention of diseases from the early years of adulthood and lowering mortality among the elderly. For this reason, preventing the occurrence and increase of non-communicable diseases (NCDs) such as cardiovascular diseases, cancer, and diabetes mellitus is an important health policy issue in both industrialized countries and developing nations[8].
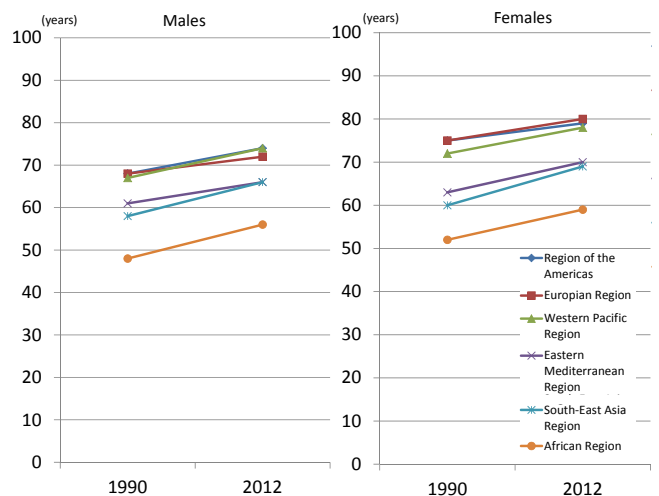
The main causes of death among the Japanese, who have the world's highest life expectancy, are heart disease, pneumonia, and cerebrovascular diseases; these account for approximately 70% of all deaths[9]. In the past 50 years, there has been a great shift in the disease structure and causes of death. Theoretically, if these diseases could be successfully prevented an extension in average life expectancy of around 3 to 4 years would be expected in the case of cancer, around 1.5 years in the case of heart disease, and around 1 year in the case of pneumonia and cerebrovascular diseases[10] (Figures 4 and 5).

Figures 6 and 7 show the number of deaths by age and the survival curve for Japanese people. The survival rate at the age of average life expectancy is approximately 60% for men and 80% for women[10]. The number of deaths peaks at age 85 in men and age 91 in women[9]. Since many Japanese live longer than the average life expectancy, the healthcare
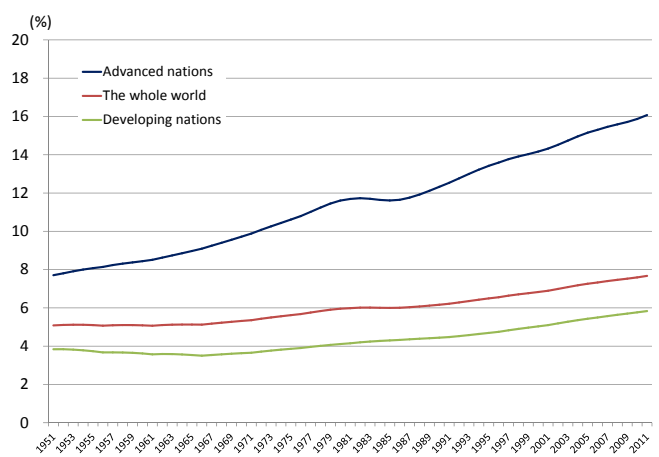

Prepared by Fukai from United Nations World Population Prospects: The 2012 Revision, 2013

Figure 1: Changes in world population and age structure

Prepared by Fukai from United Nations, World Population Prospects: The 2012 Revision, 2013

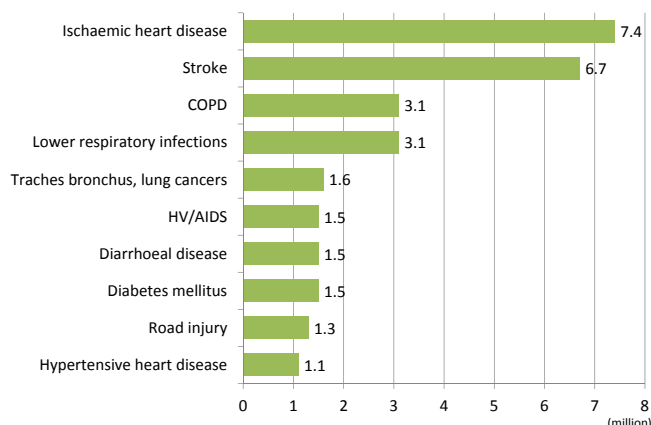Figure 2: Annual change in average life expectancy in major countries

Prepared by Fukai from United Nations, World Population Prospects; The 2012 Revision, 2013.

