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THE EFFECT OF ORAL FACTORS ON THE DIETARY CHOICES OF OLDER COMMUNITY-DWELLING GREEKS

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Επιβλέπουσα Καθηγήτρια για την εκπόνηση της Μεταπτυχιακής Διπλωματικής Εργασίας:
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Τριμελής Επιτροπή για την Αξιολόγηση της Μεταπτυχιακής Διπλωματικής Εργασίας:

1. Κοσιώνη Αναστασία
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PREFACE

Greece is one of the countries with the highest rates of older people in the world. In a population that is constantly growing old, we should always research for ways that will improve the quality of life of those who have the greatest need, including the older old. Therefore, in Greece, research in the fields of Gerontology, Geriatrics and Gerodontology is extremely important. During my MSc course in Prosthodontics I realised the importance of a functional dentition on oral function and quality of life of older people, particularly regarding mastication and food selection. As Mediterranean Diet (MD) is one of the healthiest diets associated with increased longevity and decreased morbidity, I decided to investigate how various oral factors, and particularly dental status, may affect adherence to MD. Moreover, my previous experience in the outreach training of Gerodontology in Municipal Day Centers for Older People highly motivated me to focus on this population group that presents the greatest oral health needs and may benefit the most from adherence to Mediterranean Diet.

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BACKGROUND

1. THE MASTICATORY SYSTEM IN OLDER PEOPLE

1.1 Definitions

According to the Glossary of Prosthodontic Terms (2017) the stomatognathic system includes the combination of structures involved in speech, receiving food, mastication, and deglutition as well as parafunctional actions. In addition, the stomatognathic system contributes to the maintenance of the posture of the head, mandible, tongue and hyoid bone *(Thompson 1954).*

The masticatory system, specifically, is comprised of the organs and structures primarily functioning in mastication, including the teeth with their supporting structures, craniomandibular articulations, mandible, positioning and accessory musculature, tongue, lips, cheeks, oral mucosa, and the associated neurologic complex *(The Glossary of Prosthodontic Terms 2017)*.

In the ageing process, the masticatory system undergoes several changes, in morphology and function; some of them are true age-related changes and others are related to various environmental effects.

1.2 Dental status in older people

With increasing age, older people tend to have fewer teeth and higher rates of tooth loss *(Kelly et al 1998; Kossioni 2013)*. Tooth loss, is one of the most important indicators of poor oral health and reflects the amount of oral diseases and conditions to which older people have been exposed during life-course. Tooth loss negatively affects oral function, oro-facial aesthetics, and quality of life in older adults *(Gkavela 2019; Niesten and McKenna 2020)*.

In 2015, edentulism (complete tooth loss) affected almost 276 million people worldwide *(Kassebaum et al 2017)*. Edentulism is still common in older populations with differences between countries and regions *(Petersen et al 2010; Kossioni 2013; Peltzer et al 2014)*. The prevalence of edentulism in people aged

over 65 years in Europe varied between 4 and 45% in 2017 *(CECDO & EEA database)*, while in Athens, Greece, it was 15.6% in 2019 *(Gavela et al 2020)*. On the other hand, the number of remaining teeth, especially in people aged over 75 years, is less than 20 in most countries *(Kossioni 2013)*. Only 43.8% of community-dwelling Greeks aged over 65 years in Athens, Greece have more than 20 teeth, and 15.6% have less than 11 teeth *(Gavela et al 2020)*. Tooth loss increases with care dependency, as 39.6% of older people hospitalized for psychiatric conditions in Athens were completely edentulous and only 15.3% had more than 20 teeth *(Kossioni et al 2012)*. Based on these epidemiological data, at least in high-income countries, few older people have a 20-tooth functional dentition, with potential negative effects on their masticatory function.

On the other hand, the use of removable dental prostheses increases with ageing. A total of 48% of older community-dwelling Greeks living in Metropolitan Athens used complete or partial dentures; 38% of those aged 65-74 years, 60% of those aged 75-84 years and 64% of those over 85 years of age *(Gkavela 2019)*. The majority (22.6%) used a complete maxillary denture *(Gkavela 2019)*. The use of dentures decreases in edentulous care dependent older people *(Kossioni et al 2012).*

Periodontal disease is the second most common oral disease worldwide *(Bascones-Martínez et al 2014)* with more than half a billion people having severe periodontal disease globally in 2015 *(Kassebaum et al 2017)*. The burden of periodontitis is still prevalent in industrialised countries, leading to irreversible and cumulative tissue damage.

1.3 Jaw muscles and function in older people

Age related changes affect various structures and organs of the stomatognathic system, such as teeth, oral mucosa, salivary glands, masticatory muscles, temporomandibular joints and mandibular morphology *(Schimmel and Abou-Ayash 2020)* and may result in changes in jaw muscles' mass and strength, orofacial reflexes, tongue motor function, swallowing, mastication, oral sensitivity, taste and smell.

With increasing age, and particularly after the age of 60 a significant decline is recorded in fat-free mass, appendicular skeletal muscle mass and strength, body cell mass, and total body potassium in both men and women, while fat mass continues to increase until the age of 75 *(Larsson 1995; Kyle et al 2001; Hamrick et al 2016)*. The muscle mass of a 70-year man is approximately 15% less than that of a 20 year old man, while this variation is 11% in women *(Gallagher et al 1997)*.

Jaw muscle motor performance shows smaller age-related changes in healthy older people compared to other body muscles, particularly when teeth and oral function are maintained *(Kossioni & Karkazis 1998)*. For example, simple masseteric reflex activity is retained until very old age *(Kossioni & Karkazis 1998)*. Newton et al (1993) investigated the effects of ageing and dental state in the cross-sectional area and density of the masseter and the median pterygoid muscles using computed tomography in males and females aged between 20 and 90 years old and found that both measurements decreased with age *(Newton et al 1993)*. However, the cross-sectional areas of both muscles showed greater reduction in edentulous adults *(Newton et al 1993*). This is in agreement with other studies showing significant differences in the thickness of masseter muscle between dentate and edentulous patients *(Mayil et al 2018)*.

Maximum bite force significantly decreases when natural teeth are lost. Denture wearers have less masticatory muscle strength *(Heath 1982; Carlsson 1984)* spend more time in chewing *(Helkimo et al 1978; Heath 1982)* and present 2.57 times higher masticatory muscle activity compared to dentate persons as they may apply increased mechanical efforts to prepare a bolus *(Uram-Tuculescu et al 2015).* There is a large variation in the recorded maximum bite force in various studies due to differences in the methodology applied. However, it appears that healthy dentate persons can generate unilaterally recorded average maximum bite forces, ranging from 300 to 850 N *(van der Bilt 2011)*. These forces are high enough to cut and grind all kinds of hard and tough foods. However, the average unilaterally recorded maximum bite force of complete denture wearers ranges from 77 to 135 N *(van der Bilt 2011)*. These forces may not be capable to grind and cut many types of food, such

as boiled meat, where biting forces of over 80 N are required; raw carrot, where forces over 118 N are required; or rye bread where 167 N are required *(Eerikäinen & Könönen 1987)*.

With increasing age there are also changes in the tongue muscles, maximal tongue pressure, movement of the mandible during mastication and swallowing function *(Karlsson et al 1991; Koshino et al 1997; Robbins et al 2016; Suzuki et al 2020)*.

1.4 Mastication in older adults

Mastication is a complex sensorimotor task conducted by the coordinated activity of the facial muscles, the elevator and suprahyoidal muscles, teeth, lips, cheeks, palate, tongue, salivary glands, and temporomandibular joints under the control of the central nervous system *(Laguna & Chen 2016; Peyron et al 2017; Schimmel & Abou-Ayash 2020)*. It is one of the most important functions of the stomatognathic system, associated with fragmenting the food into chewable portions by the incisors, transporting it into the oral cavity, fragmenting it into smaller pieces by the teeth, and moistening it with saliva in order to be safely swallowed *(Laguna & Chen 2016; Peyron et al 2017; Schimmel & Abou-Ayash 2020)*. Chewing is usually continued longer after the required particle size is reached, by mixing the solid particles with saliva in order to achieve the necessary viscosity, cohesiveness and stickiness of the bolus *(Peyron et al 2017)*. Chewing is important not only for the consumption and digestion of food, but also for the appreciation and pleasure of food texture and food flavour *(Chen 2009).*

It is important to notice that there is an increasing discussion on the association between poor masticatory function and physical frailty in older adults potentially induced by the nutritional pathway *(Dibello et al 2021; Konstantopoulou & Kossioni 2021)*. Therefore, the assessment of masticatory function in older people is becoming increasingly important, particularly when protein-energy malnutrition, dysphagia, sarcopenia, and frailty are implicated *(Murakami et al 2015; Schimmel et al 2015; Kossioni 2018; Watanabe et al 2020; Dibello et al 2021)*.

There has been a confusion in the literature regarding the terminology and the methodology to evaluate the masticatory process. Sometimes, similar terms are used to describe different methodologies, or the same methodologies are described using different terms, making difficult the comparison between studies.

