INSTITUTO UNIVERSITÁRIO EGAS MONIZ

MESTRADO INTEGRADO EM MEDICINA DENTÁRIA

ESTIMATION OF PERIODONTITIS NATIONAL AND REGIONAL PREVALENCE BASED ON THE STUDY OF PERIODONTAL HEALTH IN ALMADA-SEIXAL

Trabalho submetido por
Ana Brígida Alves Antunes
para a obtenção do grau de Mestre em Medicina Dentária

outubro de 2022

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Trabalho orientado por
Prof. Doutor Luís Proença

e coorientado por
Prof.ª Doutora Vanessa Machado

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Maybe it's not about having a beautiful day, but about finding beautiful moments. Maybe a whole day is just too much to ask. I could choose to believe that in every day, in all things, no matter how dark and ugly, there are shards of beauty if I look for them."

Anna White, in "Thoughts on Life, Love, and Leaps of Faith"

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Abstract

Aims: To estimate the risk of periodontitis in the Portuguese population at a regional level and the prevalence of periodontitis in the municipalities that make up the clusters with peri-urban characteristics.

Materials and Methods: In this study, we have estimated the periodontitis risk for Portuguese population, at regional/territory-level, based on a multivariate approach, using sociodemographic, economic and health services data. The information was gathered for all 308 Portuguese municipalities and compiled in a large set of 52 variables. Principal Component Analysis (PCA), Factor Analysis (FA) and clustering techniques were used to model the nationwide geographical distribution of the disease. Estimation of periodontitis risk for each municipality was achieved by calculation of a normalized score, obtained as an adjusted linear combination of six independent factors that were extracted through PCA/FA. The municipalities were also classified according to a quartile-based risk grade, in each cluster. Additionally, linear regression was used to estimate the periodontitis prevalence within the peri-urban municipalities clusters, accounting for 30.5% of the Portuguese population.

Results: A total of nine municipalities clusters were obtained with the following characteristics: mainly rural/low populated, including small villages (1), partly rural/including small cities (2), partly rural/including small and médium cities (3), mainly urban/peri-urban/including medium to large size cities (4 and 5). Uninominal clusters with their own characteristics were also obtained, grouped in clusters 6,7,8 and 9. The estimated periodontitis prevalence for the 18 municipalities included in the four peri-urban clusters, ranged from 41.2 to 69.0%.

Conclusions: Periodontitis proved to be a disease with high prevalence in Portugal. The most affected population tends to be the oldest, with the highest unemployment rate, low income, precarious housing and with less schooling. To counter these values, it is foreseen the need to invest in oral health through the National Health Service.

Keywords: Periodontitis; Risk Factors; Prevalence; Extrapolation

Resumo

Objetivos: Estimar o risco de periodontite na população portuguesa a nível regional e a prevalência de periodontite dos municípios que integram os clusters com características periurbanas.

Materiais e Métodos: Neste estudo, estimou-se o risco de periodontite para a população portuguesa, a nível regional/territorial, com base numa abordagem multivariada, utilizando dados sociodemográficos, económicos e dos serviços de saúde. A informação foi recolhida para todos os 308 municípios portugueses e compilada num conjunto de 52 variáveis. A Análise de Componentes Principais (ACP), Análise Fatorial (AF) e técnicas de agrupamento foram utilizadas para modelar a distribuição geográfica nacional da doença. A estimativa do risco de periodontite para cada município foi obtida pelo cálculo de um *score* normalizado, obtido como uma combinação linear ajustada de fatores independentes que foram extraídos por ACP/AF. Os municípios também foram classificados de acordo com um grau de risco baseado em quartis, em cada cluster. Adicionalmente, a regressão linear foi utilizada para estimar a prevalência de periodontite nos aglomerados de municípios periurbanos, representando 30,5% da população portuguesa.

Resultados: Obteve-se um total de nove aglomerados (clusters) de municípios com as seguintes características: principalmente rural/pouco povoado, incluindo pequenas aldeias (1), parcialmente rural/incluindo pequenas cidades (2), parcialmente rural incluindo pequenas e médias cidades (3), principalmente urbano/periurbano/incluindo cidades de médio a grande porte (4 e 5). Obtiveram-se ainda aglomerados uninominais com caraterísticas próprias agrupados nos clusters 6,7,8 e 9. A prevalência estimada de periodontite para os 18 municípios incluídos nos quatro clusters periurbanos variou de 41,2 a 69,0%.

Conclusão: A periodontite mostrou ser uma doença com elevada prevalência em Portugal. A população mais afetada tem tendência a ser a mais envelhecida, com maior taxa de desemprego, baixo rendimento, precariedade habitacional e com menor formação escolar. Para contrariar estes valores prevê-se a necessidade de apostar na saúde oral através do Serviço Nacional de Saúde.

Palavras-Chave: Periodontite; Fatores de risco; Prevalência; Extrapolação

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List of Abbreviations

AAP – American Association of Periodontology

BoP – Bleeding on Probing

CAL – Clinical Level Attachment

CEJ – Cementoenamel Junction

CPI – Comunnity Periodontal Index

CPITN – Comunnity Index of Periodontal Treatment Needs

CRP – C-Protein Reactive

DMFT - Decayed, Missing, and Filled Teeth

EFP – European Federation of Periodontology

FA – Factor Analysis

IBD – Inflammatory Bowel Disease

IgA – Immunoglobulin A

LAU – Local Administrative Units

NHS – National Health Service

NUT – Nomenclature of Territorial Units for Statistical Purposes

PCA – Principal Components Analysis

PD - Probing depths

PDI – Periodontal Disease Index

PI – Periodontal Index

PP – Periodontal Pockets

Q – Quartile

SP – Severe Periodontitis

WHO – World Health Organization

I. INTRODUCTION

1. PERIODONTAL HEALTH

The periodontium is a structure that encompasses the gingiva, periodontal ligament, cementum and the alveolar bone (Lindhe et al., 2015; Schroeder & Listgarten, 1997). Its main function is to allow the bonding of the tooth to the bone tissue, playing a role in supporting the teeth in the arches and maintaining the mucosal surface of the oral cavity (Lindhe et al., 2015) (Figure 1).

The gingiva, one of the elements of the periodontium, is part of the masticatory mucosa that, in addition to covering the alveolar bone, will surround the cervical portion of the tooth (Lindhe et al., 2015; Schroeder & Listgarten, 1997). There are two types of gingiva: the free gingiva and the attached gingiva. The first one has a coral pink color and a firm consistency. It comprises the gingiva that is found both on the vestibular and lingual/palatal surfaces of the teeth and which then extends in an apical direction from the gingival margin to the free gingival groove. This groove is located at a level corresponding to the cementoenamel junction (CEJ) (Lindhe et al., 2015). Therefore the free gingiva margin is rounded by a small invagination called gingival sulcus which corresponds to a space between the tooth and the gingiva and varies from 0 to 3mm in a periodontal health situation (Lindhe et al., 2015). The attached gingiva has an upper limit (coronal) situated on the free gingival groove. Sometimes, this groove is not seen and that is why we say that the attached gingiva is located in a horizontal plane located at the level of the CEJ (Lindhe et al., 2015). It has a pink coral color, a firm texture and sometimes has small surface depressions called strippling, which give the gingiva an orange peel appearance. It is a condition only found in about 30% of the population (Lindhe et al., 2015).

Along both the buccal and lingual surfaces, in the apical direction, the color of the gingiva, which until then was coral pink, will change to red. This transition is marked by the presence of the mucogingival junction and is where the mucosa begins (Schroeder & Listgarten, 1997).

The periodontal ligament is rich in vascular and cellular connective tissue. It is located around the roots of the teeth and allowing their connection to the cementum. The thickness of the periodontal ligament is approximately 0,25mm (Lindhe et al., 2015). The

presence of the periodontal ligament is extremely important as it allows forces to be exerted, namely during mastication or other dental contacts, which will be distributed and reabsorbed by the alveolar process through the proper alveolar bone. It is due to this mechanism of reception of forces and their resorption that the tooth naturally presents a mobility that we call physiological mobility (Lindhe et al., 2015).

The cementum is another element of the periodontium. It is a specialized mineralized tissue that covers the root surfaces (Lindhe et al., 2015; Schroeder & Listgarten, 1997). Contrary to what happens in bone, cementum does not have blood or lymphatic vessels, is not innervated or undergoes resorption and remodelling. However, it is characterized by a continuous deposition throughout life (Lindhe et al., 2015). Its function is to fix the periodontal ligament fibbers to the tooth root and to repair the root surface after damage (Lindhe et al., 2015).

The periodontium has its own blood and lymphatic system and has nociceptors and mechanoreceptors that allow it to feel pain, touch and pressure (Lindhe et al., 2015). In this way, the periodontium has its own defence and protection mechanisms, for example, protection against gingival and periodontal infection. This protection is effected by the salivary secretion of the major and minor salivary glands that contain high concentrations of Immunoglobulin A (IgA) as well as other mucoproteins that are responsible for disrupting bacterial colonization (Schroeder & Listgarten, 1997).

Periodontal health can be defined in several ways (Li et al., 2020). The World Health Organization (WHO) defines health as the absence of disease (Li et al., 2020). In 2018, Periodontal Health was defined as the absence of clinically detectable inflammation by World Workshop of the European Federation of Periodontology (EFP) and the American Academy of Periodontology (AAP) (Chapple et al., 2018). Specifically, periodontal health refers to a non-inflammatory state characterized by the absence of gingival bleeding (Li et al., 2020).

Although periodontal health is defined as the absence of detectable inflammation, there are always bacteria present in the oral cavity which causes a constant response of the immune system (Chapple et al., 2018; Schroeder & Listgarten, 1997). In this line of thought, wellness can be considered as a dynamic state that varies throughout the days

and each person must have an individual interpretation of their periodontal wellness (Mariotti & Hefti, 2015).

