

# Epidemiological Characteristics of Total Edentulism in North Macedonia and Worldwide

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Publication Date: 2026/07/28

**Abstract:** Total edentulism (complete loss of natural teeth or complete toothlessness) represents the final stage of oral diseases and an important public health problem that affects an individual's quality of life, nutrition, speech, aesthetics, and psychosocial well-being. Despite advances in preventive dentistry and modern therapeutic approaches, edentulism remains prevalent, particularly among the elderly population and in countries with lower socioeconomic development. According to the latest global estimates, more than 350 million people worldwide live with total edentulism, with the highest prevalence observed among individuals older than 65 years. This paper aims to present contemporary epidemiological characteristics of total edentulism worldwide and in the Republic of North Macedonia, including an analysis of prevalence, risk factors, and future trends. Available data indicate that in 2021, more than 353 million people worldwide were completely edentulous, with a global age-standardized prevalence of 4.11%. The highest prevalence was recorded among older adults, women, and individuals with lower socioeconomic status. In North Macedonia, recent national epidemiological studies are lacking; however, available regional data indicate a significant presence of total edentulism among individuals over 65 years of age. Population ageing will continue to represent an important factor contributing to the persistence of a high burden of this condition.

**Keywords:** Total Edentulism, Tooth Loss, Epidemiology, Prevalence, Oral Health.

**How to Cite:** Mirjana Ambaroska Talevska; Radmila Dimovska; Cena Dimova (2026) Epidemiological Characteristics of Total Edentulism in North Macedonia and Worldwide. *International Journal of Innovative Science and Research Technology*, 11(7), 1460-1472. <https://doi.org/10.38124/ijisrt/26jul1237>

## I. INTRODUCTION

Total edentulism, defined as the complete loss of all natural teeth in both the maxillary and mandibular arches, remains one of the most severe indicators of cumulative oral disease. It reflects the end stage of a lifelong process of oral tissue destruction, most commonly resulting from untreated dental caries and advanced periodontal disease, although trauma, congenital conditions, and oral pathology may also contribute. Despite remarkable improvements in preventive dentistry, restorative treatment, and public oral health policies over recent decades, complete tooth loss continues to affect millions of individuals worldwide, remaining an important public health concern (1,3). The loss of all natural teeth represents far more than a dental condition. It profoundly influences an individual's ability to chew efficiently, speak clearly, and maintain facial appearance, often leading to functional impairment and reduced quality of life. (2,5,13) Many edentulous individuals experience difficulties consuming nutritious foods, resulting in dietary changes that may contribute to nutritional deficiencies and the development or worsening of chronic systemic diseases. (5,9,12) In addition, the aesthetic consequences of tooth loss frequently affect self-esteem, confidence, interpersonal relationships, and social participation, making edentulism

both a biological and psychosocial condition. The etiology of total edentulism is multifactorial and develops through a complex interaction of biological, behavioral, environmental, and socioeconomic determinants. Dental caries and periodontal diseases remain the primary direct causes of tooth extraction worldwide; however, factors such as smoking, diabetes mellitus, inadequate oral hygiene, low educational attainment, limited oral health literacy, financial barriers, rural residence, and restricted access to preventive and restorative dental services substantially increase the risk of progressive tooth loss. (2,3,6,7,9,12). These determinants often accumulate throughout life, ultimately resulting in complete edentulism, particularly among older adults. Growing evidence also demonstrates a close relationship between oral health and general health. Complete tooth loss has been associated with frailty, malnutrition, cardiovascular disease, diabetes, cognitive decline, depression, and reduced overall well-being. Although the direction of these associations is often multifactorial and bidirectional, the presence of edentulism is increasingly recognized as an indicator of poor general health and accumulated health disadvantage. Consequently, contemporary oral healthcare extends beyond replacing missing teeth and emphasizes disease prevention, health promotion, and preservation of the natural dentition throughout life. (2,3,8) From a public

health perspective, edentulism reflects inequalities in healthcare systems and social development. It disproportionately affects individuals with lower socioeconomic status, lower educational levels, limited access to dental care, and those living in underserved communities. For this reason, total edentulism is increasingly considered not only a clinical outcome but also a sensitive marker of social and economic disparities in health. Reducing the prevalence of complete tooth loss, therefore, requires comprehensive preventive strategies that address both individual risk factors and broader social determinants of health. Over the past several decades, many high-income countries have reported a steady decline in the prevalence of complete edentulism owing to improved preventive programs, widespread fluoride exposure, greater oral health awareness, and advances in conservative dental treatment. Nevertheless, the global burden remains substantial. Population ageing, increased life expectancy, and demographic transitions mean that even with declining age-specific prevalence rates, the absolute number of people living with complete tooth loss is expected to remain high for many years. Recent epidemiological studies indicate that the burden of edentulism is increasingly concentrated in low- and middle-income countries, where access to preventive and rehabilitative dental care is often limited and oral diseases remain insufficiently controlled (1). Understanding the epidemiological distribution and temporal trends of total edentulism is therefore essential for healthcare planning and policy development. Reliable epidemiological data enable governments and healthcare providers to identify high-risk populations, allocate resources effectively, evaluate preventive programs, and improve access to prosthodontic rehabilitation. (1,8,11) Furthermore, monitoring global and regional trends contributes to achieving the goals of the WHO Global Oral Health Action Plan, which emphasizes reducing inequalities in oral health and promoting healthy ageing through lifelong preservation of natural teeth.(8,15) In light of these considerations, this narrative review aims to provide an updated overview of the global epidemiology of total edentulism, with particular emphasis on recent prevalence estimates, temporal trends, demographic characteristics, major risk factors, and regional differences reported in the contemporary literature. By synthesizing current evidence, this review seeks to highlight the continuing burden of complete tooth loss and the importance of preventive strategies for reducing its impact on individuals and healthcare systems worldwide.