An older definition described masticatory performance as the number of chews necessary to render food ready for swallowing *(Chauncey et al 1984)*. Based on the Glossary of Prosthodontic Terms (2017) "masticatory performance is the measure of the comminution of food, attainable under standardized testing conditions", while masticatory efficiency is "the effort required to achieve a standard degree of comminution of food» *(The Glossary of prosthodontic terms 2017)*.

A recent consensus paper stated that masticatory performance (or often chewing performance) records the individual's ability to fragment or mix a specimen of test food (natural food of artificial test material) after a predetermined number of masticatory cycles and the test must be accompanied by a description of the method employed (Gonçalves et al 2021). On the other hand, masticatory efficiency refers to the number of chewing cycles necessary to achieve a particular particle size and is calculated after multiple numbers of fixed chewing cycles *(Gonçalves et al 2021)*.

Masticatory function can be evaluated both objectively and subjectively. The subjective assessment of masticatory function, called self-assessed masticatory function, or by others chewing ability, is evaluated using questionnaires and interviews. Masticatory performance and masticatory efficiency are usually used to describe the objectively measured masticatory function. The assessment of masticatory function may include a) direct objective assessment tests such as comminution tests, mixing ability tests, or the swallowing threshold, b) indirect objective assessment using kinematics, jaw muscle activity recordings, tongue and lip motor function, and c) subjective assessment using related questionnaires *(*Gonçalve*s et al 2021)*.

The comminution tests measure the particle size of specific test foods, natural or artificial, after a specific number of chewing cycles, using the single sieve, multiple sieves or optical scanning method *(van der Bilt 2011; Gonçalves et al 2021)*. The mixing ability tests evaluate the form and colour of a bolus,

after chewing artificial food for a specific number of chewing strokes *(Gonçalves et al 2021)*. These tests include the use of colour-changing chewing gum, two-coloured chewing gum or wax *(Gonçalves et al 2021)* and the outcome is evaluated visually or opto-electronically *(Halazonetis et al 2013)*. Two-coloured chewing gums have been used to assess masticatory function in various populations, such as denture wearers *(Schimmel et al 2017; Silva et al 2018)*, implant overdenture users *(Schimmel et al 2017)*, and patients recovering from stroke *(Schimmel et al 2011)*. On the other hand, mixing ability tests depend less on maximum bite force and they may not be suitable for assessing changes of bite force *(Enkling et al 2020; Gonçalves et al 2021)*.

Masticatory performance has been associated with a large variety of general and oral factors, with many of them being affected by age related parameters. It has been associated with gender *(Leles et al 2019)*, various oral parameters including number of teeth *(van der Bilt 2011)*, use and quality of removable dentures *(van der Bilt 2011; Müller 2012; Schimmel et al 2017)*, periodontal disease *(Barbe et al 2020; Kosaka et al 2016)*, bite force *(Ikebe et al 2012),* and saliva secretion *(van der Bilt 2011; Ikebe et al 2012)*, and with general medical condition including cerebrovascular accident *(Schimmel et al 2017)*, cognitive impairment *(Elsig et al 2015; Klotz et al 2020)* and rheumatoid arthritis (Andrade 2018). It should be noted that although some studies have recorded changes in masticatory performance with increasing age *(Leles et al 2019; Arakawa et al 2020)*, these may be limited in healthy dentate individuals *(Peyron et al 2017)*.

1.5 Xerostomia and hyposalivation

Xerostomia (dry mouth) is the subjective perception of oral dryness while hyposalivation refers to the objective reduction in salivary flow rate *(Navazesh &Kumar 2008)*. Xerostomia and hyposalivation are often associated. Sometimes xerostomia exists in patients with normal salivary gland function, normal salivary composition, and normal salivation rates. Moreover, patients with very low salivation rates do not always experience xerostomia *(Guggenheimer & Moore 2003)*. Hyposalivation is considered when the flow rate of stimulated saliva is <0.5 - 0.7ml/min and that of unstimulated saliva is

<0.1mL/min *(Pedersen et al 2002; Navazesh 2003; Saleh et al 2015)*. Xerostomia is considered to occur when the normal unstimulated salivation rate decreases by 50% *(Dawes 2004)* and is a very common complaint among older adults.

The prevalence of xerostomia ranges between 12- 56% among community-dwelling older people reaching 40-60% in those living in institutions *(Ship et al 2002; Orellana et al 2006; Wiener et al 2010; Liu et al 2012; Gkavela 2019; Kossioni & Karkazis 1999, Kossioni et al 2012)*. Xerostomia symptoms (sometimes/always) among older people in Athens were recorded in 42% of those living in the community *(Gkavela 2019)* and in 45% of the hospitalised ones *(Kossioni et al 2012).* Also, xerostomia affects women more frequently compared to men *(Guggenheimer & Moore 2003; Niklander et al 2017)*.

Causes of xerostomia include medications, radiation therapy to the head and neck, and various underlying diseases such as Sjögren's syndrome, diabetes, cystic fibrosis, autoimmune diseases depression etc *(Navazesh & Kumar 2008; Saleh et al 2015; Niklander et al 2017)*.

Ageing does not significantly affect salivary flow rates in the parotid and minor glands but whole, submandibular and sublingual rates are reduced in older adults *(Affoo et al 2015)*. The effect of age per se on salivary function requires further investigation *(Saleh et al 2015)*.

On the other hand, multimorbidity and polypharmacy are common in older adults *(Tran et al 2018; Wastesson et al 2018)* and medications' intake is the most frequent cause of xerostomia *(Saleh et al 2015; Tran et al 2018)* particularly associated with urological medications, antidepressants and psycholeptics *(Tran et al 2018)*.

An adequate amount of saliva is vital for maintaining oral health and function, including speech, mastication, swallowing and quality of life. Dry mouth is associated with higher risk of caries, periodontal disease, ulcerations, denture discomfort, candidiasis, difficulties in swallowing and chewing *(Pedersen et al 2002; Guggenheimer & Moore 2003; Turner et al 2008; Saleh et al 2015)*. The production of sufficient saliva is necessary to moisten the food and transform it into a bolus that can be easily swallowed *(Pedersen et al 2002).* Subjective eating and swallowing difficulties are closely associated

with lower saliva flow rate and bubbly saliva quality *(Gkavela 2019), w*hile low salivary secretion has been associated with lower masticatory performance *(Peyron et al 2017)*.

Moreover, tastants are dissolved in saliva and more easily transported to the taste buds, enabling the sense of food taste *(Guinard et al 1997)* that is essential in older people who frequently suffer from malnutrition *(Volkert et al 2019)*. Dry mouth can also affect the ability to retain and use dentures *(Turner et al 2008)*.

Xerostomia is assessed using questionnaires; the most commonly used one is the Xerostomia Inventory (XI) *(Thomson et al 1999)*. The XI has been validated in older Greek population and was found to have satisfying validity and reliability *(Gkavela 2019)*, while hyposalivation is measured by objective tests such as sialometry, with collection of stimulated or unstimulated whole saliva *(Navazesh and Kumar 2008, Gkavela 2019)* or by a dedicated clinical examination such as the clinical oral dryness score (CODS) *(Osailan et al 2012)*.

2. ORAL FACTORS, FOOD SELECTION AND NUTRITION IN OLDER ADULTS

Nutrition is closely associated with overall health and quality of life. Nutritional problems are often met in older people, related to a variety of factors but the evidence on the association between oral health, dietary choices and malnutrition is still open to debate.

2.1 Oral health, food selection and nutritional intake

Food selection is associated with various factors including visual and olfactory cues, taste, texture, temperature, appetite, preferences, habits, availability, sex, cognitive function, loneliness, medical condition, oral factors, education, culture etc *(Peyron et al 2017; Kossioni 2018, Volkert et al 2019; Schimmel and Abou-Ayash 2020)*.

Many studies have investigated the association between dental status and dietary choices with variable findings *(Kimura et al 2013; Tada & Miura 2014; Kossioni 2018; Toniazzo et al 2018)*. Although poor dental status is associated with chewing difficulties, its effect on food selection and nutritional intake is still open to debate *(Tada &Miura 2014, Gaewkhiew et al 2017, Kossioni 2018, O'Keeffe et al 2019)*.

In many studies, tooth loss and denture-wearing have been associated with dietary changes, including reduced consumption of specific food types like raw fruits and vegetables that are major components of the Mediterranean Diet, and increased consumption of softer foods *(Sheiham & Steele 2001; Sahyoun & Krall E. 2003; Naka et al 2014; Tada & Miura 2014; Jauhiainen et al 2017; Toniazzo et al 2018; Logan et al 2020)*. Reduced masticatory performance was associated with restricted food variety and limited consumption of beans, vegetables, seaweed and nuts in Japanese older persons *(Kimura et al 2013)*.