Figure 3: Change in the percentage of older population (65 years of age and over) in industrialized and developing countries
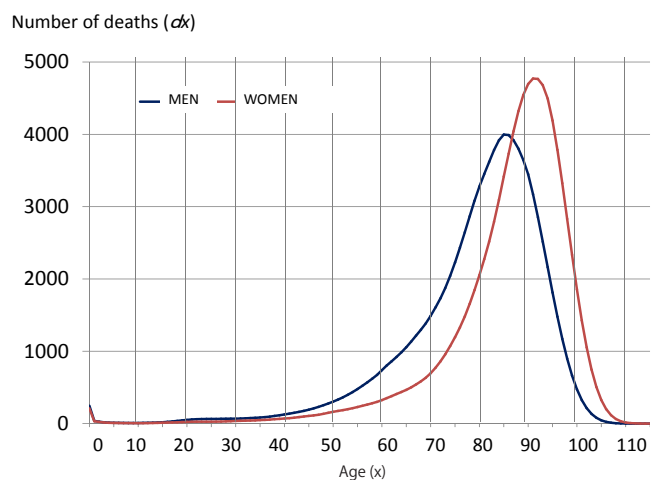
system must take this fact into consideration.

3. Aging and decline in living function

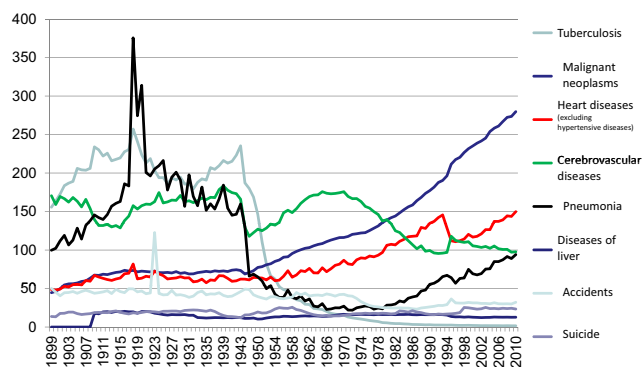Apart from diseases, other causes of death include aging

Source: WHO Fact sheet The top 10 causes of death   http://www.who.int/mediacentre/factsheets/fs310/en/

Figure 4: Top 10 causes of death in the world(2012)

Source: "Vital Statistics", Statistics and Information Department, Minister's Secretariat, MHLW(Note) The figures for 2011 are approximate.

Figure 5: Annual transition in the number of deaths among the Japanese by cause of death (per 100,000 population)

Number of deaths (dx)

Source: MHLW, 2010 Complete Life Tables

Figure 6: Number of deaths by age among the Japanese

Number of survivors (lx)

Source: MHLW, 2010 Complete Life Tables
Number of survivors (lx) : The number of survivors is calculated on the assumption that 100,000 children dieaccording to the death rate by age shown on the life table. The median life expectancy [the number of years inwhich half the children (50,000 on the complete life table) are expected to survive] is 82.60 years for men and 89.17years for women.
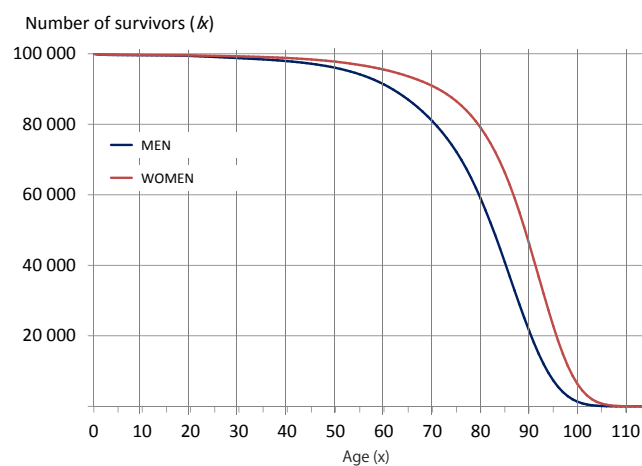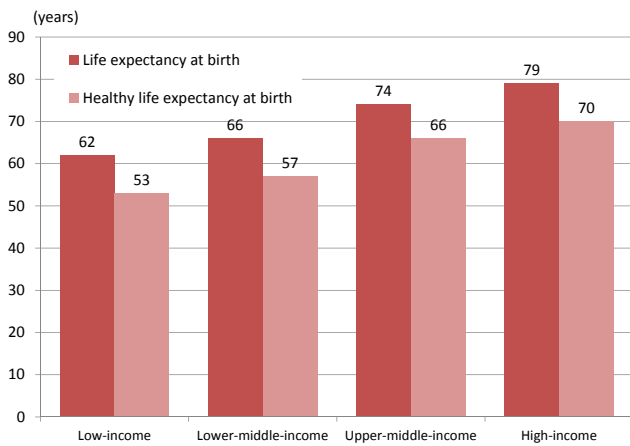
Figure 7: Survival curve by age among Japanese