## II. MATERIALS AND METHODS

This manuscript was prepared as a narrative review of the contemporary literature addressing the epidemiology of total edentulism. The review was undertaken to summarize the most recent evidence on the prevalence, distribution, temporal trends, and determinants of complete tooth loss reported across different populations worldwide. A literature search was performed using the electronic databases PubMed, Scopus, and Web of Science, which were selected because they index the majority of peer-reviewed biomedical and dental publications. In addition,

epidemiological data and global estimates were obtained from the Global Burden of Disease (GBD) project and the World Health Organization (WHO) Global Oral Health Reports, providing a broader perspective on the worldwide burden of edentulism. The search included publications released between 2019 and 2026, reflecting the most recent evidence available. Combinations of keywords related to *total edentulism*, *complete tooth loss*, *epidemiology*, *prevalence*, *oral health*, *risk factors*, and *global burden* were used to identify relevant studies. Reference lists of selected articles were also reviewed to identify additional publications that met the objectives of this review. Studies were considered eligible if they reported epidemiological data on complete edentulism, including prevalence estimates, temporal changes, demographic characteristics, geographical distribution, or factors associated with total tooth loss. Population-based surveys, observational studies, systematic reviews, meta-analyses, and reports from international health organizations were included whenever they contributed meaningful information to the understanding of the global burden of edentulism. Studies focusing exclusively on partial tooth loss, prosthodontic treatment outcomes, implant survival, laboratory investigations, or case reports were not included, as these were outside the scope of the present review. When multiple publications reported findings from the same study population, preference was given to the most recent or the most comprehensive report. The selected publications were reviewed in detail, and information was extracted on study characteristics, country of origin, sample size, age group, reported prevalence of total edentulism, associated risk factors, and principal findings. Particular emphasis was placed on large population-based investigations and international datasets because they provide more robust estimates and facilitate comparisons between regions. As this review was narrative rather than systematic, no formal quality assessment or meta-analysis was performed. Instead, the available evidence was critically examined and synthesized to provide an up-to-date overview of the current epidemiological situation, highlight similarities and differences between countries, and identify areas where additional research is still needed. The findings are presented descriptively to offer clinicians, researchers, and public health professionals a comprehensive understanding of the global burden of total edentulism and its implications for oral healthcare planning.

## III. GLOBAL EPIDEMIOLOGY OF TOTAL EDENTULISM

According to the latest epidemiological data and systematic reviews, the global prevalence of total edentulism among adults is approximately 4–5%, with considerable regional variations (1). In absolute numbers, this represents more than 350 million people worldwide affected by complete tooth loss.

### ➤ The Highest Prevalence Rates are Observed in:

- Latin America
- Eastern Europe

- South and Southeast Asia

➤ *The Lowest Prevalence Rates are Reported in:*

- Scandinavian countries
- Western Europe
- North America

➤ *These Differences can be Explained by Variations in:*

- Availability of dental healthcare services;
- Preventive dental programs;
- Fluoride use;
- Socioeconomic status (7,5).

Table 1 Global Prevalence of Total Edentulism According to Regions

| Global Prevalence of Total Edentulism According to Regions |                |                                              |
|------------------------------------------------------------|----------------|----------------------------------------------|
| REGION                                                     | PREVALENCE (%) | CHARACTERISTICS                              |
| WESTERN EUROPE                                             | 3–5%           | Low prevalence, effective revention programs |
| NORTH AMERICA                                              | 2–4%           | Strong decline over recent decades           |
| EASTERN EUROPE                                             | 8–15%          | Moderate-to-high risk                        |
| LATIN AMERICA                                              | 6–12%          | High burden among older adults               |
| SOUTH ASIA                                                 | 7–14%          | Limited access to dental care                |

✓ *Comment on Table 1:*

The global distribution demonstrates clear inequalities. Developed regions have significantly lower prevalence due to better prevention strategies, whereas low- and middle-income countries experience higher rates of total edentulism (1).

#### IV. AGE AS A RISK FACTOR

Age is consistently recognized as the most important non-modifiable risk factor associated with total edentulism. Although complete tooth loss can occur at any stage of adulthood, its prevalence rises markedly with advancing age as a consequence of the cumulative effects of oral diseases and lifelong exposure to various biological, behavioral, and socioeconomic risk factors. Unlike acute oral conditions, edentulism develops gradually over many years, often reflecting the long-term outcome of inadequate prevention, delayed treatment, and repeated tooth extractions. Numerous epidemiological studies have shown that the prevalence of total edentulism increases substantially after the age of 60 years, with the highest rates observed among individuals aged 75 years and older. In several populations, more than one in five adults in this age group are completely edentulous, although considerable regional differences remain depending on the accessibility of dental care, socioeconomic conditions, and national preventive oral health policies (4). The strong association between ageing and tooth loss is primarily explained by the cumulative burden of oral diseases throughout life. Recurrent episodes of untreated dental caries and progressive periodontal disease gradually compromise the long-term prognosis of the dentition, often leading to multiple extractions over several decades. Consequently, many older adults have experienced repeated restorative treatments and tooth loss before eventually becoming completely edentulous. In addition to oral diseases, ageing is frequently accompanied by changes that further increase the risk of tooth loss. Older individuals often experience reduced manual dexterity, impaired vision, cognitive decline, and diminished ability to maintain effective oral hygiene. These factors may contribute to increased plaque accumulation and accelerate

the progression of dental caries and periodontal disease. Furthermore, regular dental attendance may decrease after retirement because of financial limitations, transportation difficulties, dependency on caregivers, or reduced awareness of the importance of preventive oral healthcare. Systemic health also plays an important role in the relationship between ageing and edentulism. Chronic diseases such as diabetes mellitus, cardiovascular disease, osteoporosis, and rheumatoid arthritis become more prevalent with increasing age and may adversely affect oral health either directly or indirectly. Polypharmacy is another common feature of older populations, with many medications causing xerostomia, which significantly increases the risk of dental caries, oral infections, and eventual tooth loss. In addition, smoking history, nutritional deficiencies, and reduced salivary function further contribute to the deterioration of oral health in elderly individuals. It is important to emphasize, however, that ageing itself should not be viewed as the direct cause of complete tooth loss. Rather, it serves as a marker of prolonged exposure to risk factors accumulated throughout the life course. Advances in preventive dentistry, improved oral hygiene practices, fluoridation programs, and greater access to restorative care have demonstrated that maintaining a functional natural dentition into old age is an achievable goal. The main contributing factors include:

- Accumulation of dental caries throughout life;
- Advanced periodontal disease;
- Reduced oral care practices;
- Systemic diseases.