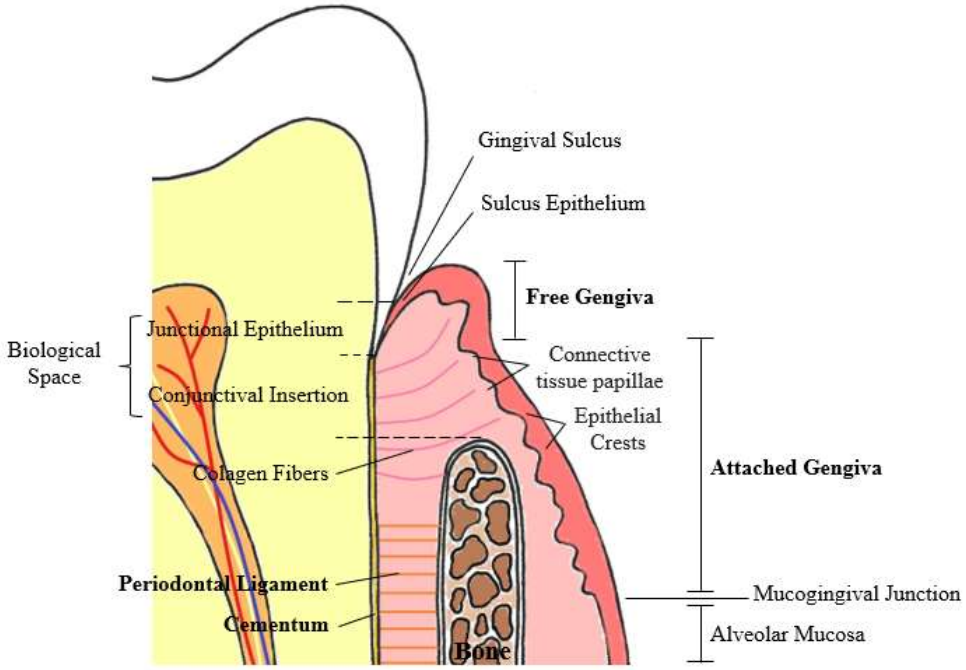

Figure 1 - Schematic drawing of a histologic section of periodontium.

2. PERIODONTAL DISEASE

The maintenance of periodontal disease or the transition to a periodontal disease state is a reflection of the continuous response of inflammatory/immune cells (periodontal residents or emigrants) to the vast microbial ecology present in the oral cavity (Ebersole et al., 2017). Due to the contact to host periodontal tissue, bacterial plaque is responsible for constant changes and responses in the host innate immune system (Darveau, 2010). When homeostasis is disrupted, the alteration of microbiological agents results in a change in the host normal defense mechanisms (Darveau, 2010).

In this context, it is important to talk about gingival crevicular fluid. This fluid is present in the gingival sulcus even in the case of periodontal health and in this case, it appears in the form of a transudate. However, in unhealthy sites, gingival crevicular fluid becomes an inflammatory exudate composed of several elements, namely tissue debris, inflammatory mediators, and antibodies. In this situation, it plays an important role in

maintaining the structure of the junctional epithelium and in the antimicrobial defense of the periodontium (Subbarao et al., 2019).

Periodontal diseases are an inflammatory condition resulting from the persistence of bacterial plaque adhesion to the tooth surface, that affect the supporting structures of the teeth (periodontium) (Kinane et al., 2017; Tonetti et al., 2018). They can be divided into gingivitis and periodontitis depending on the periodontal tissues that are affected by the disease (Chapple et al., 2018).

Gingivitis is the first manifestation of periodontal disease, that is, it constitutes the first response of the periodontium to the presence of biofilm (Bartold, 2018; Tonetti et al., 2018). It is a reversible gingiva condition characterized by an inflammation and bleeding on the gingival margin (Chapple et al., 2018; Trombelli et al., 2018). In this condition, usually painless, it's verified a gingival redness, edema and the absence of attachment loss (Murakami et al., 2018; Trombelli et al., 2018).

When the biofilm continues in contact with the periodontal tissues, the transition from gingivitis to periodontitis occurs and results in clinical attachment loss, an irreversible condition (Chapple et al., 2018). Therefore, when gingivitis is untreated and progresses to loss of gingiva, periodontal ligament and bone, periodontitis develops. In this situation, there is a decrease in bone level and the gum follows this bone loss, so there is exposure of the tooth root and the formation of periodontal pockets, characteristics of periodontitis. (Bartold, 2018; Slots, 2017).

2.1 Risk factors

Dental plaque is the major factor of periodontitis. This means that without bacterial plaque there is no periodontitis (Darveau, 2010).

Periodontitis is characterized by a microbial change. This means that in a state of periodontal health, Gram-positive microorganisms predominate and are replaced by Gram-negative ones as the disease progresses (Darveau, 2010). Thus, it is concluded that a triad of anaerobic bacteria which includes *Porphyromonas gingivalis, Treponema denticola* and *Tannerella forsythia* witch traditionally are considered as causative agents

of periodontitis, based on its degree of virulence and the presence of these bacteria in the periodontal pockets (Hajishengallis, 2015).

Although, as mentioned above, periodontitis is a disease initiated and maintained by the presence of microbial biofilm and the consequent response of the host immune system, genetic and environmental factors can influence the rate of the disease (Chapple et al., 2018; Germen et al., 2021; Slots, 2017).

Therefore, predisposing factors for periodontal disease can be defined as those that facilitate plaque retention or make it difficult to eliminate it through daily cleaning. Thus, depending on the immune response to bacterial plaque, periodontal disease may remain stable or, on the contrary, progress, resulting in chronic periodontitis (Knight et al., 2016). In this way, the predisposing factors are local factors, they are directly related to the tooth itself. Thus, these include supra and subgingival calculus, dental anatomical defects or changes in position and iatrogenic factors such as overflowing restorations (Knight et al., 2016). On the other hand, modifying factors are defined as those capable of altering the natural course of the disease and they are: smoking habits, stress, hormonal changes, socioeconomic status, diabetes mellitus, metabolic syndrome and Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome (HIV/AIDS), which influence vascular, cellular and repair responses (Bartold, 2018; Germen et al., 2021; Jiang et al., 2016; Knight et al., 2016; Krustrup & Erik Petersen, 2006). In summary, there are non-modifiable factors such as age and there modifiable factors which includes environmental, acquired or behavioral factors (Botelho et al., 2019; Lindhe et al., 2015).

2.2 Systemic manifestations of periodontitis and relationship with systemic diseases

Periodontitis has a negative influence on the pathogenesis of certain systemic diseases (Bascones-Martínez et al., 2015).

Periodontitis is associated epidemiologically with several diseases, such as cardiovascular disease, diabetes mellitus, rheumatoid arthritis, Alzheimer disease, nonalcoholic fatty liver disease and certain cancers (Hajishengallis & Chavakis, 2021; Hegde & Awan, 2019). The mechanisms that associate periodontitis with comorbidities beyond the oral cavity show to be consistent with observations carried out in a clinical setting associating

periodontitis with bacteremia, low-grade systemic inflammation, increased myelopoietic activity and the fact that local treatment of periodontitis has been shown to be effective in reducing systemic inflammatory markers improving comorbid disease activity (Hajishengallis & Chavakis, 2021). There is a two-way effect in that periodontitis can contribute to the aggravation of several diseases, but certain diseases, such as diabetes mellitus, can also worsen periodontitis (Hajishengallis & Chavakis, 2021). Diabetes mellitus can promote susceptibility to periodontitis by increasing the inflammatory load on the periodontium or by modulating microbial agents in the periodontium. (Hajishengallis & Chavakis, 2021).

As mentioned above, diabetes is a risk factor towards periodontitis. The susceptibility of an individual with diabetes to have periodontitis is three times greater when compared to an individual without diabetes mellitus (Preshaw et al., 2012). A high degree of hyperglycemia worsens the severity of periodontitis but if glycemia is in the normal range it may be easier to treat periodontitis and keep it under control (Bascones-Martínez et al., 2015; Preshaw et al., 2012).

Previous studies suggested elevated C-reactive protein (CRP) levels in patients with periodontitis, a protein produced by the liver and which is normally elevated in inflammatory or infectious processes and can be an aid in the diagnosis of various diseases (Machado et al., 2021).

In a study conducted in Portugal it was confirmed an association between high blood pressure and periodontitis (Machado, Aguilera, et al., 2020). In another study it was confirmed that periodontitis increased the likelihood of hypertension occurrence (Muñoz Aguilera et al., 2020).

Periodontitis is also implicated in female reproductive function, this because of the polymicrobial disruption of the homeostasis that may be considered as a potential risk factor that affect female fertility (Machado, Lopes, et al., 2020).

Patients with systemic lupus erythematosus have greater odds of suffering from periodontal disease but not necessarily presenting with worse periodontal inflammation as compared with the patients without systemic lupus erythematosus (Hussain et al., 2022).

Due to the implications of periodontitis not only in the oral cavity but also systemically, prevention is extremely important (Tonetti et al., 2018). Thus, there are two levels of prevention: primary prevention, which refers to the prevention of the process responsible for the loss of periodontal attachment through the removal of bacterial plaque and consequent resolution of gingival inflammation; and secondary prevention, which refers to the prevention of relapse of periodontal pockets (Tonetti et al., 2018).

2.3 Epidemiology of periodontal disease in the adult population

Severe periodontitis (SP) is the sixth most prevalent condition in the world presenting a prevalence between 1990 and 2010 of 11.2% (Kassebaum et al., 2014).

It is a disease that affects the entire population in general, not only on the European continent but also on other continents. In a study carried out in USA during 2011 to 2022 it was verified that 44.7% of adults aged ≥30 years had periodontitis (Eke et al., 2015). In another one, carried out in Brazil, the prevalence of periodontitis ranged between 18.2% and 72.0% among subjects 14-19 and 24-29 years old, respectively (Susin et al., 2011).