and accidents. For some reason, when cells and organs (which are made up of cell tissue) can no longer function, humans become incapable of maintaining their bodily functions as an individual organism, and this results in death. In fact, looking at the causes of individual deaths reveals that death occurs when any of the organs that are vital for maintaining life, such as the heart, brain, kidney, or various arteries, can no longer function. Moreover, the temporal process leading to death varies depending on the disease that causes this decline in organ function. In terms of the length of time during which one functions autonomously in daily life, activity may be restricted over a long period of time, such as with cerebrovascular diseases, or the restrictions may extend for a relatively short period, such as with cancer[11].

Aging refers to a gradually progressive decline in physical functions that occurs as a person ages. Aging at the organ level can be attributed to damage to cells that have almost no ability to divide, such as brain and nerve cells as well as myocardial cells. In other cases, aging occurs when cells stop dividing after completing about 50 cycles of sub-division, as seen in almost all organs other than the above-mentioned ones[12]. However, all organs age as one gets older, and the aging of organs manifests itself in the form of reduced functionality. This means that muscle strength, nerve conduction velocity, lung capacity, and resistance to disease decline with age, and this decline cannot be avoided in humans. For example, when evaluating changes in grip strength that occur with age in Japanese people, a decrease of about 13kg in men and about 8kg in women has been observed between late-middle age and old age[13]. Moreover, the percentage of functionality remaining at age 80 (age 30 = 100%) in nerve conduction velocity, lung capacity and renal plasma flow (PAH), and maximal voluntary ventilation decreases to about 80%, less than 60%, and about 40%, respectively[14]. Despite such a decline in organ functions due to aging, the organs function together in a complementary manner to maintain a condition where everyday living functions can be performed without any trouble. However, a variety of different causes lead to various physical and
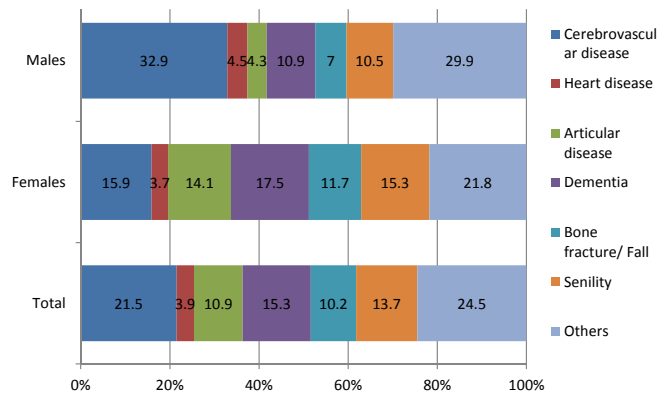
Source: WHO World Health Statistics 2014

Figure 8: Average life expectancy and healthy life expectancy by country economic status

Source: Ministry of Health, Labour and Welfare, 2010

Figure 9: Causes leading to a state requiring care (Japan)

psychological symptoms and to conditions commonly observed in the elderly, which are collectively referred to as geriatric syndrome[15].

4. Average life expectancy and healthy life expectancy

The world's average life expectancy as of 2012 is 68 years in men and 73 years in women, with a mean of 70 years for both sexes combined. In contrast to the average life expectancy of 60 years in men and 63 years in women in low-income countries, the life expectancy in high-income countries reaches 76 years and 82 years, respectively. The average life expectancy of both sexes combined is 62 years in low-income countries, 66 years in low middle income countries, 74 years in high middle income countries, and 79 years in high-income countries, indicating that life expectancy increases with greater economic development. In contrast, healthy life expectancy in those same categories of economic development is 53, 57, 66, and 70 years, respectively. Healthy life expectancy throughout the world as a whole is 62 years[16] (Figure 8). There is approximately an 8-year difference between average life expectancy and healthy life expectancy, and this does not vary with the economic status of the country.