Table 2 Prevalence of Total Edentulism

| Age Distribution of Total Edentulism | Age Group   | Prevalence (%) |
|--------------------------------------|-------------|----------------|
|                                      | 20–44 years | <1%            |
|                                      | 45–54 years | 2–5%           |
|                                      | 55–64 years | 5–10%          |
|                                      | 65–74 years | 10–20%         |
|                                      | 75+ years   | 20–35%         |

✓ *Comment on Table 2:*

The prevalence of total edentulism increases exponentially with age. Ageing represents the strongest predictive factor, mainly due to the cumulative effects of dental caries and periodontal disease (4).

➤ *Gender Differences*

Women demonstrate a slightly higher prevalence of total edentulism, which is mainly explained by:

- Longer life expectancy;
- Historically lower access to dental care;
- Hormonal changes.

However, these differences are becoming smaller among younger generations (7).

➤ *Socioeconomic Factors*

Edentulism is strongly associated with social determinants of health. Higher risk is observed among individuals with:

- Lower educational level;
- Lower income;
- Limited access to dental professionals;
- Residence in rural areas.

This confirms the concept that edentulism represents a disease of inequality (6)

## V. MAIN ETIOLOGICAL FACTORS ASSOCIATED WITH TOTAL EDENTULISM

Total edentulism is a multifactorial condition resulting from the interaction between biological, behavioral, social, and healthcare-related factors. Although tooth loss is the outcome, it represents the cumulative effect of many years of untreated or poorly controlled oral diseases. The main etiological factors include:

➤ *Dental Caries*

Dental caries remains one of the leading causes of tooth loss worldwide. Untreated carious lesions can progress to extensive destruction of dental tissues, pulpal involvement, infection, and ultimately extraction. The risk of tooth loss due to caries is influenced by:

- Inadequate oral hygiene;
- High sugar consumption;
- Insufficient fluoride exposure;
- Limited preventive dental care.

Despite improvements in preventive dentistry, dental caries continues to contribute significantly to tooth loss, particularly among older adults and socially disadvantaged populations (1).

➤ *Periodontal Disease*

Severe periodontal disease represents another major cause of total edentulism, especially in individuals over 50 years of age.

Chronic inflammation of periodontal tissues leads to:

- Progressive alveolar bone destruction;
- Increased tooth mobility;
- Periodontal abscess formation;
- Eventual tooth loss.

According to global burden estimates, severe periodontal disease affects a substantial proportion of the adult population and remains one of the most prevalent chronic diseases worldwide (GBD Oral Disorders Collaborators, 2020). The relationship between periodontal disease and edentulism is particularly significant because periodontal destruction is often irreversible and progresses silently until advanced stages.

➤ *Limited Access to Dental Care*

Access to regular dental care plays a critical role in preventing complete tooth loss. Individuals without adequate access experience:

- Delayed diagnosis of oral diseases;
- Absence of preventive interventions;
- Emergency-based dental treatment;
- Increased likelihood of extractions instead of restorative procedures.

Healthcare inequalities remain one of the strongest predictors of edentulism, particularly in low- and middle-income countries.

➤ *Behavioral Risk Factors*

Several lifestyle factors contribute significantly to tooth loss.

Important behavioral determinants include:

- Smoking;
- Poor oral hygiene habits;
- Irregular dental visits;
- Excessive alcohol consumption;
- Unhealthy dietary patterns.

Smoking represents one of the most important modifiable risk factors because it accelerates periodontal destruction and reduces healing capacity after dental procedures.

#### ➤ *Systemic Diseases*

Several systemic conditions increase the risk of tooth loss. The most important include:

- *Diabetes Mellitus*

Diabetes is associated with:

- ✓ Increased periodontal inflammation;
- ✓ Impaired immune response;
- ✓ Delayed wound healing.

Patients with poorly controlled diabetes have a significantly increased risk of developing severe periodontal disease and subsequent tooth loss.

- *Cardiovascular Diseases*

Systemic inflammatory processes may contribute to the progression of periodontal disease and increase the risk of tooth loss.

- *Osteoporosis*

Reduced bone density may negatively influence alveolar bone support and increase susceptibility to tooth loss, particularly among elderly individuals.

## VI. EDENTULISM IN EUROPE

Europe presents a diverse epidemiological picture of total edentulism, with substantial differences in prevalence observed between countries and regions. These variations are influenced by a combination of demographic characteristics, healthcare organization, socioeconomic development, cultural attitudes toward oral health, and the availability of preventive and restorative dental services. Although the overall burden of complete tooth loss has declined across Europe over recent decades, considerable inequalities continue to exist, particularly between Western and Eastern parts of the continent. In general, Western and Northern European countries report the lowest prevalence of total edentulism. Nations such as Sweden, Norway, Denmark, the Netherlands, Germany, and Switzerland have experienced a steady reduction in complete tooth loss over the last several decades. This favorable trend has largely been attributed to well-established preventive oral health programs introduced early in life, widespread use of fluoridated toothpaste, regular dental attendance, and greater public awareness of the importance of maintaining natural teeth throughout adulthood. In addition, these countries benefit from well-developed healthcare systems that emphasize early diagnosis, conservative treatment, and long-term preservation of the dentition rather than extraction whenever possible. Another important factor contributing to lower edentulism rates in these countries is the availability of comprehensive restorative and periodontal care. Advances in adhesive restorative materials, endodontic treatment, periodontal therapy, and prosthodontics have