Results of a study realized in Norwegian, suggest that about half of the subjects in the study had periodontitis; approximately 40% had non-severe periodontitis, and only 10% had severe periodontitis (Holde et al., 2017). The results found in a cross-sectional study carried out in the same country a year later are similar: 49% of participants had periodontitis, of which 9% had severe periodontitis (Holde et al., 2018).

A study carried out in Germany estimated that 89.7% of the population has periodontal pockets. In West Germany, this percentage is lower for individuals in the 35-44 age group and increases for the 65-74 age group (Schützhold et al., 2015).

In Pomerania, a historical and geographical region situated in northern Poland and Germany on the southern coast of the Baltic Sea, the prevalence of AL ≥3 mm was 89.7%, with 62.8% of teeth being affected. Probing depths (PD) ≥4 mm was prevalent in 69.7% of subjects, and 29.6% of teeth were affected. It was also found that 25.3% of the study subjects had periodontal pockets ≥6 mm (Holtfreter et al., 2009).

A study carried out in Italy, specifically in Turin reported estimated that the prevalence of severe and moderate periodontitis was 39.94% and 40.78%, respectively, by studying a sample of individuals aged between 25 and 74 years old (Aimetti et al., 2015).

In France, a study conducted between 2002 and 2003 shows that 95.40% and 82.23% of adults have CAL and periodontal pockets, respectively. Population prevalence estimates indicated that AL ≥ 5 mm is 46.68% and probing on depth (> 5 mm) is 10.21% (Bourgeois et al., 2007).

In Spanish a study was carried out to calculate the prevalence of periodontitis using the CPI methodology. The percentage of subjects with periodontal pockets was 38.4% and this percentage significantly increased with age, having been estimated a prevalence of 65.1% in the studied individuals aged 55 years or older (Carasol et al., 2016).

In Portugal, a study predict that the prevalence rate of periodontitis was 17.6% (de Araújo Nobre & Maló, 2017).

Data on the prevalence of periodontitis in Portugal is scarce. In 2015, the "Estudo de Prevalência das Doenças Orais" found the pooled prevalence to be 10,8% and 15.3% in adult and elderly population, respectively (DGS, 2015). Otherwise, the Study of Periodontal Health in Almada-Seixal (SoPHiAS) in 2018 showed a higher prevalence periodontitis (59.9%), with 24.0% and 22.2% of subjects exhibiting severe and moderate periodontitis, respectively (Botelho et al., 2019). Consequently, this results cannot be compared because the "Estudo de Prevalência das Doenças Orais" used Comunnity Index of Periodontal Treatment Needs (CPITN) to define periodontitis, a partial recording protocol that underestimate the periodontal prevalence and extent by almost 50% (Botelho et al., 2019).

3. EXTRAPOLATION OF DATA IN ORAL DISEASES

Oral diseases are among the most prevalent diseases in the world and have serious impacts on the health and economy of countries, reducing the quality of life of the affected population (Peres et al., 2019). Dental caries is the most common disease of the oral cavity followed by periodontitis, tooth loss and oral cancer (Peres et al., 2019).

Oral diseases have a major economic impact on society. Thus, it can be said that the economic costs can be direct when referring to the treatments carried out; indirect where there is productivity losses due to absence from work and school; and inherent burdens related to pain, difficulty eating, speaking and expressing emotions such as smiling (Botelho et al., 2021; Peres et al., 2019).

Given the impact that oral diseases have, there is a need to carry out studies that allow us to act in the necessary fields and that's how epidemiology comes in (Dye & Thornton-Evans, 2007). Epidemiology is the study of the distribution and determinants of health in populations. Its practical application serves to control health problems (Dye & Thornton-Evans, 2007). Several studies use regression analysis to make a model capable of predicting an outcome from one or more variables. The study model is expressed through an equation that is only valid within the data range observed in the variables under study. This numerical form of generalization is called extrapolation and allows the inclusion of measures in the regression model to make predictions, in the case of this study, for municipalities outside the range of the original data (Dye, 2012).

In European countries, public health policies are beginning to emerge with the aim of improving the health of the population by making their behaviors and food choices increasingly healthy (McDaid et al., 2015). In this way, it appears that communities are increasingly informed and reticent about the consequences of tobacco smoking, excessive alcohol consumption, unhealthy diets and sedentary lifestyles (McDaid et al., 2015). Governments can have a major impact on people's choices and behavior. One of the measures that can be adopted is to increase the monetary value of unhealthy foods, alcohol and tobacco. Another way is to make unhealthy options less appealing and accessible through commercial control and its influence on individual choices. It is also your responsibility ensure that the market has healthy products available, and wage on health literacy educating the population about healthier choices and habits (McDaid et al., 2015).

In short, by shaping environments conducive to healthy choices, the health and average life expectancy of the population tends to improve. It is hoped that the health service will be relieved with minor visits to the dentist for treatment. The population will be more productive, healthier and will enjoy a better quality of life (McDaid et al., 2015).

3.1 Importance of extrapolation in periodontal health

In fact, periodontal disease is a major public health problem with significant socio-economic impacts. Thus, it is estimated that in 2018 in the USA the disease caused a loss of $154.06 billion and €158.64 billion in Europe. These results show how impactful the costs caused by periodontal disease are (Botelho et al., 2021).

Over the years, several classifications have been used to qualify periodontitis (Mariotti & Hefti, 2015; Page & Eke, 2007; Tonetti et al., 2018; van der Velden, 2005). The development of the periodontal index (PI) in the 1950's initiated the epidemiological study of periodontal disease (Dye & Thornton-Evans, 2007). The purpose of creating the PI was to solve the lack data related to periodontal disease and to develop a system that would allow surveillance of the same, similar to the DMFT index (decayed, missing, and filled teeth) already used, created by dentists of the public health service of the United States for dental caries surveillance (Dye & Thornton-Evans, 2007).

The PI criteria is a scaled scoring system which consists of understanding the predominant etiology of periodontal disease and its progression over time. Therefore, a score of 0 refers to the absence of gingival inflammation; a score of 1 refers to the presence of a mild gingivitis; a score of 2 was given for gingivitis; a score of 6 is given when periodontal pockets are present; and a score of 8 is given for advanced destruction with loss of function (Dye & Thornton-Evans, 2007).

One of the biggest disadvantages of using the PI proved to be its subjectivity in measuring the presence of disease. This index assigned the same score to all periodontal pockets (Dye & Thornton-Evans, 2007). In an attempt to end these flaws Ramfjord introduced the Periodontal Disease Index (PDI) in 1959 and later he selected six teeth (16, 21, 24, 36, 41 and 44) to represent the full dentition in an attempt to facilitate the use of the PDI in epidemiological studies (Dye & Thornton-Evans, 2007). The CPITN created in 1978, which later was renamed the Community Periodontal Index (CPI) by WHO, was based on observing and scoring 10 index teeth. In this index, the score is between 0 and 4: 0 corresponds to clinically healthy periodontal tissue; 1 means the presence of bleeding on probing; 2 refers to the presence of supra and sub-gingival tartar; 3 is given when there is presence of shallow periodontal pockets (4-5.5mm); and 4 is given when the periodontal pockets are larger than 6mm (Dye & Thornton-Evans, 2007).

Over the last years, periodontitis case definitions has undergone some changes transitioning from a diagnosis based in clinical attachment loss (CAL) and bleeding on probing (BoP) to a diagnosis proposed in the new American Association of Periodontology (AAP)/European Federation of Periodontology (EFP) based mainly upon CAL and considering the interproximal space as an adjacent common zone (Botelho et al., 2019).

The study of the distribution of periodontitis and its risk factors allows the creation of a model where it is possible to generalize the observations made in the periodontium (Albandar & Rams, 2002; Rose et al., 2008). When different approaches to studies carried out by different investigators produce similar conclusions about the distribution of periodontal disease or associations with its risk factors, greater confidence is obtained about the described phenomena and causal relationships (Albandar & Rams, 2002; Rose et al., 2008).

Epidemiological data can be extremely important in the selection and implementation of preventive measures and in the treatment of periodontal disease (Albandar & Rams, 2002; Rose et al., 2008). In this way, we can have a strategy based on educating the population about healthy practices and unhealthy behaviors in an attempt to change them. Secondary prevention is also a strategy that can be adopted and includes the detection and treatment of individuals with periodontal disease. Finally, a measure that can be adopted will be the identification of groups of individuals at higher risk for periodontitis. It is an important planning system since the earlier the disease is detected, the sooner it can be intervened, having greater control over it and less harmful effects for the patient. On the other hand, by identifying individuals with the disease already in a more advanced stage, it allows for its proper monitoring and treatment (Albandar & Rams, 2002).

The selection of the most appropriate strategy differs from group to group, depending on the distribution of the disease and associated risk factors (Albandar & Rams, 2002; Rose et al., 2008).

Currently, periodontal diseases are still given little priority when compared to other oral diseases (Kandelman et al., 2012). Valid, complete and up-to-date data on periodontal health care are essential for adopting appropriate health policies and adapting prioritization systems for oral health care. Still, defining periodontitis in a reproducible

way has been a challenge due to the varied terms and indexes used, number and teeth examined (Beltrán-Aguilar et al., 2012; Savage et al., 2009).

To address current gap, our study aims to calculate the prevalence of periodontitis at peri-urban municipalities and calculate the risk of periodontitis in mainland Portugal and Islands.