In Japan, healthy life expectancy is defined as extending up to the point at which a person begins to experience restrictions on their daily living activities at or above Care Level 2 under the Long-term Care Insurance System (Level 2 is a state requiring partial care due to a decline in the ability to perform basic self-care tasks and other activities of daily living, or ADL). The healthy life expectancy in Japan is 70.4 years in men and 73.6 years in women, which compared with actual life expectancy is a difference of 9.1 years and 12.7 years, respectively. Of the 30.74 million people aged 65 years and over, 2.942 million are at Care Level 2 or higher, accounting for 9.6% (2012).
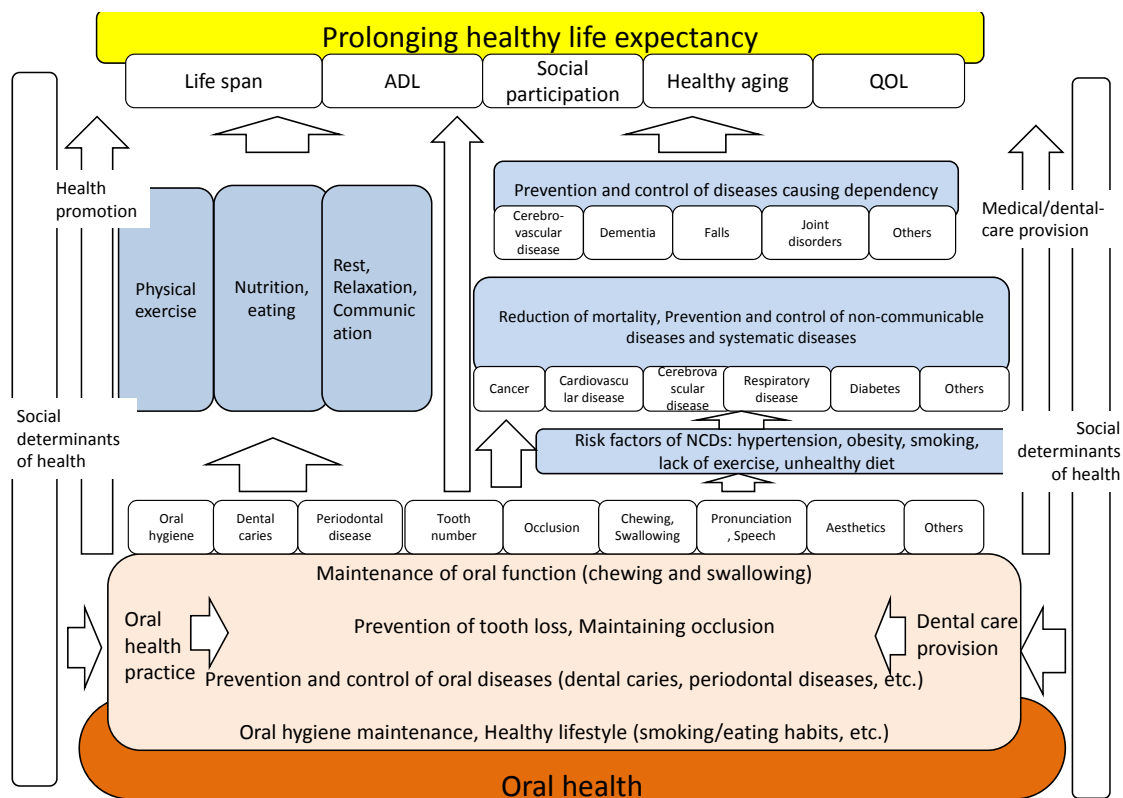
The percentage distribution of the main diseases leading to a condition requiring care, as shown in Figure 9, is 21.5% cerebrovascular diseases, 15.3% dementia, 10.9% joint disorders, and 10.2% fracture/fall[17].