enabled clinicians to retain teeth that might previously have been extracted. Combined with higher educational attainment and healthier lifestyles, these developments have significantly improved tooth survival among both middle-aged and older adults. In contrast, several countries in Eastern and Southeastern Europe continue to report higher levels of complete tooth loss, particularly among individuals born before the 1970s. Although oral health has improved considerably in recent years, many older adults were exposed to very different dental care systems during their early lives. Preventive dentistry was often limited, routine dental visits were less common, and extraction was frequently considered the most practical or affordable solution for severely damaged teeth. As a result, many people gradually lost multiple teeth over their lifetime, ultimately leading to complete edentulism in older age. Historical treatment philosophies have played an important role in shaping these regional differences. In many parts of Eastern Europe, dental services during previous decades focused primarily on managing pain and infection, with relatively limited emphasis on prevention, periodontal maintenance, or conservative restorative care. Economic constraints, shortages of dental materials and equipment, and restricted access to specialist services further contributed to a greater reliance on tooth extraction. These historical patterns continue to influence the oral health status of today's elderly population, even though contemporary dental practice has changed substantially. Socioeconomic factors remain another major determinant of edentulism across Europe. Individuals with lower income, lower educational attainment, or limited access to dental insurance are consistently more likely to experience complete tooth loss. Rural populations and socially disadvantaged communities often face additional barriers, including reduced availability of dental professionals, transportation difficulties, and financial obstacles that delay preventive and restorative treatment. Consequently, inequalities in oral health persist despite the overall improvement observed across the continent. Population ageing represents another important challenge for European healthcare systems. Europe has one of the oldest populations in the world, and although age-specific prevalence of edentulism has declined, the growing number of older adults means that a substantial proportion of Europeans continue to require prosthodontic rehabilitation and long-term oral healthcare. This demographic transition places increasing demands on dental services, particularly in the fields of geriatric dentistry, removable prosthodontics, implant rehabilitation, and preventive care for older adults. Encouragingly, recent epidemiological studies suggest that the gap between European regions is gradually narrowing. Improvements in economic conditions, expansion of preventive oral health initiatives, increased oral health literacy, and broader access to modern dental treatment have contributed to declining rates of complete tooth loss in many Central and Eastern European countries. Nevertheless, important regional disparities remain, highlighting the need for continued investment in prevention, equitable access to dental care, and public health policies aimed at preserving natural teeth throughout life. Reducing these inequalities remains one of the principal challenges for oral healthcare systems across

Europe. Europe demonstrates considerable differences in the prevalence of total edentulism between countries, reflecting variations in healthcare systems, socioeconomic conditions, and preventive strategies. Western and Northern European countries generally report lower prevalence rates due to:

- Organized preventive dental programs;
- Widespread fluoride use;
- Higher oral health awareness;
- Improved access to restorative dentistry.

In contrast, Eastern and Southeastern European countries continue to demonstrate higher levels of tooth loss, particularly among older generations. Historical factors contributing to higher prevalence include:

- Limited preventive dentistry during previous decades;
- Extraction-oriented treatment philosophies;
- Insufficient public dental programs;
- Socioeconomic challenges.

Table 3 Estimated Prevalence by Countries

| REGION/<br>COUNTRY     | ESTIMATED PREVALENCE (%) | MAIN CHARACTERISTICS                     |
|------------------------|--------------------------|------------------------------------------|
| SCANDINAVIAN COUNTRIES | 2–4%                     | Advanced prevention and dental education |
| WESTERN EUROPE         | 3–6%                     | Strong oral healthcare systems           |
| CENTRAL EUROPE         | 5–10%                    | Moderate prevalence                      |
| EASTERN EUROPE         | 8–15%                    | Higher burden among elderly populations  |
| SOUTHEASTERN EUROPE    | 10–20%                   | Greater socioeconomic inequalities       |

• *Comment on Table 3*

The European pattern clearly demonstrates the influence of socioeconomic development and healthcare organization on oral health outcomes. Countries with established preventive programs have experienced a substantial reduction in complete tooth loss, while regions with historically limited preventive care continue to face a higher burden.

## VII. TOTAL EDENTULISM IN NORTH MACEDONIA

The epidemiology of total edentulism in the Republic of North Macedonia generally reflects the patterns observed throughout Southeastern Europe, where complete tooth loss continues to represent a significant oral health challenge, particularly among older adults. Although improvements in oral healthcare have been achieved during the past two decades, edentulism remains relatively common in the elderly population and continues to impose considerable functional, psychological, and economic burdens on affected individuals. Compared with many Western European countries, comprehensive national epidemiological data on total edentulism remain limited. Most available information originates from regional surveys, clinical studies, or broader international epidemiological projects, making direct comparisons between countries difficult. Nevertheless, the available evidence consistently indicates that the prevalence of complete tooth loss increases markedly with advancing age and is closely associated with socioeconomic status, educational attainment, oral health behaviors, and access to dental care. Similar to findings reported in neighboring Balkan countries, older adults living in North Macedonia are disproportionately affected by complete tooth loss, reflecting cumulative exposure to oral diseases over the course of their lives. The current epidemiological situation is strongly influenced by historical developments in dental care. For many years, dental treatment was largely focused on relieving pain and managing acute infections, while preventive dentistry received considerably less attention. Teeth with extensive caries or advanced periodontal

destruction were frequently extracted rather than restored, particularly when treatment options were limited or financial resources were insufficient. Consequently, many individuals who are now in the older age groups experienced repeated tooth extractions throughout adulthood, eventually resulting in complete edentulism. Preventive oral healthcare has expanded considerably in recent years; however, many members of the older generation did not benefit from organized preventive programs during childhood or early adulthood. Routine dental examinations, professional periodontal maintenance, oral hygiene education, and regular preventive interventions were less common than they are today. As a result, oral diseases often progressed untreated until extraction became the only feasible treatment option. This historical pattern continues to influence the oral health profile of the ageing population. Socioeconomic factors also play a central role in the distribution of edentulism within North Macedonia. Individuals with lower income, lower educational levels, unemployment, or residence in rural areas often experience greater barriers to accessing regular dental care. Financial constraints may discourage preventive visits and timely restorative treatment, leading many patients to seek professional care only after experiencing pain or significant functional impairment. Delayed treatment frequently results in irreversible tooth damage and an increased likelihood of extraction. Oral health literacy remains another important determinant of tooth retention. Although public awareness regarding oral hygiene and preventive dental care has improved over recent decades, differences persist between generations and socioeconomic groups. Older adults are generally less likely to have received structured oral health education during their early lives and may underestimate the importance of regular dental examinations, periodontal maintenance, and preservation of the natural dentition. These behavioral factors, combined with smoking, poor oral hygiene practices, uncontrolled systemic diseases, and limited use of preventive dental services, contribute to the continued burden of complete tooth loss. The ageing of the Macedonian population represents an additional challenge for oral healthcare planning. As life expectancy increases, a