I. PUBLISHED MANUSCRIPT

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Article

Geographical Distribution of Periodontitis Risk and Prevalence in Portugal Using Multivariable Data Mining and Modeling

Ana Antunes [1], João Botelho [1,2], José João Mendes [1,2], Ana Sintra Delgado [1], Vanessa Machado [1,2] and Luís Proença [1,2,*]

[1] Clinical Research Unit (CRU), Centro de Investigação Interdisciplinar Egas Moniz (CiiEM), Egas Moniz—Cooperativa de Ensino Superior, Caparica, 2829-511 Almada, Portugal
[2] Evidence-Based Hub, CiiEM, Egas Moniz—Cooperativa de Ensino Superior, Caparica, 2829-511 Almada, Portugal
* Correspondence: lproenca@egasmoniz.edu.pt

Abstract: We aimed to estimate the geographical distribution of periodontitis prevalence and risk based on sociodemographic and economic data. This study used sociodemographic, economic, and health services data obtained from a regional survey and governmental open data sources. Information was gathered for all 308 Portuguese municipalities and compiled in a large set of 52 variables. We employed principal component analysis (PCA), factor analysis (FA) and clustering techniques to model the Portuguese nationwide geographical distribution of the disease. Estimation of periodontitis risk for each municipality was achieved by calculation of a normalized score, obtained as an adjusted linear combination of six independent factors that were extracted through PCA/FA. The municipalities were also classified according to a quartile-based risk grade in each cluster. Additionally, linear regression was used to estimate the periodontitis prevalence within the peri-urban municipality clusters, accounting for 30.5% of the Portuguese population. A total of nine municipality clusters were obtained with the following characteristics: mainly rural/low populated, including small villages (one), partly rural, including small cities (two), mainly urban/peri-urban, including medium-sized to large cities (4), and urban/large cities (2). Within the clusters, a higher periodontitis risk was identified for municipalities with lower income, older populations. The estimated periodontitis prevalence for the 18 municipalities included in the four peri-urban clusters ranged from 41.2% to 69.0%. Periodontitis prevalence estimates range from 41.2% to 69.0% for the municipalities characterized as peri-urban and mainly urban, most of them located in the Lisbon Metropolitan Area, the tenth largest in Europe.

Keywords: periodontitis; periodontal disease; prediction; prevalence; risk; modeling; public health; oral health

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1. Introduction

Periodontitis is a disease caused by a dysbiotic polymicrobial community surrounding teeth [1–3]. Without adequate treatment, it can lead to progressive periodontal destruction, tooth loss [4] decrease in oral health-related quality of life [5,6], and have an impactful economic burden [7]. Between 1990 and 2010, periodontitis was ranked one of the most prevalent noncommunicable diseases in adults [8,9], and a recent update confirmed that prevalence and incidence is increasing among younger individuals [10].

To date, the epidemiology of periodontal diseases in the Portuguese population has been inadequately reported. A single national epidemiological study, carried out in 2015, estimated a prevalence of 10.8% and 15.3% for the adult and elderly population, respectively [11]. These results contrasted with a regional prevalence of 59.9% reported in the study of periodontal health in Almada-Seixal (SoPHiAS), conducted in the southern Lisbon Metropolitan Area [12] and with European estimations that ranged between 38.4%

and 89.7% [13–18]. Periodontitis risk and progression is known to be strongly dependent on several key indicators, including age, education, oral care access, deleterious behaviors (smoking and alcohol habits), socioeconomic status, and uncontrolled systemic diseases (i.e., diabetes mellitus and hypertension, among others) [19–22].

The current gap of knowledge on periodontal status among the Portuguese population highlights the need for further studies. In our view, a comprehensive projection of risk trends for the disease at both national and regional levels based on current evidence is relevant. The geographical distribution of periodontitis prevalence and risk estimates are critical for understanding the burden of this disease for each specific region. This permits conducting a region-targeted adequate planning of the oral health policy in order to prevent and give early access to treatment for those in need. In this study, we aimed to develop a model able to estimate periodontitis risk for the Portuguese population at regional/territory level based on a multivariate approach using governmental sociodemographic, economic, and health services data along with epidemiological data.

2. Materials and Methods

2.1. Study Area

Secondary data were included to characterize and fingerprint the sociodemographic, economic, and health profiles at municipality level. Portugal is divided into 308 municipalities, also known as local administrative units, level 1 (LAU 1).

The risk of periodontitis was considered the main outcome. It was estimated for each municipality by calculation of a numerical score, obtained as an adjusted linear combination of six independent factors that were extracted through a dimension reduction process. The normalized score, ranging from 0 to 25, was further used to categorize, within each cluster, the municipalities in a 4-level risk grade, identified by its quartile position (from Q1—higher risk to Q4—lower risk).

2.2. Variables

A large set of 52 variables was considered and the correspondent values gathered for each municipality.

The variables included data on the following areas: population, including sex, age and area distribution (population density); education; purchasing power; unemployment/employment; inactive/active population; longevity; aging; elderly dependence and health personnel (number of doctors, dentists, pharmacists and nurses).

All data were gathered from open public sources (official government statistics). Sociodemographic data were obtained from PORDATA, an official and certified statistics data website (https://www.pordata.pt, accessed on 1 May 2022). Overall, data included comprised age, sex distribution, male/female ratio, population density from the 2021 CENSUS, number of doctors, dentist, nurses and pharmacists in 2019, illiterates in total, education (categorized as no education, basic 1st, basic cycle 2nd, basic cycle 3rd, secondary cycle, upper middle), employment status, inactive and active population per 100, level of purchasing power in 2019, total population, dependence index of elderly from the 2021 census, aging index from the 2021 census, and longevity index from the 2021 census.

2.3. Sample Size

The sample size used for periodontal prevalence estimates was derived from secondary data previously collected in the SoPHiAS study. The sample size has further explained elsewhere [12]. This study was approved by the Research Ethics Committee of the Regional Health Administration of Lisbon and Tagus Valley, IP (Portugal) (approval 3525/CES/2018 and 8696/CES/2018) and each participant provided signed informed consent prior to evaluation.

Originally, we based the sample-size estimation on the reported national prevalence data of 10.8% and 15.3% for adults and elderly, respectively [11]. For a minimum sample

of 962 individuals, we were able to include 1064 participants, stratified according to the number of adults (age-group 18–64 years) and elderly (65 years or older) subjects assigned to each health center of the Almada-Seixal health centers group. The periodontal diagnosis followed the American Academy of Periodontology (AAP)/European Federation of Periodontology (EFP) consensus [3] based on a circumferential recording (six sites per tooth—mesiobuccal, buccal, distobuccal, mesiolingual, lingual, and distolingual).

2.4. Statistical Analysis

Principal component analysis (PCA), factor analysis (FA), and cluster analysis (CA) were used to model the nationwide geographical distribution of the disease. Through the PCA/FA dimension reduction process, six factors were extracted from the original set of 52 variables. The factors were further used to categorize the municipalities through a CA procedure.

Additionally, linear regression was used to estimate the periodontitis prevalence within the peri-urban municipality clusters (18 municipalities), accounting for 30.5% of the total Portuguese population. The estimations were based on the calculated risk score and prevalence values previously obtained in the SoPHiAS, which was conducted in two peri-urban municipalities in the Lisbon Metropolitan Area [12]. All analyses were conducted through IBM SPSS Statistics 28.

Using an online map-creator website (mapchart.net) we created a customized map for the risk of periodontitis on the Portuguese mainland and autonomous islands per region. To create this map, we categorized the risk per quartile as described in the Section 2.2. Variables.

3. Results

3.1. Model Development

Prior to the model development and to reduce the complexity of the dimension data, the 52 variables were grouped into six factors through a PCA/FA extraction procedure. The distribution of variables among the factors was as follows: factor 2—inactive and active population for female and male subjects, dependence index of elderly, and longevity index; factor 3—number of doctors and nurses, and level of purchasing power; factor 4—employment status for female and male subjects; factor 5—illiterates in total and male/female ratio; factor 6—unemployment ratio; factor 1—all variables except those mentioned in the remaining factors. The factors were used to categorize the municipalities in clusters.

The developed model resulted in a 9-cluster based distribution (Table 1). In this, 4 clusters were based on one municipality each (Porto, V. N. Gaia, Lisbon and Sintra), two were based on eight municipalities each (clusters 4 and 5) and two clusters were based on over 100 municipalities (clusters 1–3). We also obtained a periodontitis normalized risk score and range for each cluster (Table 2) that contributed to the development of the model for the risk towards periodontitis. In this, Lisbon (25.11) and Porto (23.52) presented the higher normalized risk scores while municipalities of cluster 1 had the lowest (9.69).

Table 1. Local Administrative Units 1 (municipalities) cluster distribution. Table reports the socio-demographic and number of municipalities.

Cluster	Sociodemographic Characteristics	N	Municipalities
1	mainly rural/low populated, including small villages	143	(*)
2	partly rural/including small cities	104	(*)
3	partly rural/including small to medium cities	41	(*)
4	mainly urban/peri-urban/including medium-sized to large cities	8	Leiria, Barcelos, S. Maria Feira, V. F. Xira, V. N. Famalicão, Maia, Setúbal, Funchal
5	mainly urban/peri-urban/including medium-sized to large cities	8	Guimarães, Loures, Braga, Seixal, Gondomar, Cascais, Almada, Matosinhos
6	urban/large city	1	Porto
7	peri-urban/large city	1	V. N. Gaia
8	urban/large city	1	Lisbon
9	peri-urban/large city	1	Sintra

(*) full list in Supplementary Materials.

Table 2. Periodontitis normalized risk score for each cluster.