5. Aging society and social security

Improvements in pension, medical insurance, and long-term care insurance programs are essential in order for the elderly to live a secure life. In Japan, which has become the world leader in terms of longevity, a universal national health insurance and pension system was started in 1961 and has been maintained up to the present time. Japan's insurance and pension systems are funded by both insurance fees and tax revenues, and also effectively redistribute income among age groups while improving the health conditions and average life expectancy of the Japanese. Nevertheless, rapid population aging and a falling birth rate pose an enormous financial burden on the country[18].

A look at the current state of population aging in Japan from a generational perspective reveals that when the "baby-boom generation" (born in 1947-1949) turned 65 years old in 2012, the number of people aged 65 years and over reached 30.74 million, topping the 30 million mark for the first time ever. As a result, Japan has become a super-aging society with the percentage of people aged 65 years and over reaching 24.1%, which breaks down to people aged 65-74 years accounting for 12.2%, and those aged 75 years and over accounting for 11.9% of the population. Around 20 years in the future (2035), when this baby-boom generation reaches the current average life expectancy, people aged 65 years and over are projected to make up 33.4% of the population[19].

Meanwhile, social security benefits in Japan reached 107.4950 trillion yen in fiscal 2011, which breaks down to 53.0623 trillion yen for pensions (49.4%), 34.0634 trillion

Fukai K. Future directions for research on the contributions of dental and oral health to a healthy aging society. Health Science and Health Care 2013; 13 (2) 39–42

Figure 10: Conceptual pathway showing the relationship between dental care/oral health and healthy life expectancy

yen for medical care (31.7%), and 7.8881 trillion yen for long-term care (7.3%). These numbers have been increasing since the start of record-keeping in 1950[20]. This is due to the rapid aging of the population accompanied by an improvement in the survival rate, giving rise to issues related to the financial foundation of this system as well as the quality of health care and long-term care.

6. Dental care/oral health and healthy life expectancy

Based on the relationship between dental/oral and general health, the following two factors are involved in the pathway by which dental care and oral health contribute to healthy longevity: (1) prevention of aging and promotion of health including improvements in systemic tolerance or resistance and (2) reduction in diseases and risk of disease. The former includes promotion of health through exercise, nutrition, and rest. The latter includes reducing the risk factors for NCDs and preventing the development and worsening of diseases that lead to death or to a condition requiring care.

Based on the results from previous research, I postulate a conceptual pathway which shows the extent to which dental and oral health as well as the resulting maintenance and recovery of oral functions would lead to the maintenance of QOL and ADL as well as the extension of life expectancy[3,4] (Figure 10). The relationship between oral and general health

and life expectancy sometimes reciprocally correlates to the function and condition of each organ, so caution is needed when showing causes and results in a simple diagrammatic form. On the other hand, when providing explanations to policymakers and laypeople, it is necessary to demonstrate a simple and easily understandable concept along with its rationale. This makes it necessary to accumulate individual evidence which supports and/or refines this pathway.

[Discussion]

Population aging occurring at the global level is an unavoidable fact. The issue is how to prolong the healthy period of human life.

The survival curve by gender and age among the Japanese is shown in the Results section of this paper. The survival rate at age 80 years is about 80% for women and about 60% for men. Assuming that 100,000 persons will eventually die in accordance with the death rate shown on the life table, then the number of deaths peaks at age 85 in men and 91 in women (Figure 6). The death rate increases linearly (log plot) with age from about 30 years until reaching old age, and then the rate decreases after reaching about 90 years. This is known as the Gompertz law (1825), which states that the probability of death exponentially increases with age, and that there is a twofold increase in the probability

of death every 8 years from age 30, and that people at 80 years of age are 30 times more likely to die than those at 40 years of age. This law is also used as a definition of aging (aging means increased susceptibility to death). Aging makes humans more susceptible to death and diseases. The world's oldest person on record was a French woman called Calmant, who died at the age of 122 years in 1997. The lifespan limit for human beings is considered to be about 120 years[21]. The survival curve becomes markedly rectangular with age[22]. This is an important point in understanding why an extension in healthy life expectancy is needed to bring the average life expectancy of humans closer to the lifespan limit. To achieve this, preventive measures against the main causes of death and health promotion aimed at the prevention of aging are required. Specifically, to further enhance the health of the population, it is necessary to improve other risk factors such as hyperglycemia, lack of exercise, drinking, excess weight and obesity, and high intake of salt in addition to smoking and high blood pressure[23]. It is also important to clarify the diseases that lead to a condition requiring care and to prevent such diseases.