The discussion on the association between oral health and malnutrition is still open to debate. People with impaired dentition such as having no posterior pairs of teeth, having less than four pairs of remaining teeth or using complete dentures, had lower Healthy Eating Index scores, consumed

fewer servings of fruits, and had lower serum values of beta carotene and ascorbic acid, lower dietary intake levels of vitamin A, carotene, folic acid, and vitamin C, and scored less well on diet variety, cholesterol, and sodium components of the Healthy Eating Index. *(Sahyoun et al 2003)* Oral health status has also been associated with future dietary intake *(Logan et al 2020)*. Older adults with larger number of natural remaining teeth achieved better quality dietary intake than adults with lower number of teeth after an average study period of 13 years *(Logan et al 2020)*. More specifically, having 21 or more natural teeth was positively associated with future intake of fruits, vegetables, and nuts, and higher diet quality scores compared to those with 1–20 teeth or those with no natural teeth *(Logan et al 2020)*. A relationship between reduced masticatory function and poor diet has also been shown. *(Walls & Steele 2004; Kimura et al 2013; El Osta et al 2014)*

On the other hand, others did not find any association between edentulousness, oral health problems and malnutrition *(Bakker et al 2018).* Based on a meta-analysis by Toniazzo et al (2018), the number of functional tooth units and the mean number of teeth were significantly associated with nutritional status, while edentulism and use of dentures were not *(Toniazzo et al 2018).* Another systematic review did not find any significant association between mastication and nutrition and suggested that masticatory ability explains only part of the variance in food and nutrient intake in older people *(Tada & Miura 2014)*. Moreover, intervention studies did not reveal any changes in nutritional status after prosthodontic treatment, apart from cases where dietary counselling was offered *(Kossioni 2018)*. A systematic review of prospective cohort studies in all settings showed conflicting evidence that dental status, periodontal disease and swallowing are determinants of malnutrition and moderate quality evidence that chewing difficulties, mouth pain and gum problems are not determinants of malnutrition *(O'Keeffe et al 2019)*. However, as the authors concluded, strong robust evidence is lacking for many studies and better prospective cohort studies should be conducted.

An interesting finding was that older Greeks did not exclude specific food types from their diet, such as meat, nuts, fruits, and vegetables because of their dental status *(Anastassiadou & Heath 2002; Kossioni & Bellou 2011)*. They reported that they continue to eat difficult to chew foods, by adapting food preparing methods common in the local diet *(Anastassiadou & Heath 2002; Kossioni & Bellou 2011)*.

2.2 Dry mouth, swallowing problems, dysgeusia and nutrition

Dry mouth, difficulty in swallowing and dysgeusia are also factors that have been associated with nutritional problems *(Andersson et al 2004; Vanderwee et al 2010; El Osta et al 2014)*. Dry mouth has been associated with nutritional problems and low nutrient intakes, resulting in nutritional deficiencies *(Lee et al 2020)*. People with dry mouth presented reduced appetite and taste perception and, trouble eating dry foods *(Rusthen et al 2017; Tashbayev et al 2017)* and were 3.49 times more likely to be malnourished than others *(El Osta et al 2014)*.

3. MEDITERRANEAN DIET (MD) AND BENEFITS TO OVERALL HEALTH

Many different dietary patterns have been studied, concerning their benefits to overall health (*Gunge et al 2017; Gabriel* et al 2018*)*, but the MD, common in the Mediterranean area including Greece, has gained global recognition as one of the healthiest patterns of eating/living *(Willett et al 1995)*.

3.1 Main components of the Mediterranean Diet

The MD is the result of the complex interaction between the long history of people living in the Mediterranean area and the natural local food resources and has become a valuable medical tool in the modern world *(Trichopoulou & Lagiou 1997)*. The MD prevailed in the olive-growing areas of the Mediterranean region in the 1950s and 1960s and the first indications on its benefits derived from the Seven Countries Study that was largely based on Greek populations *(Keys 1980; Trichopoulou & Lagiou 1997)*. The MD is now a single entity of different diets prevailing in various Mediterranean regions that have olive oil as the main common component as well as other common characteristics *(Keys 1980; Trichopoulou & Lagiou 1997)*.

There is a variety of healthy diets and some components of the MD may overlap with other dietary patterns, whereas other aspects are unique. The first unique element of the MD is that fat intake is allowed, provided it comes from olive oil, tree nuts and fatty fish, and the second one is the moderate intake of wine during meals *(Trichopoulou et al 2009; Gea et al 2014)*. The main components of the MD include extra-virgin olive oil, as the main type of added and cooking lipid and the main source of fat, and also high consumption of vegetables, legumes, fruits, nuts, grains, and cereals *(Keys 1980; Willett et al 1995; Trichopoulou & Lagiou 1997; Trichopoulou et al 2003)*. The consumption of fish and seafood is moderate to high, depending on the proximity to the sea; that of dairy products, such as cheese, milk and yogurt is moderate to low*;* while meat and sweets are rarely consumed *(Keys 1980; Willett et al 1995;*

Trichopoulou & Lagiou 1997; Trichopoulou et al 2003). Finally, it includes regular but moderate intake of ethanol, mostly wine, during meals while other alcoholic beverages, like beers and liquors are rare *(Keys 1980; Willett et al 1995; Trichopoulou & Lagiou 1997; Trichopoulou et al 2003; Korre et al 2016; Martínez-González et al 2017)*

3.2 Benefits of the Mediterranean Diet to overall health

Nowadays, MD is highly recommended by many healthcare providers all over the world as one of the healthiest dietary patterns, associated with many benefits for the overall health.

A significant benefit is the reduction in mortality *(Trichopoulou et al 2003; Sofi et al 2010)*, even when modified to be consumed in other European countries *(Trichopoulou et al 2005)*. Many studies have shown that a healthy dietary pattern, like the MD pattern, was associated with lower incidence of chronic diseases, lower physical impairment in old age and lower risk of premature death *(Akbaraly et al 2013; Samieri et al 2013)*.

Another major benefit of the MD is the prevention of frailty *(León-Muñoz et al 2014; Ntanasi et al 2018; Veronese et al 2018; Woolford et al 2020)* and the protection from sarcopenia *(Mohseni et al 2017)*. According to a cross-sectional study by Ntanasi et al in a Greek population, a higher adherence to MD was associated with lower odds of frailty *(Ntanasi et al 2018)*. Moreover, MD has been associated with reduced risk of falling *(Ballesteros et al 2020)*.

The MD also contributes to the primary and secondary prevention of cardiovascular diseases *(Trichopoulou et al 2003; Dontas et al 2007; Psaltopoulou et al 2004; Sofi et al 2010; Wright 2011; Gotsis et al 2015; Capurso et al 2020; Shannon et al 2020)*. The MD has inverse associations with the incidence of cardiovascular events *(Estruch et al 2018)*, incidence of coronary heart disease *(Mente et al 2009)*, survival from coronary heart disease *(de Lorgeril et al 1994)* and incidence of thrombotic stroke *(Misirli et al 2012)*.

Also, the MD has protective abilities against cancer *(Trichopoulou et al 2003; Sofi et al 2010)* and is associated with lower incidence of cancer overall *(Benetou et al 2008; Couto et al 2011)*, and particularly breast cancer *(Trichopoulou et al 2010)* and colorectal cancer *(Bamia et al 2013)*.

There is also an association between adherence to the MD and reduced risk of metabolic diseases. *(Gotsis et al 2015; Huo et al 2015; Capurso et al 2020).* The MD is beneficial against the development of type 2 diabetes *(Mozaffarian et al 2007; Martínez-González et al 2008; Esposito et al 2010),* and the metabolic syndrome in adults *(Kastorini et al 2011; Huo et al 2015)*.

In addition, the MD has been associated with reduced risk of obesity, particularly when combined with physical activity *(Mendez et al 2006; Beunza et al 2010; Esposito et al 2011; Gotsis et al 2015; Konieczna et al 2020).* Adherence to MD has been associated with a favourable evolution of abdominal obesity *(Romaguera et al 2009)* and favourable weight changes *(Beunza et al 2010)*. As a result, MD has been recognised as more effective in obesity-related diseases prevention compared to many other diets *(Romagnolo et al 2017).*

Finally, many studies have confirmed the therapeutic ability of MD against many neurodegenerative diseases *(Sofi et al 2010; Gotsis et al 2015)*, the lower risk of symptomatic forms of knee osteoarthritis *(Veronese et al 2019)* and the benefits for cognitive health and depression *(Mantzorou et al 2021)*.

To the best of our knowledge, till today there are no studies investigating the effect of oral health on the adherence to MD in older Mediterranean populations.

MAIN PART

1. AIM

The aim of this study was to explore the association between oral factors and dietary choices among Greek community-dwelling older adults, including two objectives. The first objective was to investigate the effect of various demographic, social, medical, dental and denture-related factors on masticatory performance using a mixing ability test, and the second objective was to assess the impact of oral factors on the adherence to the MD.

2. MATERIALS AND METHODS

2.1 Study population

The study was conducted between June 2019 and March 2020 in Open Care Community Centers for Older People in Metropolitan Athens, Greece in areas of different socio-economic level that were preselected by the research team. The managers of these centers informed all members about the conduction of this study and its objectives, and those who were interested to participate made an appointment. Participants came for examination on specific days and hours and the examination was performed in private rooms, mainly medical offices. Before the examination, the participants received detailed information on the scope and methodology of the study by the researcher. All study participants signed appropriate written consent forms and the data were anonymously recorded and analysed. The study was approved by the Athens School of Dentistry Ethics and Research Committee (418/2019).