Cluster	N	Average	Range (Min.–Max.)	Observations
1	143	9.69	0.00–15.76	-
2	104	11.11	3.72–16.51	-
3	41	12.27	9.40–16.66	-
4	8	12.57	10.84–15.72	-
5	8	13.69	12.13–15.64	-
6	1	23.52	-	Only one municipality (Porto)
7	1	13.96	-	Only one municipality (V. N. Gaia)
8	1	25.11	-	Only one municipality (Lisbon)
9	1	10.81	-	Only one municipality (Sintra)

3.2. Periodontitis Risk and Prevalence Estimation

When analyzing the map encompassing the predicted risk score for each cluster, the major population areas in Portugal, particularly the Lisbon and Porto metropolitan areas, have the largest population high-risk clusters for periodontitis (Figure 1). Furthermore, the less populated areas seem to at lower risk, areas populated by older people, with higher levels of tooth loss.

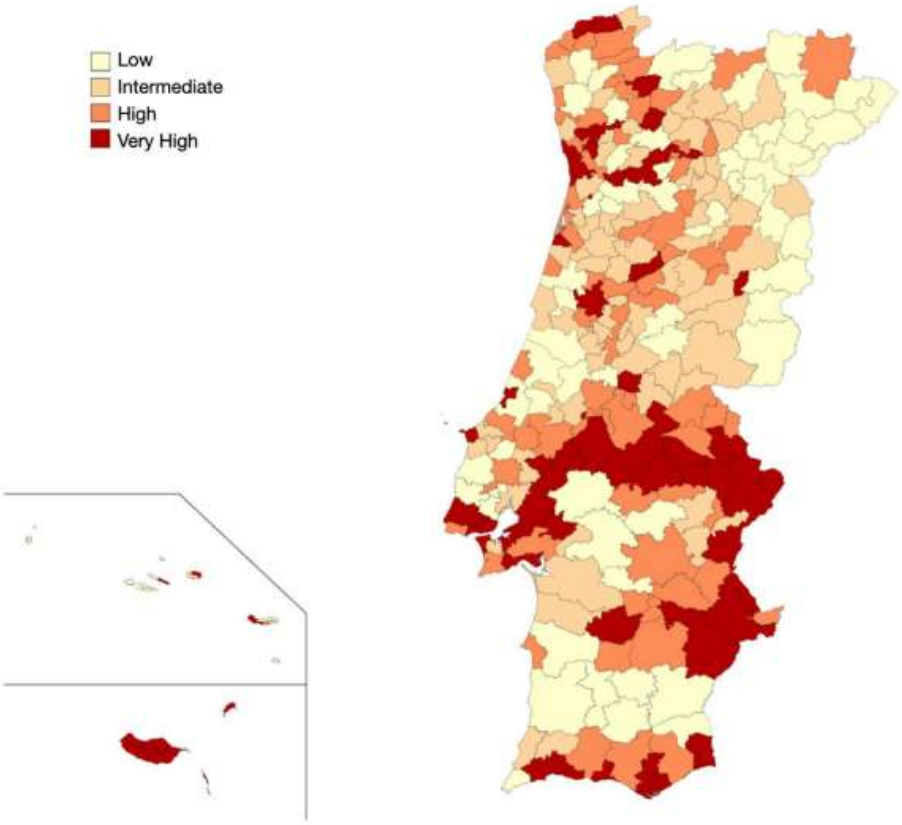

Figure 1. National distribution of the periodontitis risk grade for each LAU 1 (municipality) within the correspondent cluster. The municipalities are identified in a 4-level color risk grade, by quartile position: from Q1—higher risk (red) to Q4—lower risk (yellow).

When forecasting the estimated periodontitis prevalence, the prevalence ranged between 41.4% and 69.0% (Table 3). The lowest estimated prevalence was in Leiria, while Funchal presented the highest score.

Table 3. Estimation of periodontitis prevalence (%) for the municipalities integrating the peri-urban clusters with reference to the geographical distribution under Eurostat Nomenclature of Territorial Units for Statistics (NUTS) region codes (NUTS 1 and 2).

Cluster	Municipalities	Population (n)	NUTS 1	NUTS 2	Estimated Periodontitis Prevalence (%)
4	Leiria	128,640	PT16	PT16F	41.4
	Barcelos	116,777	PT11	PT112	41.6
	S. Maria Feira	136,720	PT11	PT11A	46.7
	V. F. Xira	164,255	PT17	PT170	47.5
	V. N. Famalicão	134,959	PT11	PT112	48.2
	Maia	134,959	PT11	PT11A	57.1
	Setúbal	128,640	PT17	PT170	57.7
	Funchal	105,919	PT30	PT300	69.0
5	Guimarães	164,255	PT11	PT119	48.7
	Loures	201,646	PT17	PT170	53.3

	Braga	193,333	PT11	PT112	54.9
	Seixal	166,693	PT17	PT170	55.2 (*)
	Gondomar	164,255	PT11	PT11A	55.5
	Cascais	214,134	PT17	PT170	60.9
	Almada	177,400	PT17	PT170	63.3 (*)
	Matosinhos	172,669	PT11	PT11A	68.6
7	V. N. Gaia	304,149	PT11	PT11A	59.1
9	Sintra	385,954	PT17	PT170	41.2

(*) Values previously obtained from the field study SoPHiAS [12]. Abbreviations: n—number of subjects; NUTS—nomenclature of territorial units for statistics; PT—Portugal.

4. Discussion

The present study was able to predict estimates for risk of periodontitis on the Portuguese mainland and autonomous regions (Azores and Madeira) based on sociodemographic/economic reference data from national governmental sources. Additionally, it was possible to produce estimates for periodontitis prevalence from secondary data previously obtained in a regional field study. The periodontitis prevalence estimates range from 41.2% to 69.0%, for the municipalities characterized as peri-urban and mainly urban, including some medium-sized to large cities. Most of them are located in the Lisbon Metropolitan Area (NUTS 2, PT170), which is the largest urban area in the country and the tenth largest in Europe. However, it is worth noting that the highest prevalence (69.0%) was estimated for Funchal municipality, in the Madeira autonomous region. These findings contrast with those presented in the DGS oral health study in 2015. In other words, and according to DGS data, the prevalence of periodontitis in Madeira was 6.6% and 10.8% in those aged 35–44 and 65–74 years, respectively. Nevertheless, our results are similar for other regions, and ultimately confirm previous epidemiological studies conducted mainly in the Portuguese metropolitan areas (Lisbon and Porto) [12,23,24]. In particular, the estimates for the Porto Metropolitan Area were slightly above those estimated by Relvas et al. [23], yet this study was conducted in a university dental clinic and this could explain the slight differences due to lower generalizability of the results by this prevalence study. Nonetheless, the prevalence estimates obtained and the agreement with previous studies corroborate alarming levels of periodontitis in Portugal and the demand for periodontal health programs along with the Health General Directorate and health center groupings.

A lack of financial support has often been a serious obstacle, in most countries, to permit adequate and sufficient dental care [25]. In Portugal, most oral health services are provided by private dentists who are not associated or have any agreement with public health protection mechanisms. Thus, in cases of illness, it is often the patients who pay the full cost of treatment, which often creates problems in accessing oral health care [25].

In 2008, a "dental voucher" strategy was added to the program of the Portuguese National Health Service (NHS). Dental vouchers are awarded by primary care health centers to certain beneficiary patients, such as children, pregnant women followed in the NHS, receivers of specific social protection benefits, and people diagnosed with human immunodeficiency virus. This allows access to a range of preventive and curative treatments, free of charge, at any private dental surgery that has an agreement with the NHS [25]. Finally, another strategy was defined in 2016, which consisted of the integration of dentists in the performance of primary oral health care in health centers in order to provide treatment to patients referred by family doctors [25].

Despite the measures adopted, periodontitis remains one of the diseases that most affects the oral cavity in Portugal [12]. It is therefore so important to have studies that show us the prevalence of this disease so that measures can be adopted to counter this trend [26]. Epidemiological data can form the basis for selection and implementation of strategies to prevent and treat periodontal diseases. Three broad strategies have been

advanced: a community-wide approach in which health education and other favorable life practices are introduced into the community; a secondary prevention strategy which includes detecting and treating individuals with destructive periodontal diseases; and identification of groups at high risk of periodontitis [27,28].

Given this, the present study acquires extreme importance. It is an innovative study that has never been carried out before and that gives us information about periodontitis risk by county. Even so, this study presents some limitations due to the lack of information on sociodemographic and socioeconomic issues and the lack of information on oral health habits, such as tooth brushing per day and interproximal cleaning. In this way, this study was carried out by the county and not by the parish, as it had been initially planned. Analyzing the risk map, within each cluster, it is possible to identify the counties with the greatest risk for periodontitis based on a score from 1 to 4, where 4 represents the greatest risk.

The values obtained in this study show a high prevalence of periodontitis in Portugal, the second most common disease concerning the oral cavity. Thus, the need for greater inclusion of dentistry in health centers is foreseen, with a greater interconnection between dentistry and the national health service, and a greater coverage of the treatments available.

There are limitations worth mentioning. The results of these forecasts are always dependent on the availability, amount, and quality of data used to model the results. Although the data available could assemble a model, the amount is far from ideal, and requires further enhancement in the future. No prediction is entirely exact and possible variations or deviations from these forecasts are mandatory. Nevertheless, the periodontal data used were based on updated periodontal case definitions and high-quality epidemiological designs, hitherto confined to the Lisbon Metropolitan Area; therefore, national and regional studies should be carried out on a regular basis to allow consistent results and forecasting. Despite the abovementioned limitations and strengths, we developed a model to identify risk per municipality of periodontitis in Portugal. This geographical distribution of periodontitis risk allows region targeting for adequate planning of oral health policy. These findings provide important data to explore through regional/territory-level epidemiological studies.

5. Conclusions

The periodontitis prevalence estimates range from 41.2% to 69.0% for the municipalities characterized as peri-urban and mainly urban, most of them located in the Lisbon Metropolitan Area, the tenth largest in Europe.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijerph192013634/s1. Supplementary Table S1—Local Administrative Units 1 (municipalities) cluster distribution.