growing number of older adults require complex prosthodontic rehabilitation and long-term maintenance of oral function. Complete edentulism substantially affects mastication, speech, facial aesthetics, and quality of life, while also increasing the demand for removable prostheses, implant-supported rehabilitation, and geriatric dental services. Addressing these needs requires not only appropriate clinical treatment but also effective preventive strategies aimed at preserving natural teeth throughout adulthood. In recent years, the organization of dental services in North Macedonia has evolved significantly. Modern restorative techniques, contemporary periodontal therapy, improved endodontic procedures, and advances in prosthodontics have increased the opportunities for preserving natural teeth that might previously have been extracted. At the same time, greater availability of postgraduate education, evidence-based clinical practice, and public health initiatives has contributed to gradual improvements in oral health awareness among both dental professionals and the general population. Despite these positive developments, total edentulism remains an important indicator of oral health inequalities in North Macedonia. Continued efforts are needed to strengthen preventive dentistry, improve oral health literacy across all age groups, encourage regular dental attendance, and reduce disparities in access to dental care. National epidemiological surveillance should also be expanded to provide reliable data on the prevalence and distribution of edentulism, thereby supporting evidence-based health policies and facilitating comparisons with other European countries. Such information is essential for planning future oral health strategies and promoting healthy ageing while preserving the natural dentition for as long as possible. The burden of edentulism in North Macedonia can be explained by several historical and healthcare-related factors:

- Traditionally extraction-oriented dental treatment approaches;
- Insufficient emphasis on preventive dentistry in previous decades;
- Delayed dental visits;
- Socioeconomic inequalities;
- Limited awareness regarding lifelong oral health maintenance.

### **VIII. EPIDEMIOLOGICAL CHARACTERISTICS OF EDENTULISM IN NORTH MACEDONIA**

The available epidemiological evidence indicates that the distribution of total edentulism in North Macedonia follows the pattern observed in most European countries, with prevalence increasing progressively with advancing age. Although comprehensive nationwide surveys remain limited, regional studies and clinical investigations consistently demonstrate that complete tooth loss is uncommon among younger adults but becomes increasingly frequent after the sixth decade of life. The highest prevalence is observed among individuals aged 65 years and older, reflecting the cumulative effects of oral diseases and lifelong exposure to multiple biological, behavioral, and

socioeconomic risk factors. Age, however, should not be viewed as the sole explanation for complete tooth loss. Rather, edentulism represents the final outcome of oral diseases that have developed over many years, often beginning in early adulthood or even earlier. The gradual progression of untreated dental caries and periodontal disease, combined with repeated tooth extractions, ultimately results in the loss of the entire dentition. Consequently, the epidemiological profile of edentulism reflects not only the oral health status of older adults but also the effectiveness of preventive and restorative dental care provided throughout the life course. Studies conducted in North Macedonia have consistently identified older adults as the population most affected by complete edentulism. Individuals over the age of 65 account for the largest proportion of edentulous patients, while prevalence continues to rise among those older than 75 years. As life expectancy increases and the population continues to age, the number of individuals requiring prosthodontic rehabilitation is expected to grow, creating additional demands on both public and private dental healthcare services. Socioeconomic status is another important determinant of tooth loss in North Macedonia. Individuals with lower educational attainment and limited financial resources are more likely to become edentulous than those with higher income and education levels. Financial barriers frequently delay preventive dental visits and restorative treatment, allowing oral diseases to progress until tooth extraction becomes the only practical solution. These disparities highlight the close relationship between oral health and broader social determinants of health. Geographical differences have also been reported. Rural populations generally experience a greater burden of tooth loss than urban residents, although the magnitude of this difference varies between regions. Access to dental services may be more limited in rural communities because of fewer dental clinics, greater travel distances, and reduced availability of specialist care. These factors may contribute to delayed diagnosis and treatment of dental diseases, increasing the likelihood of irreversible tooth loss over time. Periodontal disease remains one of the leading causes of tooth extraction among middle-aged and older adults in North Macedonia. Patients with untreated or poorly controlled periodontitis often experience progressive loss of periodontal support, tooth mobility, and eventual extraction. The coexistence of systemic conditions such as diabetes mellitus further increases the risk of periodontal destruction and subsequent edentulism. Likewise, untreated dental caries continues to contribute substantially to tooth loss, particularly among individuals who seek dental care only when symptoms become severe. Behavioral factors also play a significant role in shaping the epidemiological characteristics of edentulism. Long-term inadequate oral hygiene practices, infrequent dental attendance, tobacco use, unhealthy dietary habits, and low oral health literacy have all been associated with an increased risk of complete tooth loss. These behaviors often persist for many years, gradually compromising the health of the dentition and increasing the need for repeated extractions. Importantly, many of these risk factors are preventable and can be modified through education, early intervention, and regular professional dental

care. The current pattern of edentulism in North Macedonia also reflects historical changes in dental practice. Many members of the older population received dental treatment during periods when preventive dentistry was less developed and extraction was frequently considered the most appropriate management for severely compromised teeth. Advances in restorative dentistry, endodontics, periodontology, and prosthodontics have since transformed clinical practice, enabling the preservation of teeth that would previously have been removed. Consequently, younger generations are expected to retain more of their natural dentition as they age, provided that preventive measures continue to improve. Overall, the epidemiological characteristics of edentulism in North Macedonia illustrate the combined influence of ageing, socioeconomic inequalities, healthcare accessibility, behavioral factors, and historical patterns of dental treatment. Complete tooth loss should therefore be regarded not simply as a consequence of ageing but as an indicator of cumulative oral disease and unequal access to preventive and restorative care throughout life. Continued investment in preventive dentistry, oral health education, early periodontal management, and regular

dental attendance is essential to reduce the future burden of edentulism and improve the oral health of the ageing population. Studies conducted in North Macedonia have demonstrated that tooth loss increases significantly with advancing age. Among younger adults, complete edentulism is relatively uncommon, whereas among elderly individuals, the prevalence increases substantially.