The study included interviews using structured questionnaires, clinical oral examination and recordings of masticatory performance (Appendix 1).

2.1.1 Inclusion- exclusion criteria

The inclusion criteria were being over 60 years of age, not having any urgent oral problem at the time of the investigation that might affect masticatory function or dietary choices and being able to

speak and understand the Greek language. The exclusion criteria were having cognitive or sensory problems affecting the ability to effectively communicate with the researchers and give written consent.

2.1.2 Sample size calculation

The G*Power 3.1.9.2 software was used to determine the appropriate sample size for objectives #1 and #2.

2.1.3 Reproducibility of testing

The interviews and the clinical oral examinations were performed by one dentist who was standardized according to an experienced examiner, after relevant theoretical and clinical training. Intra-observer reliability was tested in a sample of 15 older people by repeating the examination 15 days later, and a significant repeatability of the measurements was recorded. For example, the intra-observer variation for masticatory performance using Pearson Product Moment Correlation coefficient revealed high repeatability $r^2=1$, $p<0.001$.

2.2 Oral interviews

The interview recorded demographic information, such as gender, age, family status (married, divorced, widowed, unmarried), living alone, previous or current profession, education and income. The classification of education was based on the years of education (<6, 6-12, >12 years) and the classification of financial condition was based on the monthly family income (≤590 €, 591-1200 € and >1200€).

The questionnaire also recorded smoking history (active smoker, previous smoker, never smoked), medical condition based on the ICD-10 classification (International Classification of Diseases, 10th Revision), drugs' intake based on the ATC classification (Anatomical Therapeutic Classification

System), and body mass index (BMI). Participants were previously asked to bring their medical booklets and all medications they received at the period of the examination to record even the over-the-counter drugs. However, this was not always possible and for many participants the medical history and the drugs intake was based solely on their personal statement.

The dental history included dental visitation habits (more often than once per year, every year, every 2-3 years, when needed, never, don't remember, other), last visitation to the dentist (≤1 year, 1-5 years, 6-10 years, >10 years, never, don't remember), dental brushing habits (more often than once per day, once per day, not every day, never, other), and presence of oral problems at the time of the investigation (Appendix 1)

The participants were asked about the subjective assessment of their oral health (very poor, poor, moderate, good, very good), and the subjective assessment of their chewing function using a general question "can you chew your food well?" (not at all, poorly, moderately, well, very well) and more specific questions if they can chew steak, almonds, oranges (Appendix 1).

In addition, there were questions related to the use of dentures, partial or complete, either in the maxillary and/or the mandibular arch, the age of dentures (years), the displacement of dentures during speech and mastication, and the presence of pain associated with dentures' use (Appendix 1).

The evaluation of xerostomia was based on two methods:

a. Asking a general question: "does your mouth dry out"? (never, rarely, sometimes, often, always)

b. The completion of the Greek version of the Xerostomia Inventory *(Gkavela 2019)*. The Xerostomia Inventory consisted of eleven questions with five possible answers and a score ranging between 11 and 55; a higher score is associated with more dry mouth complaints.

The adherence to the MD was recorded using the MDI_BNC4H index *(Bamia et al 2017)*. The questionnaire consisted of 14 questions investigating the frequency of consumption of servings of

12 foods, common in the Mediterranean area, such as olive oil, fruits, vegetables, legumes, red meat, white meat, fish and shellfish, nuts and seeds (with and without salt), olives (with and without salt), cereals, dairy products, and wine. Each participant was asked to report the number of servings for each one of these items consumed per week or day during a typical week, over the past 3 months, with a subjective assessment of the serving size. Each question was scored with 0 for minimal adherence or 1 for maximal adherence to MD (range 0-14), based on cut-offs developed by the Credits4Health scientific consortium *(Bamia et al 2017)*. More specifically, score 1 was assigned for 3 or more servings of fruits per day, 4 or more servings of vegetables per day, 2 or more servings of legumes per week, 7 or more servings of cereals per day, consumption of olive oil every day always or mostly, 2 or more servings of fish/shellfish/seafood per week, less than 2 servings of red or white meat per week, 2 servings of dairy products per day, 4-5 servings of regular olives or 4-7 servings of low salted olives per week, 4-5 servings of salted or 4-7 servings of unsalted nuts and seeds per week and regarding wine consumption score 1 was assigned for 7 or less glasses of wine per week for women and 14 or less glasses of wine for men. The participants were also asked about following a specific diet, due to health problems (i.e. diabetes), allergy to specific food or personal/religious preferences (i.e. vegetarian, vegan).

2.3 Clinical oral examination

For the clinical oral examination, it was necessary to use a portable oral examination kit that included gloves, face masks, cotton swabs, gauzes, dental examination instruments, tongue depressors, infection control equipment and an examination torch. During the examination, all the necessary measures were taken to control infections.

The oral examination included the recording of the existing natural teeth, teeth mobility, number of posterior and anterior chewing pairs and removable prosthetic restorations' prevalence and quality.

The examination of tooth mobility was performed using the handles of 2 dental tools, according to the Miller's classification *(Miller 1950)*. The assessment of mobility depends on the size of movement, buccally and lingually or palatally. Horizontal movement of less than 1 mm was classified as grade #1 mobility, movement between 1mm and 2mm was classified as mobility grade #2 and movement more than 2 mm and/or vertical movement of tooth was classified as grade #3 mobility. Teeth with increased mobility were considered those with mobility grade #2 or #3 that were expressed as a percentage of the total number of remaining teeth.

The number of occlusal pairs included both natural and prosthetic teeth. Removable dental prostheses were evaluated in terms of retention, stability, occlusion, vertical dimension of occlusion and neuromuscular control. The modified Kapur Scale was calculated to evaluate complete dentures retention and stability *(Olshan et al 1992)*. The retention criteria were based on the resistance that dentures offered to vertical pull and lateral force. The retention score ranged from 0 (no retention) to 5 (excellent retention). The degree of complete dentures' stability was evaluated on a 5-point scale, ranging from 0 to 4. The classification was based on rocking on the supporting structures under pressure. Finally, the total score for retention and stability of maxillary and mandibular dentures was calculated by summing up the scores for both their retention and stability. Clinically poor denture pairs have scores <6, clinically fair dentures had scores 6-9, clinically good dentures had scores 10-14 and clinically very good dentures had scores>14 *(Olshan et al 1992)*.

The vertical dimension of occlusion was evaluated through the recording of the rest face height and the assessment of the freeway space. If the freeway space was over 4 mm the occlusal face height was scored as reduced. Occlusion was evaluated by assessing if posterior teeth met in occlusion when the participant clenched the teeth. Neuromuscular control of dentures was assessed by asking the participants to gently open the mouth; if the maxillary denture fell or the mandibular rose, they had been evaluated as lacking neuromuscular control *(Karkazis & Kossioni 1993)*.

2.4 Recordings of masticatory performance

The evaluation of the masticatory performance was carried out using a two-colour chewing gum (Hue-check Gum, University of Bern) (Figure 1). This test has been proved to be a simple, effective and clinically reliable method for the evaluation of masticatory performance *(Schimmel et al 2011)*. The chewing gum consisted of two parts, a pink and a bleu.

Figure 1. The two-colour Hue-check Gum, University of Bern

The two parts were wetted with water, stuck together, and given to the participant for chewing with the blue part facing down (Figures 2, 3).

Figure 2

Figure 3

Figure 2. The two-colour gum is wetted with water, Figure 3. The two-colour gum is placed in the mouth with the blue part facing down.

The gum was chewed for 20 cycles, in the patient's preferred chewing side or in both sides (Figure 4). After removal from the mouth and removal of the saliva, the gum was placed in a transparent plastic bag. Each participant had a special unique code that was marked in each plastic bag. The transparent plastic bag with the gum was then compressed on a wafer of 1mm thickness especially constructed at the Dental School of the NKUA for the reasons of this study (Figure 5). The degree of gum's colour mixing indicated the individual's masticatory performance.

Figure 4.

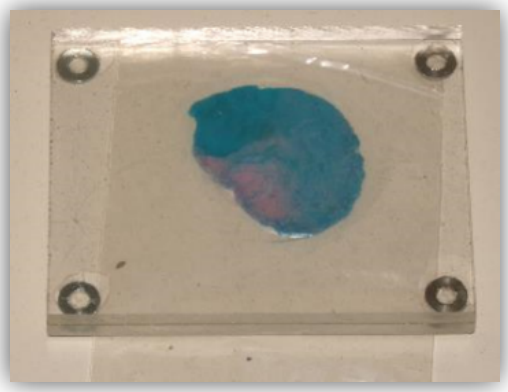

Figure 5.