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II. DISCUSSION

Through the analysis of the scores obtained, it is possible to identify, through the division by quartiles, the municipalities that present a higher risk for periodontitis (Q1), represented in the risk map in red.

Therefore, within cluster 1, consisting of 143 municipalities, 36 of them have a higher risk. These include Vila de Rei and Moura. Vila de Rei is a municipality in the interior of Portugal with rural characteristics and a tendency towards desertification (*Vila de Rei: Uma Vila de Oportunidades*, 2021). In this context, a project entitled "Vem Residir em Vila de Rei" was developed. It's a project that has a multidisciplinary team and that tries to attract people mainly residing on the coast of the country, countering the trend of desertification. For this purpose, these individuals have support such as: support for fixation, home tele-assistance; free intra-municipality transport; and are part of the "Esperança Porta-a-Porta" program, which brings various services to their homes (*Vila de Rei: Uma Vila de Oportunidades*, 2021). As a result, the number of migrants has increased significantly (*Vila de Rei: Uma Vila de Oportunidades*, 2021). Still on Vila de Rei, it appears that 3.7% of the population is unemployed and has low purchasing power. A similar case to that of Vila de Rei occurs in Moura. Moura is also a municipality located in the interior of the country with a high number of migrant population (*Relatório de Diagnóstico de Moura*, 2018). Therefore, population groups of various origins or ethnicities are identified, with emphasis on: Romanians, Brazilians, Chinese and Spaniards (*Relatório de Diagnóstico de Moura*, 2018). It's also worth noting the aging population, the precariousness of housing conditions and the unemployed population, which represents 11.7% (6.8% more than the percentage of unemployment in Portugal) (*Relatório de Diagnóstico de Moura*, 2018).

In cluster 2, with 104 municipalities, 26 of them present a score in Q1. Among these ones we find, for example, Peniche, Nazaré and Coimbra. Both Peniche and Nazaré are two municipalities located on the coast where there is a predominance of primary and secondary economic activities. In fact, the fishing activity in these municipalities still remains an important economic activity (*Agenda 21 Local - Munícipio da Nazaré*, 2005; DICAD, 2014). In Peniche there is an aging population, a trend in most of the country.

There are also situations of unemployment, low levels of education and low housing qualifications (DICAD, 2014). In addition, there are 11 social neighborhoods where there are situations of drug consumption and trafficking; physical degradation of buildings; job insecurity; low incomes; low educational and professional qualifications; single-person families constituted by elderly people with chronic pathologies; and additive consumption (DICAD, 2014). Regarding Nazaré, it can be concluded that it is in the health and social assistance index (which refers, for example, to the availability of equipment, infrastructure and personnel at the service) that it is further away from the national average, being below this at 44 .5% (*Agenda 21 Local - Munícipio da Nazaré*, 2005). It should also be noted that with regard to education and culture (where the number of schools, teachers and employees and the level of education stand out), Nazaré is one of the municipalities with the worst national qualifications, with only 6 municipalities in the country with a lower index (*Agenda 21 Local - Munícipio da Nazaré*, 2005). Concerning Coimbra, it is worth mentioning the increase in the number of elderly people as well as the increase in its dependency rate (*Diagnóstico Social do Concelho de Coimbra*, 2018). In this municipality there is a high number of collective accommodation (shared by more than one family) which encompasses a multisectoral problem, namely in terms of public and individual health, taking into account the precarious conditions it provides to its residents (*Diagnóstico Social do Concelho de Coimbra*, 2018). Another relevant problem is the high number of individuals receiving the social insertion income intended for households in serious situations of economic need and at risk of social exclusion (*Diagnóstico Social do Concelho de Coimbra*, 2018).

Through the analysis of cluster 3, constituted by 41 municipalities, it appears that 10 of them present the maximum risk for periodontitis. Within these we find Barreiro and Amadora. In Barreiro there is an increase in the elderly population; reduced availability of preventive health services, especially in less urbanized areas; and socio-economic deprivation (impoverished population) (*A Região de Lisboa e Vale do Tejo em 2001: Análise dos Resultados Preliminares dos Census*, 2001; Nogueira, 2009; Nogueira & Lourenço, 2015). In Amadora, as in Barreiro, we also see an aging population and socio-economic deprivation, which translates into lower purchasing power (*Amadora em Números*, 2014). In Amadora there are still other situations to be highlighted, namely: 10% of the resident population is foreign; 3.8% of the population lives in social neighborhoods in a state of degradation; 95 out of every 1000 inhabitants are beneficiaries

of the social insertion income. In addition, a small percentage of the population has completed compulsory education (*Amadora em Números*, 2014).

Cluster 4 is constituted by 8 municipalities, 2 of them (Funchal e Setúbal) with a higher risk for periodontitis. Setúbal is a municipality located in the Lisbon metropolitan area with rural but predominantly urban characteristics, where the largest population group is concentrated. In this municipality, only 48% of residents are of working age, and of these, 16% are unemployed (*Setúbal, Território Intercultural*, 2017). Between 2010 and 2011 there was a 6% increase in the unemployment rate (*Setúbal, Território Intercultural*, 2017). Social exclusion due to aging, unemployment and marginalization is another of the problems of this municipaliy, with Setúbal being one of the most representative municipalities of phenomena of marginalization and unemployment (*Setúbal, Território Intercultural*, 2017). In summary, Setúbal presents high values in the following typologies: unemployment, decrease in income, dependence on subsidies or social support, poor housing conditions, crime, vulnerability associated with the immigrant population and risk groups (*Setúbal, Território Intercultural*, 2017).

Finally, cluster 5 consists of 8 municipalities, namely the base municipalities used in this study (Almada and Seixal), with 2 of them (Almada and Matosinhos) having a maximum score (Q1). In Almada we find an increase in unemployment, with a higher incidence in the young population, since the economic crisis that the country went through in 2008 (*ENVOL20 Almada*, 2020). Precarious work affects 1 in 4 workers and salaries are below the national average. There are low school qualifications. There has been a budget constraint with an impact on social support. As a result of these factors, there is high social inequality, increased levels of poverty, and social exclusion (*ENVOL20 Almada*, 2020). In Matosinhos there has been an aging population and, associated with it, an increase in the number of elderly people living alone (*Diagnóstico Social do Concelho de Matosinhos 2020*, 2020; *Plano de Desenvolvimento Social de Matosinhos 2021-2024*, 2021). The increase in unemployment has also been notorious (*Diagnóstico Social do Concelho de Matosinhos 2020*, 2020; *Plano de Desenvolvimento Social de Matosinhos 2021-2024*, 2021). The increase in skilled unemployment as a result of the pandemic caused by the Covid-19 virus should be highlighted. There are also precarious working conditions that affect mainly young adults and women (*Diagnóstico Social do Concelho de Matosinhos 2020*, 2020; *Plano de Desenvolvimento Social de Matosinhos 2021-2024*, 2021). Inequality situations are striking, accentuating the vulnerability and poverty of

some groups. Thus, there is a barrier to the integration and full participation of elderly people in life in society; homeless people; and persistence of prejudice towards individuals of other origins or ethnicities (*Diagnóstico Social do Concelho de Matosinhos 2020*, 2020; *Plano de Desenvolvimento Social de Matosinhos 2021-2024*, 2021).

The following clusters (6, 7, 8 and 9) are uninominal and are respectively constituted by Porto, Vila Nova de Gaia, Lisbon and Sintra. The most populous municipalities in the country are found in these clusters and are, in descending order: Lisbon, Sintra, Vila Nova de Gaia and Porto. Lisbon shows a trend towards a decrease in the resident population (*Censos*, 2021). The number of elderly people has remained stable since 2001, contrary to the aging trend seen in most municipalities in the country, and the aging rate of elderly people per 100 young people has shown lower values since the same date (*Censos*, 2021). 63.5% of the population is of working age and it should be noted that around 200,000 inhabitants (out of its 545,923) have higher education, which makes up approximately 37% of the population (*Censos*, 2021). In Sintra the same is not verified for the elderly population since it has been increasing as well as the aging index (*Relatório de Caraterização e Diagnóstico do Concelho de Sintra*, 2014). Approximately 9% of the resident population is foreign with a focus on Chinese and Romanian nationalities (*Relatório de Caraterização e Diagnóstico do Concelho de Sintra*, 2014). There has been a decrease in the number of students in higher education and an upward trend in youth unemployment. In this way, it appears that 23,737 inhabitants are in the unemployment fund where individuals with low qualifications predominate (*Relatório de Caraterização e Diagnóstico do Concelho de Sintra*, 2014). It is also worth mentioning an increase in the population receiving the social insertion income post-economic crisis in 2008, although there is a reversal of this pattern due to policies that restrict access to this type of income (*Relatório de Caraterização e Diagnóstico do Concelho de Sintra*, 2014). In Vila Nova de Gaia, there has been an increase in the elderly population, in the aging rate and in the dependency rate of the elderly, with a consequent decrease in the working-age population comparing the 2021 data with the 2001 data (*Plano de Desenvolvimento Social de Vila Nova de Gaia 2017-2021*, 2017). Approximately 2% of the resident population is an immigrant (3998 individuals) and 36% of these are from Brazil (*Plano de Desenvolvimento Social de Vila Nova de Gaia 2017-2021*, 2017). In Porto there is the same trend as in Vila Nova de Gaia, an aging population, and a decrease in the active population (*Censos*, 2021). As in Lisbon, there is a high number of individuals with higher

education (*Censos*, 2021). There are about 74,000 inhabitants with higher education and this number has an increasing trend compared to 2011 data (*Censos*, 2021).

The sociodemographic and socioeconomic characteristics pointed out for the municipalities mentioned above (from clusters 1 to 5) are possible aspects that increase the risk of periodontitis in that municipality, considering the cluster in which it is inserted.

Oral diseases have a high prevalence representing a major public health problem with consequences for the general health and quality of life of populations (Albuquerque et al., 2019).