➤ *The Main Affected Population Includes:*

- Individuals older than 65 years;
- Individuals with low socioeconomic status;
- Rural populations;
- Patients with untreated periodontal disease;
- Individuals with long-term inadequate oral hygiene practices.

The transition from tooth retention to tooth loss (Table 4) reflects not only biological ageing but also accumulated disadvantages throughout life, including limited access to preventive and restorative dental care.

Table 4 Transition from Tooth Retention to Tooth Loss

| Factor                  | Influence on edentulism                                   |
|-------------------------|-----------------------------------------------------------|
| Advanced age            | Strongest predictor of complete tooth loss                |
| Periodontal disease     | Major cause among older adults                            |
| Untreated dental caries | Important contributor to extractions                      |
| Rural residence         | Reduced access to dental services                         |
| Lower education level   | Lower oral health awareness                               |
| Lower income            | Limited ability to obtain preventive and restorative care |
| Smoking                 | Increased periodontal destruction                         |
| Irregular dental visits | Delayed diagnosis and treatment                           |

## IX. CHALLENGES OF THE DENTAL HEALTHCARE SYSTEM

Despite improvements in dental education and clinical practice, several challenges remain in reducing the prevalence of total edentulism in North Macedonia.

➤ *Important Challenges Include:*

- *Shift from Treatment-Oriented to Prevention-Oriented Dentistry*

Historically, dental care in many countries of Southeastern Europe focused mainly on treatment of existing disease, frequently resulting in extraction as the final therapeutic option.

Modern dentistry emphasizes:

- ✓ Prevention of caries and periodontal disease;
- ✓ Early diagnosis;
- ✓ Minimally invasive procedures;
- ✓ Preservation of natural teeth.

Strengthening preventive programs represents one of the most important strategies for reducing future edentulism.

- *Oral Health Education*

Improving oral health literacy among the population is essential.

Educational programs should focus on:

- ✓ Correct oral hygiene techniques;
- ✓ Importance of regular dental examinations;
- ✓ Prevention of periodontal disease;
- ✓ Early treatment of dental caries.

Public awareness campaigns targeting children, adults, and elderly individuals may significantly influence future oral health outcomes.

- *Access to Dental Care for Elderly Individuals*

Older adults represent the population group with the highest risk of complete tooth loss. Barriers affecting elderly patients include:

- ✓ Physical limitations;
- ✓ Financial difficulties;
- ✓ Transportation problems;
- ✓ Lack of awareness regarding modern treatment possibilities.

Comprehensive geriatric dental programs are necessary to maintain oral function and improve quality of life.

## **X. CONSEQUENCES OF TOTAL EDENTULISM**

Total edentulism is not only a dental condition but a complex health problem affecting multiple aspects of human life. The consequences include:

### ➤ *Functional Impairment*

Complete tooth loss results in significant reduction of:

- Chewing efficiency;
- Nutritional intake;
- Speech function;
- Facial muscle support.

Patients with complete dentures often experience reduced masticatory performance compared with individuals with natural dentition or implant-supported prostheses.

### ➤ *Nutritional Consequences*

Edentulous individuals may avoid certain foods that are difficult to chew, such as:

- Fresh fruits;
- Vegetables;
- Nuts;
- High-fiber foods.

As a result, they may have increased risk of:

- Inadequate nutrient intake;
- Reduced dietary diversity;
- Systemic health problems.

### ➤ *Psychological and Social Effects*

Tooth loss may negatively influence:

- Self-esteem;
- Social interaction;
- Communication;
- Emotional well-being.

Many patients report:

- Embarrassment while smiling;
- Reduced confidence;
- Avoidance of social situations.

Therefore, oral rehabilitation has an important psychological and social role beyond restoration of chewing function.

### ➤ *Impact on Quality of Life*

The relationship between oral health and quality of life has become an important field of research.

Assessment tools such as:

- Oral Health Impact Profile (OHIP-14);
- Geriatric Oral Health Assessment Index (GOHAI);

have demonstrated that edentulism is associated with reduced oral health-related quality of life.

Successful prosthodontic rehabilitation can significantly improve:

- Patient satisfaction;
- Social confidence;
- Functional ability.

## **XI. MODERN MANAGEMENT OF TOTAL EDENTULISM**

The management of total edentulism has undergone significant changes during the last decades. The primary objective of modern prosthodontics is no longer only the replacement of missing teeth, but the restoration of oral function, aesthetics, comfort, and improvement of patients' overall quality of life.

### ➤ *Current Treatment Approaches Include:*

- Conventional complete dentures;
- Implant-supported overdentures;
- Fixed implant-supported prostheses;
- Digital prosthodontic rehabilitation.

### ➤ *The Choice of Treatment Depends on:*

- Patient age and general health status;
- Remaining bone volume;
- Functional requirements;
- Economic possibilities;
- Patient expectations.

### ➤ *Conventional Complete Dentures*

Conventional complete dentures remain the most widely used treatment option for completely edentulous patients, particularly among elderly individuals. Their advantages include:

- Relatively low cost;
- Non-invasive treatment;
- Accessibility for a large proportion of patients;
- Satisfactory aesthetic rehabilitation.

However, conventional dentures also present several limitations:

- Reduced chewing efficiency;
- Decreased retention, especially in the mandible;
- Progressive alveolar bone resorption;
- Adaptation difficulties among some patients.

The mandibular complete denture represents a particular clinical challenge because the reduced denture-bearing area and continuous bone resorption often lead to instability and discomfort.

#### ➤ *Implant-Supported Overdentures*

The introduction of dental implants has significantly changed the treatment possibilities for edentulous patients. Implant-supported overdentures provide:

- Improved retention;
- Increased chewing efficiency;
- Better patient comfort;
- Enhanced psychological satisfaction.

The mandibular two-implant overdenture has become a widely accepted treatment concept for improving the quality of life of completely edentulous patients. Compared with conventional dentures, implant-supported solutions demonstrate superior outcomes regarding:

- Functional performance;
- Patient satisfaction;
- Stability;
- Confidence during speaking and eating.