Figure 4. The two-colour gum is chewed for 20 cycles, Figure 5. The transparent plastic bag with the gum bolus is compressed on a wafer of 1mm thickness especially constructed at the NKUA

The plastic bag with the gum was then scanned on both sides, using the EPSON_L386_Series scanner (settings: dpi 600, 24-bit-colour depth) and saved as a jpeg file. For each participant two jpeg files were scanned, one for each side (Figure 6). Scanning was performed within 24 hours from the time of chewing, as the colour of the gum may be modified with time by the action of various saliva enzymes.

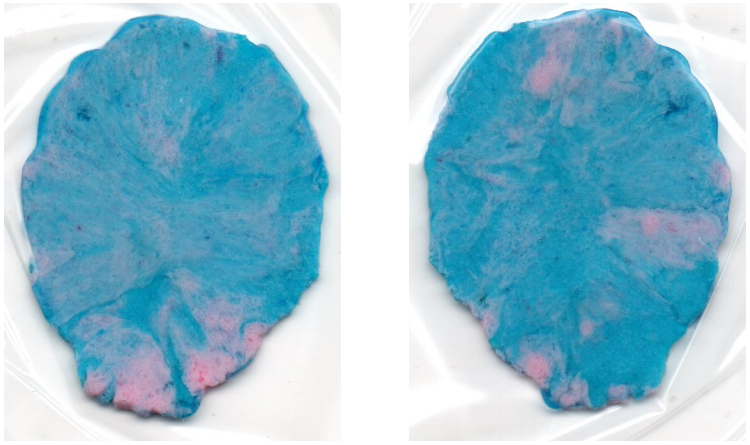

Figure 6. The two sides of the gum bolus are scanned

The final stage was the gum analysis using the View Gum software program (dHAL Software, Greece) with the hue variation representing the degree of mixing (Figure 7) *(Halazonetis et al 2013)*. The results were exported into excel and further anonymously statistically analysed. Higher values indicated lower masticatory performance.

At the end of the examination, the participants were informed about the findings of the clinical examination and the need of referral to a dentist for further examination/treatment. Also, they were given detailed oral hygiene and oral care instructions, both oral and printed.

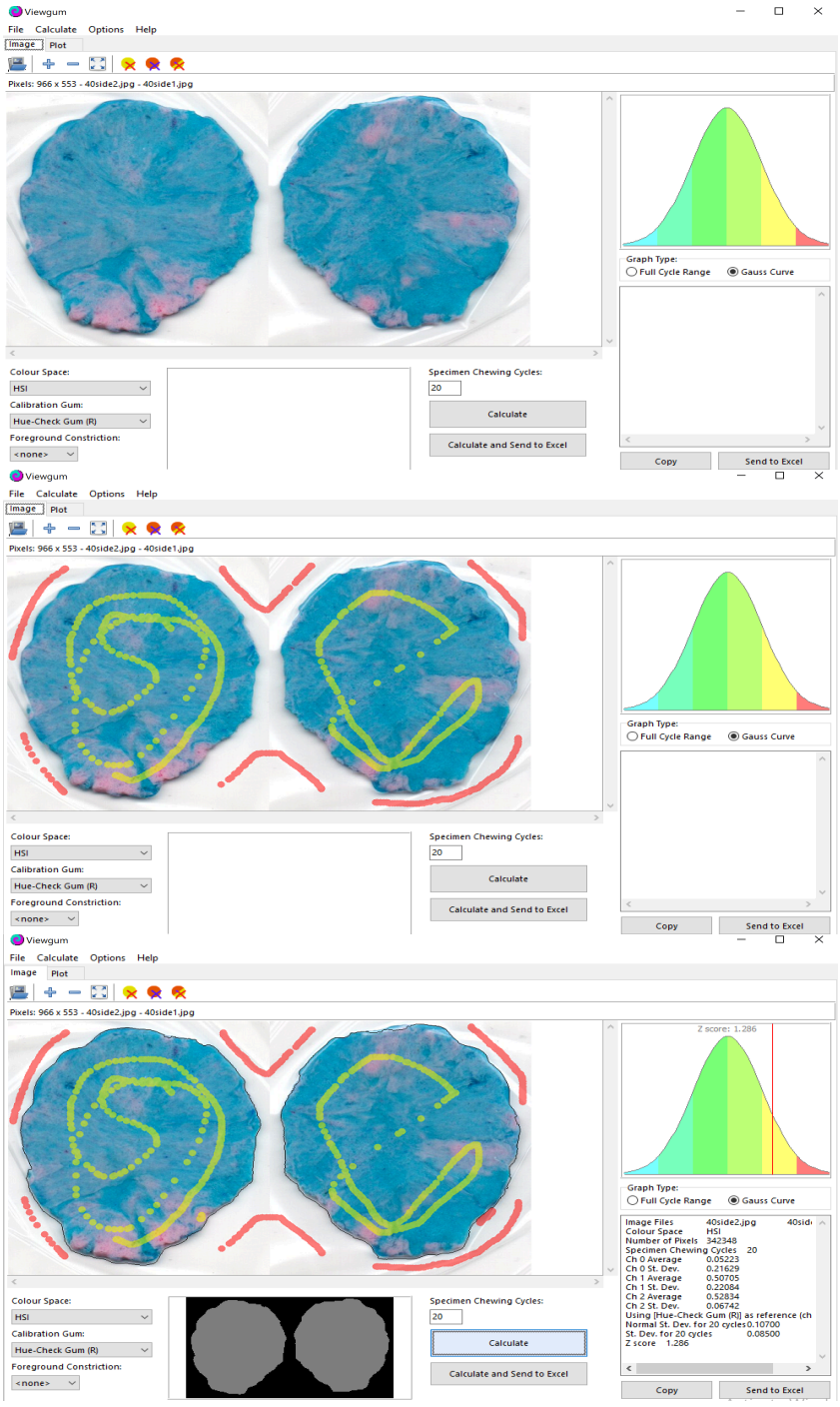

Figure 7. The gum bolus analysis using the View Gum software program (dHAL Software, Greece)

3. STATISTICAL ANALYSIS

The data analysis included descriptive statistics, univariate analyses and multivariable analysis models after anonymization of the records.

Descriptive analysis included frequencies, means, ranges, standard deviations, median values, and quantiles. The normality of distribution was tested by the Shapiro-Wilk test and in cases where the relevant conditions were not met, non-parametric tests were performed.

The univariate and multivariable models used as dependent variables the recordings of masticatory performance (objective 1) and the adherence to the MD score (objective 2) separately.

3.1 Univariate analyses

3.1.1 Dependent variable: masticatory performance

The statistical analysis using as dependent variable the recordings of masticatory performance included univariate quantile regression analyses and Kruskal-Wallis one-way analysis of variance on ranks tests. The independent variables were various sociodemographic factors (i.e. age, gender, marital status, education, income, living alone, smoking), medical factors (i.e. medical conditions, medications received, BMI), subjective oral health indicators (subjective oral health status, current oral problem, xerostomia, subjective chewing ability), last dental visit, dental visitation habits, frequency of oral hygiene, use of dentures and related complaints (dislocation during speech, dislocation during mastication and pain related to dentures' use), dental status indicators (number of natural teeth, number of occluding teeth contacts, tooth mobility) and denture quality indicators (retention, stability, occlusion, neuromuscular control).

3.1.2 Dependent variable: adherence to MD

The statistical analysis, using as dependent variable the adherence to the MD score, included univariate linear regression analyses and Kruskal-Wallis one-way analysis of variance on ranks tests. The independent variables included all the previously described (#3.1.1) sociodemographic, medical and dental factors plus masticatory performance.

3.2 Multivariable analyses

3.2.1 Dependent variable: masticatory performance

Independent variables that were statistically significantly or marginally significantly associated with masticatory performance were included in a multivariable quantile regression analysis with backward elimination of nonsignificant predictors (deletion criterion p>0.10) *(*Greenland & Pearce 2015; *Chowdhury & Turin 2020)*.

3.2.2 Dependent variable: adherence to MD

Independent variables that were statistically significantly or marginally significantly associated with the dependent variable were further analysed using multivariable linear regression modelling with backward elimination of nonsignificant predictors (deletion criterion p > 0.10)

The level of statistical significance was set at $p \leq 0.05$. The analysis was performed using statistical software (STATA® 16, Statacorp, College Station, Texas, USA, & IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.).

4. RESULTS

4.1 Sociodemographic, medical and oral characteristics of the sample

4.1.1 Sociodemographic characteristics

A total of 130 persons over 60 years of age (mean age 73.9 ± 8.5 years) participated in this study;97 women and 33 men. Sixty-nine persons (53.1%) were aged between 60 and 74 years; 43 (33.1%) between 75 and 84 years, and 18 (13.8%) over 85 years (Table 1.1). Many participants (40.8%) were living alone. The majority were either married (48.5%) or widowed (46.2%). Regarding the educational level, the majority (46.5%) had received ≤6 years of education and only 41 (31.5%) more than 12 years.