Periodontitis is the second most common disease of the oral cavity, followed by dental caries, so it is necessary a greater government intervention in response to the prevention and treatment of this disease. The creation of a National Health Service that would include dentists from the various areas of dentistry capable of responding to the necessary treatments free of charge or at reduced costs would be an important measure to be adopted. It is therefore suggested a partial transition from totally private dentistry to dentistry available to the entire population. Special attention should be given to population groups such as: children, pregnant women, the elderly, individuals with HIV/AIDS and the economically disadvantaged population, among others.

Behavioural risk factors, not only for periodontitis but also for other oral diseases, are multiple in society such as an unhealthy diet, often high in free sugars, poor oral hygiene, smoking and excessive consumption of alcohol (Albuquerque et al., 2019). In addition to the unhealthy behaviors of the population, there is a strong association between the prevalence of periodontitis and socioeconomic status (Albuquerque et al., 2019).

The financial support has been an obstacle in most countries to providing an adequate and sufficient dental care (Albuquerque et al., 2019). In Portugal, most of the dental health care provided is private, that is, it is provided by dentists who are not associated with the national health service. This means that in case of illness the patient must pay the costs of the associated treatments in full. This situation means that visits to the dentist are reduced and, often, patients only resort to the same in cases of pain or in situations where the tooth has no viable treatment possible (Albuquerque et al., 2019).

In an attempt to counter this situation, the dental voucher was created in 2008 and inserted into the program of the National Health Service (NHS). Dental Vouchers are awarded by primary care health centers to certain beneficiary patients such as children, pregnant women followed in NHS, receivers of specific social protection benefits, people diagnosed with human immunodeficiency virus. This method allows free access to various treatments, whether preventive or curative in any dental clinic (private) as long as it has an agreement with the NHS (Albuquerque et al., 2019).

Another strategy has been implemented since 2016, which consisted of the integration of dentists in health centers available to provide the necessary health care. In this way, patients referred by their family doctors can enjoy NHS dental consultations (Albuquerque et al., 2019).

Despite the measures adopted, periodontitis remains one of the diseases that most affects the oral cavity in Portugal (Botelho et al., 2019). It is therefore so important to have studies that show us the prevalence of this disease so that meausures can be adopted to counter this trend (Dye & Thornton-Evans, 2007). Epidemiologic data can be extremely useful for selection and implementation of strategies to prevent and treat periodontal diseases (Dye & Thornton-Evans, 2007).

Through the conclusions of the epidemiological studies, several strategies can be considered. The first measure to be adopted is the education of the population through the teaching of good practices and good choices favorable to a better quality of life. When the disease is already installed, secondary prevention arises in which individuals with periodontal disease must be identified and treated. Finally, the identification of groups with higher risk for periodontitis (Albandar & Rams, 2002; Rose et al., 2008).

In this lign of thought, it's notorious that data on the prevalence of periodontitis in Portugal is scarce and there are no national-level epidemiological results. Additionally, the reported prevalence of periodontitis varies significantly among the existent studies. In 2015, the "Estudo de Prevalência das Doenças Orais" found the pooled prevalence to be 10,8% and 15.3% in adult and elderly population, respectively (DGS, 2015). Otherwise, the Study of Periodontal Health in Almada-Seixal (SoPHiAS) in 2018 showed a higher prevalence periodontitis (59.9%), with 24.0% and 22.2% of subjects exhibiting severe and moderate periodontitis, respectively (Botelho et al., 2019). Consequently,

these results cannot be compared because the “Estudo de Prevalência das Doenças Orais” used CPITN, a partial recording protocol that underestimate the periodontal prevalence and extent by almost 50% (Botelho et al., 2019).

III. CONCLUSION

Given the lack of studies on the prevalence of periodontitis in Portugal, the need to continue this study is expected. In this way, it is suggested the continuous collection and updating of sociodemographic, socioeconomic and health service data from each municipality to obtain new prevalence studies. If they present similar values, we are facing reliable studies.

This innovative study, never done before in Portugal, which showed that, although measures have been applied in the field of dentistry, the prevalence of periodontitis seems to be high. So, as mentioned above this study should be continued and may present a good contribution to the adoption of new public health policies that counter the growing trend in the prevalence of periodontitis.

After researching the sociodemographic, socioeconomic and health service characteristics of the municipalities that are expected to have a higher risk of periodontitis, some common factors between them should be highlighted. Thus, it appears that a higher risk of periodontitis seems to be associated mainly with aging, low educational level, unemployment and low income.

The prevalence of periodontitis in Portugal was shown to be high, with values varying between 41.2% and 69% (in the municipalities for which the prevalence study was carried out). In this case, the municipalities with the highest prevalence were Cascais (60.9%), Almada (63.3%), Matosinhos (68.6%) and Funchal (69.0%), all of them with prevalence values above 60%. In contrast, Sintra (41.2%), Leiria (41.4%) and Barcelos (41.6%) showed to be the municipalities with a lower prevalence when compared to the other municipalities in the study, although they still present a significant prevalence.

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V. APPENDICES

International Journal of *Environmental Research and Public Health*

MDPI

Article

Geographical Distribution of Periodontitis Risk and Prevalence in Portugal Using Multivariable Data Mining and Modeling

Supplementary Materials

Supplementary Table S1. Local Administrative Units 1 (municipalities) cluster distribution.

Municipalities	Cluster	Score
Abrantes	2	11.78
Águeda	2	10.54
Aguiar da Beira	1	6.90
Alandroal	1	10.82
Albergaria-a-Velha	2	10.62
Albufeira	2	12.96
Alcácer do Sal	2	10.69
Alcanena	2	10.82
Alcobaça	3	10.54
Alcochete	2	14.70
Alcoutim	1	6.52
Alenquer	2	11.17
Alfândega da Fé	1	8.24
Alijó	1	9.06
Aljezur	1	9.05
Aljustrel	1	9.73
Almada	5	14.71
Almeida	1	7.90
Almeirim	2	12.94
Almodôvar	1	7.70
Alpiarça	1	13.57
Alter do Chão	1	12.00
Alvaiázere	1	8.95
Alvito	1	10.11
Amadora	3	16.66
Amarante	3	10.23
Amares	1	10.12
Anadia	2	10.74
Angra do Heroísmo	2	10.95
Ansião	1	9.38
Arcos de Valdevez	1	10.50
Arganil	1	10.03
Armamar	1	8.47
Arouca	2	9.19
Arraiolos	1	8.12
Arronches	1	11.02
Arruda dos Vinhos	2	9.30
Aveiro	3	12.93
Avis	1	10.88
Azambuja	2	10.77

Baião	1	10.81
Barcelos	4	10.89
Barrancos	1	10.70
Barreiro	3	14.61
Batalha	2	10.27
Beja	2	11.08
Belmonte	1	12.41
Benavente	2	12.89
Bombarral	2	10.63
Borba	1	10.02
Boticas	1	8.04
Braga	5	13.23
Bragança	2	11.18
Cabeceiras de Basto	1	10.16
Cadaval	2	9.91
Caldas da Rainha	3	12.74
Calheta [R.A.A.]	2	5.82
Calheta [R.A.M.]	1	12.02
Câmara de Lobos	2	15.53
Caminha	2	11.52
Campo Maior	2	12.69
Cantanhede	2	10.07
Carrazeda de Ansiães	1	8.33
Carregal do Sal	1	10.85
Cartaxo	2	12.35
Cascais	5	14.29
Castanheira de Pêra	1	9.52
Castelo Branco	3	11.27
Castelo de Paiva	1	11.71
Castelo de Vide	1	9.98
Castro Daire	1	8.25
Castro Marim	1	11.97
Castro Verde	2	9.90
Celorico da Beira	1	10.36
Celorico de Basto	1	11.02
Chamusca	1	10.86
Chaves	2	11.48
Cinfães	1	11.37
Coimbra	2	16.51
Condeixa-a-Nova	2	11.33
Constância	2	11.78
Coruche	2	10.11
Corvo	1	0.00
Covilhã	3	11.93
Crato	1	10.37
Cuba	1	9.88
Elvas	1	14.00
Entroncamento	2	12.28
Espinho	2	14.64
Esposende	2	11.28
Estarreja	2	10.99

Estremoz	2	10.63
Évora	3	12.42
Fafe	3	12.32
Faro	3	14.98
Felgueiras	3	11.30
Ferreira do Alentejo	1	10.82
Ferreira do Zêzere	1	8.44
Figueira da Foz	3	11.82
Figueira de Castelo Rodrigo	1	9.37
Figueiró dos Vinhos	1	9.94
Fornos de Algodres	1	9.26
Freixo de Espada à Cinta	1	8.31
Fronteira	1	11.14
Funchal	4	15.72
Fundão	2	10.98
Gavião	1	11.21
Góis	1	8.72
Golegã	2	11.29
Gondomar	5	13.33
Gouveia	1	10.54
Grândola	1	8.91
Guarda	3	12.09
Guimarães	5	12.13
Horta	2	9.49
Idanha-a-Nova	1	8.02
Ílhavo	2	12.36
Lagoa	2	12.75
Lagoa [R.A.A.]	2	11.34
Lagos	2	13.78
Lajes das Flores	2	3.72
Lajes do Pico	2	6.78
Lamego	2	11.55
Leiria	4	10.84
Lisboa	8	25.11
Loulé	3	12.95
Loures	5	12.94
Lourinhã	2	10.71
Lousã	2	11.04
Lousada	2	11.92
Mação	1	9.15
Macedo de Cavaleiros	1	8.40
Machico	2	15.38
Madalena	2	8.98
Mafra	3	11.09
Maia	4	13.61
Mangualde	2	10.91
Manteigas	1	9.73
Marco de Canaveses	3	11.19
Marinha Grande	2	11.32
Marvão	1	9.99
Matosinhos	5	15.64