#### ➤ *Fixed Implant-Supported Rehabilitation*

For patients with adequate bone availability and suitable systemic conditions, fixed implant-supported prostheses represent one of the most advanced treatment options. Advantages include:

- Improved masticatory function;
- Excellent stability;
- Superior aesthetic outcomes;
- Increased patient confidence.

However, these treatments require:

- Sufficient bone volume;
- Surgical intervention;
- Higher financial investment;
- Careful patient selection.

#### ➤ *Digital Dentistry and New Technologies in Edentulous Rehabilitation*

The development of digital technologies has transformed modern prosthodontics. Important innovations include:

##### • *Intraoral Scanning*

Digital impressions provide:

- ✓ Increased patient comfort;
- ✓ Improved accuracy;
- ✓ Reduced clinical procedures;
- ✓ Easier communication between clinicians and laboratories.

#### • *Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM)*

CAD/CAM technology enables:

- ✓ Precise denture fabrication;
- ✓ Predictable prosthetic outcomes;
- ✓ Shorter treatment time;
- ✓ Improved reproducibility.

#### • *3D Printing*

Three-dimensional printing has become increasingly important in prosthodontics.

Applications include:

- ✓ Printed denture bases;
- ✓ Artificial teeth;
- ✓ Surgical guides for implant placement;
- ✓ Diagnostic models.

The advantages include:

- ✓ Rapid production;
- ✓ Reduced laboratory costs;
- ✓ Customization according to patient anatomy.

## **XII. FUTURE TRENDS IN THE MANAGEMENT OF TOTAL EDENTULISM**

Future approaches in edentulous rehabilitation are expected to focus on personalized, minimally invasive, and digitally integrated treatment strategies. Important future directions include:

#### ➤ *Artificial Intelligence in Prosthodontics*

Artificial intelligence (AI) may contribute to:

- Automated denture design;
- Prediction of treatment outcomes;
- Analysis of facial aesthetics;
- Implant planning;
- Personalized treatment recommendations.

AI-based systems may improve diagnostic accuracy and clinical decision-making.

#### ➤ *Regenerative Dentistry*

Future regenerative approaches aim to restore biological structures rather than only replace missing teeth. Potential developments include:

- Stem cell-based therapies;
- Tissue engineering;
- Biomaterials promoting bone regeneration.

Although still experimental, these approaches may significantly influence the future treatment of tooth loss.

### ➤ *Personalized Geriatric Dentistry*

With increasing life expectancy worldwide, dental care for older adults will become increasingly important. Future geriatric dentistry should integrate:

- Prevention;
- Functional rehabilitation;
- Nutritional support;
- Psychological care;
- Multidisciplinary management.

The goal is not only the prolongation of oral function but also the preservation of independence and quality of life.

## XIII. DISCUSSION

Total edentulism remains a complex and multifactorial oral health condition that continues to affect millions of people worldwide. Although the loss of all natural teeth has become less frequent in many countries due to advances in preventive dentistry, improved oral hygiene awareness, and better access to dental treatment, it remains a significant challenge, especially among older adults. (1,2) The findings reviewed in this paper confirm that complete tooth loss should not be regarded simply as an inevitable consequence of ageing. Rather, it represents the cumulative result of lifelong exposure to oral diseases, individual behaviors, social circumstances, and the characteristics of the healthcare system in which a person has lived. (1,3) One of the most consistent findings reported in the literature is the strong relationship between increasing age and the prevalence of total edentulism. Older adults demonstrate the highest rates of complete tooth loss, particularly those over 65 years of age. (3,4) However, the association between age and edentulism requires careful interpretation. Age itself does not directly cause tooth loss; instead, it reflects the accumulation of biological and social disadvantages over many years. Individuals who experienced inadequate preventive care, limited access to dental treatment, or extraction-based dental approaches earlier in life are more likely to become edentulous later in life. (5) The reduction of edentulism observed in many Western European countries provides important evidence that tooth loss can be prevented. Improvements in oral healthcare systems, regular dental examinations, fluoride use, periodontal treatment, and modern restorative techniques have changed the approach to dental care. In the past, extraction was often considered the simplest and most predictable solution for severely damaged teeth. Today, the emphasis has shifted toward preserving natural teeth whenever possible. This transition represents one of the most important achievements of contemporary dentistry and demonstrates that complete tooth loss is not an unavoidable outcome of ageing. (6) Nevertheless, significant differences in the prevalence of edentulism persist among European regions. Countries with strong preventive healthcare systems generally report lower levels of tooth loss, whereas several Eastern and Southeastern European countries continue to experience a higher burden, particularly among older generations. These differences are explained not only by variations in individual oral hygiene practices but also by historical, economic, and

organizational factors in dental care. Populations who lived through periods when preventive dentistry was less developed often received dental treatment mainly when pain or infection occurred, resulting in delayed interventions and increased reliance on tooth extraction. (7,8) The situation in North Macedonia reflects many of these regional characteristics. Although available epidemiological data are more limited compared with some Western European countries, existing studies indicate that complete tooth loss remains an important oral health issue, particularly among elderly individuals. As in other countries in Southeastern Europe, the current burden of edentulism is closely related to the dental experiences of previous generations, when preventive approaches were insufficiently emphasized, and restorative options were more limited. Many older adults lost teeth after years of untreated caries, advanced periodontal disease, and repeated extractions, reflecting not only their individual oral health history but also the healthcare environment available during their lifetime. Socioeconomic inequalities represent another important factor influencing the prevalence of edentulism. The literature consistently shows that individuals with lower income, lower educational levels, and reduced access to dental services are more likely to experience extensive tooth loss. (9) In North Macedonia, as in many countries with similar healthcare challenges, financial limitations, geographic barriers, and differences in oral health awareness may influence the timing of dental visits and the possibility of receiving conservative treatment. Patients who seek dental care only when symptoms become severe often present with conditions that could have been prevented or treated at an earlier stage. Periodontal disease and dental caries remain the main biological causes leading to complete tooth loss. Both diseases develop gradually and are strongly influenced by daily oral hygiene practices, regular professional care, smoking habits, dietary factors, and systemic health conditions. In older adults, these factors may become more difficult to control because of reduced physical ability, chronic diseases, medication use, and changes in saliva production. Therefore, prevention of edentulism requires a life-course approach that begins early and continues throughout adulthood rather than focusing only on treatment after tooth loss has occurred. (2) The consequences of total edentulism extend well beyond the absence of teeth. Complete tooth loss affects essential daily functions, including chewing and speech, and may influence food choices, nutritional status, appearance, self-confidence, and social interactions. (11,12) Many edentulous individuals experience difficulties adapting to their condition, particularly when tooth loss occurs at an older age and is accompanied by other health problems. This highlights the importance of considering edentulism not only as a dental diagnosis but as a condition that can significantly influence overall quality of life. The relationship between edentulism and general health has received increasing attention in recent years. Several studies have reported associations between complete tooth loss and conditions such as diabetes, cardiovascular disease, frailty, and cognitive decline. Although these relationships are influenced by multiple shared risk factors, they reinforce the concept that oral health is closely connected with general health.