4.1.2 Medical history, smoking, drugs intake, BMI

Concerning their medical history, the most common diseases were endocrine, nutritional and metabolic disorders observed in 90 participants (69.2%), diseases of the circulatory system observed in 86 participants (66.2%), diseases of the musculoskeletal system and connective tissue in 33 (25.4%) and digestive system disorders in 22 participants (16.9%). Only 16 participants (12.3%) were active smokers at the time of the study (Table 1.2). Their mean BMI was 28.5±4.7 (range: 20.3-49.0). They received 3.1±2.3 drugs per day (range: 0-13), mostly for the cardiovascular system (95, 73.1%), alimentary tract and metabolism (56, 43.1%), hormonal preparations excluding sex hormones and insulins (40, 30.8%) and nervous system medication (30, 23.1%) (Table 1.3).

4.1.3 Subjective assessment of oral status and self-assessed masticatory ability and xerostomia

A total of 72 participants (55.4%) reported that they had very good or good oral health status, while 29.2% reported that they had oral problems at the time of the investigation (Table 1.4).

A total of 111 (85.4%) reported that they had “very good” or “good” masticatory ability, 14 (10,8%) moderate masticatory ability and 5 (3,8%) a poor or very poor one (Table 1.4). When asked questions about chewing specific food types, all participants reported that they could chew oranges, while 13.1% could not chew steaks and 10.8% could not chew almonds.

The mean xerostomia index score was 15.5±7.1 and ranged from 11 to 47. A total of 32 (24.6%) of the participants had xerostomia index scores over the 75th percentile (Table 1.4).

4.1.4 Dental visitations and oral hygiene habits

Fifty-nine participants (45.4%) had visited a dentist in the past year (Table 1.5), but the majority (94, 72.3%) reported that they visited the dentist only when dental problems occurred. A total of 97 participants (74.6%) made a dental appointment less often than every 2 years (Table 1.5). The frequency of oral hygiene was at least once per day for most of the participants (115, 88.5%), while 15 participants cleaned their teeth or dentures less often than once per day.

4.1.5 Removable dentures use and complaints

A total of 58 participants (44.6%) were using removable dentures and 20 (15.4%) were using a pair of complete dentures; 24.6% were using at least one complete denture, while 23.8% were using at least one partial denture (Table 1.6).

For those wearing a maxillary complete or partial denture, 12.5% reported dislocation, always or rarely, during speech; 14.6% dislocation, always or rarely, during mastication; and 12.5% pain caused by their denture, always or rarely. For those wearing a mandibular denture, dislocation was met, always or rarely, in 11.6% during speech, and in 25.6% during mastication, while 14% reported that they had always or rarely pain caused by their mandibular denture.

4.1.6 Dental status

Fifty-nine participants (45.4%) had more than 20 teeth, 30 (23.1%) had from 11 to 20 teeth, and 20 (15.4%) were edentulous (Table 1.7). Among the dentate, the mean number of teeth was 18.7±8.3

(range 1-31). The mean number of chewing contacts between natural or prosthetic teeth was 10.5±3.1 (range: 2-16), with the majority of the participants (61.5%) having more than 10 chewing contacts. Sixteen participants (14.5%) presented tooth mobility grade #2 or #3 in more than 10% of their teeth.

4.1.7 Assessment of dentures

The majority of the maxillary complete denture wearers (73.1%) had acceptable retention and stability of their denture (Kapur Index >5), in contrast to only 28% among mandibular complete denture wearers.

4.1.8 Assessment of masticatory performance

The mean variance of the hue was 0.27 ± 0.21 with a range of 0.02-0.76 and median value 0.19.

4.1.9 Adherence to MD

The adherence to the MD score was 5.6±1.4 and ranged from 3 to 9; 65 participants (50%) presented low adherence to MD, 31 (23.8%) moderate, and 34 (26.2%) high.

4.2. Sociomedical and oral factors affecting masticatory performance

Tables 1.1- 1.7 present the univariate analyses between sociodemographic, medical and oral factors and masticatory performance in the participants.

4.2.1 Sociodemographic and medical factors

Concerning the sociodemographic characteristics of the sample, the only parameters that were statistically significantly associated with better masticatory performance were younger age (p=0.002) and being widowed compared to unmarried (p=0.004). Gender, education, income and living alone were not significant modifiers (Table 1.1).

Medical conditions, BMI and smoking, were not statistically significantly associated with masticatory performance, as shown in Table 1.2.

The lack of significant associations between masticatory performance and different medications as well as the number of daily drugs' intake is presented in Table 1.3.

4.2.2 Subjective oral health indicators

The association between subjective oral health indicators and masticatory performance is presented in table 1.4. The parameters that were statistically significantly associated with lower masticatory performance were moderate/poor/very poor subjective chewing ability ($p=0.001$), poor ability to chew steak ($p=0.024$) and poor ability to chew almonds ($p=0.015$), while subjective oral health status and the existence of a current oral problem were not statistically significantly associated with the dependent variable. Although higher scores of the Xerostomia Inventory were associated with lower masticatory performance, this association was not statistically significant.

4.2.3 Dental visitation and oral hygiene habits

Table 1.5 reveals that dental visitation and oral hygiene habits were not statistically significantly associated with masticatory performance.

4.2.4 Dentures' use and complaints

Table 1.6 presents statistically significant associations between lower masticatory performance and use of removable dentures ($p<0.001$), use of complete dentures ($p<0.001$), use of maxillary ($p<0.001$) and mandibular ($p<0.001$) complete dentures and finally use of a pair of complete dentures ($p<0.001$). On the other hand, the use of partial dentures, either maxillary or mandibular, was not significantly associated with masticatory performance.

Only pain caused by the use of the maxillary denture was a subjective oral complaint marginally related with lower masticatory performance ($p=0.05$).

4.2.5 Dental and dentures' examination

Concerning dental status, a significant association was found between lower masticatory performance and being edentulous ($p<0.001$), having fewer teeth ($p<0.001$), having severely mobile teeth ($p=0.011$), having fewer posterior chewing pairs ($p=0.005$) and having fewer chewing contacts, either natural or prosthetic ($p=0.013$) (Table 1.7). Lower masticatory performance was also significantly associated with poor retention of mandibular partial denture ($p=0.033$) and poor occlusion in denture wearers ($p=0.029$).

4.2.6 Multivariable analysis

All the above-mentioned parameters that were statistically significantly associated with masticatory performance were further analysed using multivariable quantile regression analysis with masticatory performance being the dependent variable. The results of this analysis were shown in Table 1.8.

Smaller number of natural teeth (95% CI: −0.02 to −0.01, $p<0.001$), being edentulous and

using of a pair of complete dentures (95% CI: 0.09–0.35, $p=0.001$), and having a larger percentage of severely mobile teeth (95% CI: 0.07–0.82, $p=0.020$) were associated with lower masticatory performance.

4.3 Oral factors and adherence to MD

4.3.1 Sociodemographic and medical factors

The association between sociodemographic characteristics of the sample, such as gender, age, marital status, education, monthly income and living alone, and adherence to the MD was not statistically significant ($p>0.05$).

From all the medical factors that were examined, only mental and behavioral disorders were statistically significantly associated with adherence to the MD ($p=0.043$) (Table 2.2). Participants

with higher BMI presented statistically significantly lower adherence to the MD (p=0.041), as well as active smokers (marginally) (p=0.053) (Table 2.2).

No significant associations were found between all the categories of medications and adherence to MD, except for the number of drugs' intake per day, with those receiving more medications presenting marginally lower adherence to the MD (p=0.056) (Table 2.3).

4.3.2 Subjective oral health indicators

Concerning the subjective oral health indicators, only the existence of a current oral problem was statistically significant associated with lower adherence to MD (p=0.042), but not the Xerostomia Inventory scores or subjective chewing ability, although better adherence was recorded in participants with fewer xerostomia and chewing complaints (Table 2.4).

4.3.3 Dental visitation and oral hygiene habits

Dental visitation and oral hygiene habits were not statistically significantly associated with adherence to MD (Table 2.5).

4.3.4 Dentures use

The use of removable dentures was not significantly associated with adherence to MD (Table 2.6).

4.3.5 Dental and dentures' examination

All dental status indicators were not significantly associated with adherence to MD, except for masticatory performance (p=0.05) (Table 2.7). Among denture wearers, the only factors that were significantly associated with adherence to the MD were the occlusion (p=0.029) and the centric relation (p=0.038).

4.3.6 Multivariable analysis

The multivariable analysis resulting by backward elimination of nonsignificant predictors revealed that lower adherence to MD was significantly associated with higher BMI ($p = 0.047$) and lower masticatory performance ($p = 0.050$) (Table 2.8).

5. Discussion

The results of the present study, based on the multivariate regression analysis models, indicated that better masticatory performance and lower BMI were significantly associated with better adherence to MD. In addition, fewer teeth, the use of complete dentures (as an indicator of edentulousness) and increased percentage of mobile teeth were significantly associated with lower masticatory performance using a mixing ability test.