Mealhada	2	11.00
Mêda	1	7.24
Melgaço	1	9.09
Mértola	1	7.24
Mesão Frio	1	10.72
Mira	1	10.38
Miranda do Corvo	2	10.73
Miranda do Douro	1	8.07
Mirandela	2	10.57
Mogadouro	1	8.23
Moimenta da Beira	1	8.68
Moita	3	14.94
Monção	1	11.29
Monchique	1	9.68
Mondim de Basto	1	9.60
Monforte	1	12.14
Montalegre	1	7.89
Montemor-o-Novo	2	9.65
Montemor-o-Velho	2	10.17
Montijo	3	13.35
Mora	1	9.89
Mortágua	1	8.80
Moura	1	13.33
Mourão	1	12.61
Murça	1	8.68
Murtosa	1	10.29
Nazaré	2	12.18
Nelas	1	10.13
Nisa	1	9.91
Nordeste	1	6.98
Óbidos	1	9.22
Odemira	2	6.72
Odivelas	3	14.68
Oeiras	2	15.97
Oleiros	1	5.57
Olhão	2	12.79
Oliveira de Azeméis	3	10.12
Oliveira de Frades	2	10.23
Oliveira do Bairro	2	10.78
Oliveira do Hospital	2	10.23
Ourém	3	9.40
Ourique	1	7.74
Ovar	3	12.42
Paços de Ferreira	3	11.67
Palmela	3	12.76
Pampilhosa da Serra	1	7.75
Paredes	3	11.93
Paredes de Coura	1	10.70
Pedrógão Grande	1	9.69
Penacova	1	9.93
Penafiel	3	10.78

Penalva do Castelo	1	8.02
Penamacor	1	5.82
Penedono	1	6.88
Penela	1	9.68
Peniche	2	12.10
Peso da Régua	2	12.28
Pinhel	1	7.72
Pombal	3	9.44
Ponta Delgada	3	13.06
Ponta do Sol	1	12.00
Ponte da Barca	1	10.79
Ponte de Lima	3	10.13
Ponte de Sor	1	14.28
Portalegre	2	12.35
Portel	1	10.51
Portimão	3	14.64
Porto	6	23.52
Porto de Mós	2	9.85
Porto Moniz	1	13.56
Porto Santo	2	13.79
Póvoa de Lanhoso	2	11.29
Póvoa de Varzim	3	12.90
Povoação	1	9.02
Proença-a-Nova	1	8.45
Redondo	1	9.40
Reguengos de Monsaraz	2	11.51
Resende	1	8.42
Ribeira Brava	1	14.51
Ribeira de Pena	1	8.47
Ribeira Grande	2	9.79
Rio Maior	2	11.37
Sabrosa	1	10.01
Sabugal	1	7.59
Salvaterra de Magos	2	13.09
Santa Comba Dão	1	10.98
Santa Cruz	2	13.41
Santa Cruz da Graciosa	2	7.78
Santa Cruz das Flores	2	9.29
Santa Maria da Feira	4	11.79
Santa Marta de Penaguião	1	9.85
Santana	1	14.26
Santarém	3	12.44
Santiago do Cacém	2	9.69
Santo Tirso	3	13.27
São Brás de Alportel	1	12.95
São João da Madeira	2	13.51
São João da Pesqueira	1	6.56
São Pedro do Sul	1	8.99
São Roque do Pico	2	9.22
São Vicente	1	12.01
Sardoal	1	10.50

Sátão	1	9.28
Seia	2	10.63
Seixal	5	13.27
Sernancelhe	1	8.63
Serpa	1	11.92
Sertã	1	9.13
Sesimbra	2	11.51
Setúbal	4	13.72
Sever do Vouga	1	9.60
Silves	2	11.23
Sines	2	11.36
Sintra	9	10.81
Sobral de Monte Agraço	2	11.18
Soure	1	9.62
Sousel	1	10.10
Tábua	1	10.30
Tabuaço	1	8.83
Tarouca	1	9.30
Tavira	2	12.04
Terras de Bouro	1	10.47
Tomar	2	11.96
Tondela	2	10.81
Torre de Moncorvo	1	7.18
Torres Novas	2	10.89
Torres Vedras	3	11.06
Trancoso	1	8.51
Trofa	2	13.14
Vagos	2	10.65
Vale de Cambra	2	9.60
Valença	1	12.02
Valongo	3	13.81
Valpaços	1	7.05
Velas	2	7.87
Vendas Novas	2	10.25
Viana do Alentejo	2	10.00
Viana do Castelo	3	12.04
Vidigueira	1	12.78
Vieira do Minho	1	10.99
Vila da Praia da Vitória	2	8.70
Vila de Rei	1	11.13
Vila do Bispo	2	9.97
Vila do Conde	3	12.24
Vila do Porto	2	9.94
Vila Flor	1	8.00
Vila Franca de Xira	4	11.93
Vila Franca do Campo	1	10.00
Vila Nova da Barquinha	1	10.00
Vila Nova de Cerveira	2	11.96
Vila Nova de Famalicão	4	12.05
Vila Nova de Foz Côa	1	7.49
Vila Nova de Gaia	7	13.96

Vila Nova de Paiva	1	9.82
Vila Nova de Poiares	2	10.36
Vila Pouca de Aguiar	1	9.64
Vila Real	3	11.95
Vila Real de Santo António	1	15.76
Vila Velha de Ródão	1	9.29
Vila Verde	3	10.48
Vila Viçosa	2	10.58
Vimioso	1	6.77
Vinhais	1	5.51
Viseu	3	12.44
Vizela	2	13.46
Vouzela	1	9.77

Autorização para estrutura da tese

AA **Ana Brígida Antunes <abantunes99@gmail.com>**

20/10/2022 17:26

Para: iuem@egasmoniz.edu.pt; cmanso@egasmoniz.edu.pt; galcoforado@egasmoniz.edu.pt; anazul2@gmail.com; iventura@egasmoniz.edu.pt; pmauricio@egasmoniz.edu.pt; vmachado@egasmoniz.edu.pt; lproenca@egasmoniz.edu.pt

Autorização para estrutura da...
20,27 KB

Boa tarde,

No decorrer da realização da minha Tese de Mestrado elaborei um artigo que foi hoje publicado. Por essa razão envio em anexo o meu pedido de alteração de estrutura da minha tese. Fico a aguardar resposta.

Espero que este e-mail vos encontre bem,

Ana Antunes

Exmos.
Magnífico Reitor do IUEM, Professor Doutor Gil Alcoforado
Vice-Reitora do IUEM, Prof.ª Doutora Cristina Manso,
Coordenadora do MIMD Prof.ª Doutora Ana Mano Azul
Presidente da Comissão Científica do MIMD Prof.ª Doutora Irene Ventura
Regente da UC Orientação Tutorial de Projeto Final, Prof. Doutor Paulo Maurício

No seguimento da minha tese de mestrado, com o tema "**Estimation of Periodontitis National and Regional Prevalence Based on the Study of Periodontal Health Almada-Seixal**", orientada pelo **Prof. Doutor Luís Proença** e co-orientada pela **Prof.ª Doutora Vanessa Machado**, vimos questionar-vos relativamente às Normas para Apresentação das Dissertações, Trabalhos de Projeto e Monografias Integrantes do Relatório de Estágio (Anexo I do R.EM.DI.04).

Face aos resultados meritórios deste projeto, este grupo de trabalho viu-se premiado com a publicação de um artigo científico: Antunes, A., Botelho, J., Mendes, J. J., Delgado, A. S., Machado, V., & Proença, L., (2022). **Geographical Distribution of Periodontitis Risk and Prevalence in Portugal Using Multivariable Data Mining and Modeling.** International Journal of Environmental Research and Public Health, *19, 13634,* **DOI: 10.3390/ijerph192013634**

Consequentemente, urge a necessidade de esclarecer alguns pontos relativamente ao formato de apresentação da dissertação:

- Como desposto no ponto 5.do Anexo I R.EM.DI.04, "Corpo do trabalho dividido nos capítulos considerados relevantes (ex.: Introdução, Desenvolvimento do tema e Conclusões; ou Introdução, Materiais e Métodos, Resultados e Discussão, e Conclusões);".
- Pela interpretação deste ponto, parece-nos existir latitude para a apresentação do artigo publicado como um capítulo individual.
- Parece-nos existir latitude para não existir um capítulo de Materiais e Métodos isolada, já que a metodologia está descrita nos "Material and Methods" do artigo.
- Esclarecemos que a publicação do artigo integral está prevista e aprovada pela revista onde foi publicado, e comprometemo-nos a anexar as mesmas autorizações na zona de Anexos da dissertação.

Assim, a organização prevista para a presente dissertação é a seguinte:

1. Introdução (inclui Objetivos)
2. Manuscrito publicado - **Geographical Distribution of Periodontitis Risk and Prevalence in Portugal Using Multivariable Data Mining and Modeling.**
3. Discussão
4. Conclusão

Gostaríamos de questionar a adequabilidade e permissão para proceder com a mesma.

Na esperança de que estejam todos bem, ficamos a aguardar com entusiasmo o vosso parecer.

Os melhores cumprimentos,
Ana Antunes (112821)

RE: Autorização para estrutura da tese

MM **Maria Manuel Marnoto <mmarnoto@egasmoniz.edu.pt>**
14:58

Para: Ana Brígida Antunes

Ex.ma Ana,

A pedido da Reitoria informo que a sua solicitação foi deferida.

Com os meus melhores cumprimentos,

Secretária da Reitoria do IUEM
Maria Manuel Marnoto
INSTITUTO UNIVERSITÁRIO EGAS MONIZ
e-mail: iuem@egasmoniz.edu.pt
ou
mmarnoto@egasmoniz.edu.pt