In terms of social security costs, a system that will effectively and efficiently reduce preventable diseases is needed. The factors that damage health are genetic, lifestyle-related, social security and health system-related, and social determinants. Among these, the genetic factor accounts for about 25 to 30% of all factors that contribute to death[24,25]. In fact, in a well-known follow-up study on Japanese-Americans investigating the prevalence of ischemic heart disease and cerebrovascular disease, the Japanese-Americans (first-generation immigrants) were reported to have a higher risk of ischemic heart disease and a lower risk of cerebrovascular disease than Japanese people living in Japan[26]. When judging disease risks, therefore, lifestyle and social environments are more important than genetic background. From this standpoint, an approach which aims to prevent NCDs by targeting the risk factors thereof should be pursued[27].

In order to create and maintain a society in which elderly people can live with security and dignity, it is important to provide income support for the elderly and to create an environment ensuring their social activity[1]. A system in which elderly people can receive high-quality, effective, efficient healthcare sevices[28] through better collaboration between medical and dental fields is required not only in industrialized countries but also in developing countries.

[Conclusions]

In order to attain a healthy society of longevity based on the relationship between oral and general health, the currently available scientific evidence showing the contributions to general health made by dental care and oral health must be clarified. There is an urgent need to verify the effects of dental care and oral health on various factors impairing health and to prepare new policy proposals for the social security system based on the currently available evidence. In order to realize a healthy society marked by longevity, the following four goals should be our priority: 1) to increase life expectancy and prevent early death, 2) to prevent people from falling into a state of dependency, 3) to prevent the decline in living functions due to aging, and 4) to promote health from the early years of adulthood based on the life course approach.

[Conflict of interest]

There are no items applicable to "conflict of interest" in this article.

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Conclusion

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The realization of a "society of longevity" is a result of human advancement. On the other hand, the decline of vital functions and health with age is something we cannot avoid biologically. To address this seemingly paradoxical issue, we urgently need to develop a social structure and health care system that will allow elderly individuals to lead their lives with purpose and dignity. To this end, specific measures have been taken to reduce health inequalities among generations and regions, thereby extending healthy life expectancy in each and every individual.

Since the implementation of a universal health insurance system in 1961, the health status of the people of Japan has improved considerably and the country has achieved a level of longevity greater than anywhere else in the world. As the nation standing at the forefront of the society of longevity, Japan has a responsibility to report its experiences to the world, particularly concerning its healthcare policies and campaigns as well as our attempts to reform its healthcare system.

As the evidence and analyses presented in this publication confirm, basic dental and oral functionality is associated with self-expression and socialization -which are fundamental human rights- through diet and communication. In the long run, dental and oral health is also associated with vital prognosis in humans. In fact, an accumulation of evidence suggests that dental care and oral health can and do contribute to the realization of healthy longevity.

Against this backdrop, and based on the analyses in this book, I make the following recommendations regarding healthy longevity, dental care, and oral health.

1. Health and medical care systems should be developed in such a way that even in old age, anyone can receive the dental care and oral health services they need, no matter where they live.
2. Dental health care personnel should make continuous efforts to communicate the current evidence regarding dental care, oral health, and healthy longevity to citizens and health policymakers.
3. The development of health and medical technology should be promoted, in addition to training human resources that provide evidence-based health and medical services.

4. A strong body of evidence shows that the prevention of tooth loss contributes to healthy longevity. Through bidirectional efforts involving medical and community health services, greater efforts should be made to prevent dental diseases (e.g., dental caries and periodontal disease) and the tooth loss that results from these diseases.
5. Dental health care personnel and relevant organizations should work together to enact measures that target the risk factors which are common to both oral diseases and non-communicable diseases (NCDs), and they should also work to develop health systems based on a continuous life-course approach covering the period from adulthood to old age.
6. Efforts should be made, from the standpoint of dental health care provision, to accumulate evidence regarding the effects of maintaining and recovering masticatory function and occlusal support, as well as the effect of prevention and control of dental diseases on systemic health.
7. High-quality research should be conducted to accumulate evidence which further clarifies the causal relationship linking dental and oral health to healthy longevity.
8. Efforts should be made to estimate the medical economic effects of dental and oral health policy implementation as well as evidence accumulation.
9. Evidence-based health policies which reflect the association between current dental and oral health and the extension of healthy life expectancy should be implemented, and studies verifying the effectiveness of these policies should be undertaken.

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