5.1 Factors affecting masticatory performance in older adults

The univariate analyses in the present study revealed several associations between general and oral factors, and masticatory performance using a mixing ability test. Lower masticatory performance was recorded in older participants, in the widowed ones, in edentate people and complete denture wearers, in those complaining about poor chewing ability or pain caused by maxillary denture use, in persons with fewer natural teeth and fewer occluding pairs of teeth (natural and prosthetic) particularly in the posterior area of the dental arch, and in those with many teeth with increased mobility. On the other hand, the medical conditions and the drugs' intake did not affect masticatory performance. Likewise, masticatory performance was not associated with the quality of the dentures or the xerostomia scores. However, when a multivariable analysis was performed, only fewer natural teeth, being edentulous and using a pair of complete dentures and increased percentage of mobile teeth remained statistically significantly associated with lower masticatory performance.

The method used to assess masticatory performance was a mixing ability test using a two-colour chewing gum. The test is simple, quick, and easy to perform in medical and dental offices as well as in geriatric wards and nursing homes *(Gonçalves et al 2021)*. The test is appropriate for geriatric patients as it has been used in patients with dysphagia *(Schimmel et al 2011)*, dementia *(Weijenberg et al 2013)* and impaired dentition, such as complete denture wearers *(Speksnijder et al 2009; van der Bilt 2011; Schimmel et al 2017; Silva et al 2018)*.

Although a large number of sociodemographic and medical factors were included in the analysis, the masticatory performance using a mixing ability test was affected only by oral factors such as edentulousness, number of teeth and tooth mobility. The multivariable analysis did not reveal any age or gender effects on masticatory performance in contrast to some previous studies *(Leles et al 2019; Arakawa et al 2020)*. Moreover, the Xerostomia Inventory scores were not significantly associated with masticatory performance in contrast to some previous related findings *(van der Bilt 2011; Ikebe et al 2012)*. It should be noticed that mixing ability tests are less dependent on the saliva flow rate; this is important when applying this method in geriatric patients who frequently present oral dryness.

Self-assessment of masticatory function was not associated with the objectively recorded masticatory performance in the multivariable analysis. This may be explained by the fact that many persons, and particularly older complete denture wearers, often overestimate their subjective masticatory function *(van der Bilt 2011; Pedroni-Pereira et al 2018; Gonçalves et al 2021)*.

5.1.1 Tooth loss and masticatory performance

The number of remaining teeth and being edentulous using complete dentures had a significantly negative impact on masticatory performance, in agreement with many previous findings *(van der Bilt 2011; Kugimiya et al 2020; Montero et al 2021)*. People with more than 20 teeth have fewer chewing difficulties *(Helkimo et al 1978; Witter et al 1990; Sheiham et al 1999)* and when missing teeth are not replaced, the masticatory function deteriorates *(Pereira et al 2015)*. In the present study, the masticatory performance of persons with 11–20 teeth was almost two times lower compared to those with more than 20 teeth. In those with 1–10 teeth it was three times lower, while in the edentulous ones using complete dentures it was five times lower.

The significant effect of occlusal support/ functional tooth units on masticatory function has been reported in many previous studies *(Kossioni & Karkazis 1999; Sheiham et al 1999; Fontijn-Tekamp et al 2000; Ikebe et al 2012; Naka et al 2014; Klotz et al 2020; Montero et al 2021)*. In the present study those with more than ten occluding teeth contacts had almost twice higher masticatory performance values compared to those with less than six, but a relevant association was only recorded in the univariate analysis.

Another finding was the significant association between using a pair of complete dentures and poorer masticatory performance. Being edentulous and using complete dentures is associated with lower masticatory performance compared to having natural teeth, using partial dentures or implant-supported prosthetic restorations *(Müller et al 2012; Schimmel et al 2017; Klotz et al 2020)*. Generally, complete denture wearers experience difficulties during mastication due to reduced maximum bite forces *(Müller et al 2012; Schimmel et al 2017)* poor retention and stability of dentures, and denture-associated pain in the oral tissues *(Veyrune et al 2007; van der Bilt 2011)*. They tend to chew for longer periods, with an increased number of chewing strokes at a decreased rate, and they often swallow bigger food particles compared to the dentate adults *(Veyrune et al 2007; van der Bilt 2011;* Woda et al 2006*)*. It should be noticed that in Athens, the prevalence of community-dwelling older people wearing a pair of complete dentures was 14.8% *(Gkavela 2019),* while all edentulous persons in the present investigation used a pair of complete dentures.

The multivariable analysis has shown that the subjective and objective denture quality indicators, including patients' complaints about dislocation during function and the objective evaluation of retention, stability, and dentures' occlusion, were not significantly associated with masticatory performance, as opposed to the findings in previous studies *(Eberhard et al 2018; Elmoula et al 2018; Leles et al 2019; Klotz et al 2020]*. This finding may be associated with the successful neuromuscular adaptation to the use of dentures that was recorded in all edentulous persons, revealing the importance of denture construction techniques enhancing neuromuscular adaptation such as copy dentures and recordings of the neutral zone.

5.1.2 Tooth mobility and masticatory performance

The multivariable analysis has shown that increased percentage of severely mobile teeth had a significantly negative impact on masticatory performance. This finding is very important considering the large prevalence of periodontal disease in older adults *(López et al 2017)*. Periodontal disease has been associated with lower masticatory performance as the compromised periodontal support may impair masticatory activity and occlusal forces *(Gilbert & Newton 1997; Takeuchi & Yamamoto 2008; Kosaka et*

al 2016; Palinkas et al 2019; Barbe et al 2020; Lamba et al 2020). Moreover, the electromyographic activity of anterior temporalis and masseter muscles was found to decrease in patients with chronic periodontitis *(Lamba et al 2020)*.

Based on these findings a thorough periodontal examination should be considered when evaluating masticatory function in older adults, and masticatory performance may be included in the periodontal disease treatment planning and outcomes *(Palinkas et al 2019; Barbe et al 2020)*.

5.2 Oral factors affecting adherence to the MD

This study investigated the effect of several medical and oral factors on the adherence to the MD. Based on the univariate analyses being a non-smoker, having a lower BMI, receiving lower number of medications per day, and having better masticatory performance were significantly, or marginally significantly, associated with better adherence to MD. The multivariable analysis has, however, shown that only better masticatory performance and lower BMI were significantly associated with better adherence to MD.

5.2.1 Adherence to MD and BMI

In the present study, the BMI of the participants was 28.5±4.7 and ranged between 20.3 and 49. In agreement with previous studies in the older local population *(Panagiotakos et al 2004)*, more than half (51.5%) of the participants had a BMI score between 25.0 and 29.9 kg/m^2. The lower BMI in persons with better adherence to MD confirms previous findings that following a MD pattern is associated with lower risk of weight gain and developing obesity, particularly when combined with physical activity *(Mendez et al 2006; Esposito et al 2011)*. Other studies have not revealed any association between BMI and adherence to MD, probably as a result of the westernisation of the MD and the limited physical activity *(Trichopoulou, Naska et al 2005)*.

5.2.2 Adherence to MD and oral factors

Most oral factors, apart from masticatory performance, were not associated with better adherence to MD in the multivariable analysis.

There has been a long discussion on the potential association between oral factors and nutrition but the findings remain inconclusive *(Kossioni 2018; O'Keeffe et al 2019)*, with many studies showing that dental parameters such as the number of teeth, the number of occluding teeth contacts, and the use and quality of dentures do not necessarily predict dietary choices and nutritional intake in many populations *(Kossioni & Bellou 2011; Wallace et al 2018; Nomura et al 2020)*. The scientific evidence points at the multifactorial nature of dietary choices in older people, apart from the quality of dental status *(Schimmel et al 2015; Kossioni 2018)*.

On the other hand, better masticatory performance was associated with better adherence to MD. It can be speculated that participants with better masticatory performance can have a large variety of dietary choices associated with MD such as fruits, vegetables, nuts and cereals that are often difficult to chew. Based on previous studies, older Greeks did not exclude from their diet any type of food because their dental condition *(Anastassiadou & Heath 2002; Kossioni & Bellou 2011)*. A possible explanation offered was the local food preparing strategies based on the MD pattern such as vegetables cooked in olive oil.

Poor masticatory performance may affect dietary choices leading to malnutrition and increased risk for sarcopenia and frailty *(Iwasaki et al 2018; Watanabe et al 2020)*. Low maximum bite force, seemed to increase the risk for developing frailty, irrespective of dental status *(Iwasaki et al 2016)*. Moreover, a simple masticatory performance test using a colour-changing chewing gum has been proposed as a useful early indicator of frailty in older adults *(Watanabe et al 2020)*.

Another potential association may be related to the MD myoprotective action. MD is associated with lower odds of frailty and sarcopenia due to various reasons such as positive effects on chronic medical conditions, antioxidant and anti-inflammatory properties and sufficient intake of multiple myoprotective micronutrients and proteins *(León-Muñoz et al 2014; Mohseni et al 2017; Ntanasi et al 2018)*.

This protective effect of MD may be extended to masticatory muscles, as masticatory performance is independently associated with generalised sarcopenia *(Murakami et al 2015)* and frailty *(Iwasaki et al 2018; Watanabe et al 2020)*.