Maintaining natural teeth should therefore be considered an important component of healthy ageing. The future management of edentulism represents an important challenge for healthcare systems, particularly as populations continue to age. The increasing number of older adults will require not only prosthodontic rehabilitation but also preventive strategies aimed at preserving remaining teeth for as long as possible. (15) While dentures and implant-supported solutions provide valuable improvements in function and quality of life, prevention remains the most effective approach to reducing the burden of complete tooth loss. For North Macedonia, further development of national oral health surveillance would provide valuable information for planning preventive programs and allocating healthcare resources. More comprehensive epidemiological studies are needed to determine the current prevalence of total edentulism, identify vulnerable population groups, and evaluate changes over time. Particular attention should be given to older adults, rural communities, and socially disadvantaged groups, where the burden of tooth loss is likely to be greatest. In conclusion, total edentulism should be understood as the result of a lifelong process influenced by biological, behavioral, and social factors. The reduction of complete tooth loss requires more than advanced dental treatment; it requires effective prevention, improved oral health literacy, equitable access to care, and a healthcare philosophy focused on preserving natural teeth throughout life. The experience of countries that have successfully reduced edentulism demonstrates that tooth loss is largely preventable, and continued efforts in this direction are essential for improving oral health and quality of life in ageing populations. (1,2)

#### ➤ *Limitations of the Review*

Although this review provides a comprehensive overview of the epidemiological characteristics, risk factors, and management approaches related to total edentulism, several limitations should be considered. First, differences in epidemiological methodologies among countries make direct comparisons difficult. Variations in:

- Diagnostic criteria;
- Age groups examined;
- Sampling methods;
- Healthcare systems;

May influence reported prevalence rates. Second, some regions, particularly low- and middle-income countries, have limited epidemiological data available. Therefore, the global burden of total edentulism may be underestimated. Third, this review included mainly studies published between 2019 and 2026; therefore, older epidemiological trends and historical changes may not have been fully represented. Future research should focus on:

- Standardized international surveillance systems;
- Long-term population-based studies;
- Evaluation of preventive dental programs;
- Oral health inequalities among vulnerable populations.

## XIV. CONCLUSION

Total edentulism remains a significant global oral health problem, affecting hundreds of millions of individuals worldwide. Although its prevalence has declined in many developed countries, complete tooth loss represents an important challenge, particularly among elderly populations and socially disadvantaged groups. The development of edentulism is influenced by multiple interacting factors, including:

- Dental caries;
- Periodontal disease;
- Socioeconomic conditions;
- Healthcare accessibility;
- Behavioral factors;
- Systemic diseases.

Age remains the strongest predictor of total edentulism, reflecting the cumulative impact of oral diseases throughout life. The epidemiological differences observed between regions demonstrate that tooth loss is not an unavoidable consequence of ageing but rather a preventable condition strongly influenced by social and healthcare determinants. Modern dentistry provides multiple effective rehabilitation options, including:

- Conventional complete dentures;
- Implant-supported overdentures;
- Fixed implant rehabilitation;
- Digitally assisted prosthodontic solutions.

However, prevention remains the most effective strategy for reducing the global burden of edentulism. Future efforts should focus on:

- Strengthening preventive oral healthcare programs;
- Improving access to dental services;
- Increasing oral health education;
- Reducing socioeconomic inequalities.

A lifelong preventive approach, combined with modern rehabilitation methods, represents the most effective pathway toward preserving oral function, improving quality of life, and promoting healthy ageing.

#### ➤ *Clinical Implications*

The findings of this review have several important implications for clinical dental practice. Dental professionals should recognize total edentulism as a preventable chronic condition rather than an inevitable consequence of ageing. Clinical priorities should include:

- Early detection and management of dental caries and periodontal disease;
- Individualized preventive programs for high-risk patients;
- Patient education regarding oral hygiene and regular dental attendance;
- Smoking cessation support;

- Preservation of natural teeth whenever possible.

For patients who have already become completely edentulous, treatment planning should consider not only functional rehabilitation but also psychological and social aspects. Modern prosthodontic treatment should be personalized according to:

- Patient expectations;
- Anatomical conditions;
- Systemic health;
- Functional requirements;
- Financial possibilities.

The integration of digital technologies, implant dentistry, and multidisciplinary care provides new opportunities for improving treatment outcomes and patient satisfaction.

#### ➤ Key Messages

- Total edentulism remains an important global public health issue.
- Older age, periodontal disease, and dental caries are the strongest contributors to complete tooth loss.
- Social inequalities significantly influence the risk of becoming edentulous.
- Prevention and early intervention are the most effective strategies for reducing tooth loss.
- Modern implants and digital technologies have improved rehabilitation possibilities.
- Maintaining natural teeth and improving oral health throughout life should remain the primary goals of dental healthcare.

#### ➤ Final Statement

The epidemiology of total edentulism demonstrates the close relationship between oral health, ageing, social conditions, and healthcare systems. Reducing the global burden of complete tooth loss requires coordinated efforts involving individuals, dental professionals, healthcare institutions, and public health authorities. A future-oriented approach combining prevention, innovation, and equitable access to dental care is essential to ensure that tooth loss becomes an increasingly rare outcome rather than a common consequence of ageing.

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