5.3 Study Limitations and further studies

There are some limitations in the present study. The cross-sectional design and the recordings in only functionally independent urban older persons restrict the generalisation of the findings to other older groups living in rural areas or having various levels of functional dependencies. However, as most known confounders were taken into consideration in the statistical analysis, the confounding effects were minimised. Moreover, the cross-sectional design of the study and the multiple confounders precluded the identification of any causal relationships.

Self-reporting of medical conditions, drugs' intake and dietary patterns might have induced a recall bias that cannot be completely excluded. However, regarding adherence to MD, the whole dietary pattern was analysed instead of the intake of specific food types and recall bias has been considerably reduced.

Another limitation is related to the characteristics of the mixing material and the methodology applied to assess masticatory performance, jeopardising the comparisons with other studies that used different testing methods. Moreover, the study recorded only tooth mobility and did not investigate other periodontal indicators that may had affected masticatory performance.

The findings should be considered with caution if applied to non-Mediterranean populations where the diet scores may be adapted to study-specific cut-off values *(Trichopoulou et al 2009)*.

More studies should be conducted in larger samples of older adults, in different locations, to thoroughly elucidate the association between oral factors, including masticatory performance, and nutritional choices such as adherence to MD and other "healthy diets". Longitudinal studies are necessary to identify any causative effects between oral factors and adherence to MD and other

healthy diets. Finally, cut-off values for masticatory deficiency should be determined using standardised techniques to enable comparisons among different investigations.

5.4 Conclusion

Within the limitations of the present study in a functionally independent community dwelling urban older population, higher masticatory performance and lower BMI were independently associated with better adherence to MD. In addition, lower masticatory performance was significantly associated with fewer teeth, increased prevalence of severe tooth mobility and use of a pair of complete dentures among edentulous persons. Maintaining or improving masticatory performance by preventive interventions keeping natural dentition and managing periodontal disease may be beneficial to improve dietary quality in older adults.

6. SUMMARY

Aim: The aim of this study was to explore the association between oral factors and dietary choices in Greek community-dwelling older adults, including two objectives. The first objective aimed to assess the sociomedical and oral factors affecting masticatory performance, while the second objective aimed to investigate the impact of oral factors on the adherence to the Mediterranean diet (MD).

Materials and methods: The sample included community-dwelling persons over 60 years of age visiting Open Care Community Centers for Older People in Metropolitan Athens, Greece. Oral interviews recorded demographic and sociomedical information, subjective oral complaints, and dental habits. An oral and denture examination was performed including number of natural teeth, tooth mobility, number of occluding tooth pairs, and removable dentures' prevalence and quality, and an evaluation of the masticatory performance using a mixing ability test with two-colour chewing gum (Hue-check Gum, University of Bern) that was digitally analysed using the View Gum software program (dHAL Software, Greece). Adherence to MD was assessed using the MDI_BNC4H index (range: 0–14) and xerostomia was assessed using the validated in Greek Xerostomia Inventory. Statistical analysis included a) univariate analyses using univariate quantile regression, univariate linear regression and Kruskal-Wallis one-way analysis of variance on ranks, and b) multivariable analyses using multivariable quantile regression with backward elimination of nonsignificant predictors and multivariable linear regression modelling with backward elimination of nonsignificant predictors using as dependent variables masticatory performance and adherence to the MD respectively. The level of statistical significance was set at $p \leq 0.05$.

Results: 130 persons, 97 women and 33 men (range: 60–93 years) participated in the study with a mean age of 73.9 ± 8.5 years. The majority were either married (48.5%) or widowed (46.2%); 46.5% had received ≤6 years of education and only 41 (31.5%) more than 12. Only 12.3% were active smokers. They received 3.1 ± 2.3 different medications per day (range: 0–13), and their mean BMI

score was 28.5 ± 4.7 (range: 20.3–49.9). Fifty-nine participants (45.4%) had more than 20 teeth, 30 (23.1%) had from 11 to 20 teeth and 20 (15.4%) were edentulous. Among the dentate, the mean number of teeth was 18.7±8.3 (range 1-31). The mean number of chewing contacts between natural or prosthetic teeth was 10.5±3.1 (range: 2-16), with the majority of the participants (61.5%) having more than 10 chewing contacts. Sixteen participants (14.6%) presented tooth mobility grade #2 or #3 in more than 10% of their teeth. Fifty-eight (44.6%) used various types of removable prostheses, while all edentulous persons (20) used a pair of complete dentures. Seventy-two participants (55.4%) reported that they had very good or good oral health status. A total of 111 (85.4%) reported that they had “very good” or “good” masticatory ability, 14 (10,8%) moderate masticatory ability and 5 (3,9%) a poor or very poor one. The score of adherence to the MD ranged from 3 to 9 (5.6 ± 1.4).

Univariate analyses revealed statistically significant associations ($p \leq 0.05$) between masticatory performance and age, marital status, subjective chewing ability, use of removable dentures, use of various combinations of complete dentures, pain caused by maxillary denture, number of teeth, tooth mobility, posterior chewing pairs, all chewing contacts natural or prosthetic, retention of mandibular partial dentures, and dentures’ occlusion. In addition, the parameters that were statistically significantly associated with better adherence to the MD were higher masticatory performance, smaller number of drugs per day, lower BMI and no smoking.

The multivariable quantile regression analyses revealed that fewer natural teeth (95% CI: −0.02–0.01, $p<0.001$), being edentulous and using a pair of complete dentures (95% CI: 0.09–0.35, $p=0.001$), and larger percentage of severely mobile teeth (95% CI: 0.07–0.82, $p=0.020$) were associated with lower masticatory performance. Lower adherence to the Mediterranean diet was significantly associated with higher BMI (95% CI: − 0.10 –0.00, $p = 0.047$) and lower masticatory performance (95% CI: − 2.23–0.00, $p = 0.050$).

Conclusions: Within the limitations of the present study in a functionally independent community dwelling urban older population, higher masticatory performance and lower BMI were

independently associated with better adherence to MD. In addition, lower masticatory performance was significantly associated with fewer teeth, increased prevalence of severe tooth mobility and use of a pair of complete dentures among edentulous persons. Maintaining or improving masticatory performance by preventive interventions keeping natural dentition and managing periodontal disease may be beneficial to improve dietary quality in older adults.

ΠΕΡΙΛΗΨΗ

Σκοπός: Σκοπός αυτής της μελέτης ήταν να διερευνήσει τη συσχέτιση μεταξύ στοματικών παραγόντων και διατροφικών επιλογών σε Έλληνες ηλικιωμένους που διαβιούν στην Κοινότητα, με δύο στόχους. Ο πρώτος στόχος είχε σκοπό την αξιολόγηση των κοινωνικοϊατρικών και στοματικών παραγόντων που επηρεάζουν τη μασητική επίδοση, ενώ ο δεύτερος στόχος τη διερεύνηση της επίδρασης των στοματικών παραγόντων στην υιοθέτηση της μεσογειακής διατροφής (ΜΔ).

Μεθοδολογία: Το δείγμα περιλάμβανε άτομα άνω των 60 ετών που κατοικούσαν στην Κοινότητα και επισκέπτονταν Κέντρα Ανοιχτής Προστασίας Ηλικιωμένων (ΚΑΠΗ) στον Τομέα της Αθήνας της Περιφέρειας Αττικής.

Η μελέτη περιλάμβανε λήψη συνέντευξης με τη χρήση δομημένων ερωτηματολογίων και κλινική εξέτ

α σ η . Οι συνεντεύξεις κατέγραψαν δημογραφικά και κοινωνικοϊατρικά δεδομένα, στοματικά

παράπονα και οδοντιατρικές συνήθειες. Η κλινική εξέταση περιλάμβανε δείκτες σχετικά με την κατάσταση των στοματικών ιστών και των κινητών προσθετικών εργασιών. Καταγράφηκε ο αριθμός των φυσικών δοντιών, η κινητικότητα των δοντιών, ο αριθμός των ζευγών ανταγωνιστών (μασητικών μονάδων), και η παρουσία και ποιότητα των κινητών προσθετικών αποκαταστάσεων. Η μασητική επίδοση αξιολογήθηκε με τη μάσηση ειδικής δίχρωμης τσίχλας (Hue-check Gum, University of Bern) και την ψηφιακή ανάλυσή της χρησιμοποιώντας το λογισμικό πρόγραμμα View Gum (dHAL Software, Greece). Η υιοθέτηση της ΜΔ αξιολογήθηκε με τον δείκτη MDI_BNC4H (εύρος: 0–14) και η ξηροστομία με τον Δείκτη Ξηροστομίας (Xerostomia Inventory). Η στατιστική ανάλυση περιλάμβανε α) μονομεταβλητές αναλύσεις όπως μονομεταβλητή εκατοστότομη παλινδρόμηση, μονομεταβλητή γραμμική παλινδρόμηση και Kruskal-Wallis one-way analysis of variance on ranks, και β) πολυμεταβλητές αναλύσεις όπως εκατοστότομη παλινδρόμηση με ανάστροφη απαλοιφή μη σημαντικών μεταβλητών και πολυπαραγοντική γραμμική παλινδρόμηση με ανάστροφη απαλοιφή μη σημαντικών μεταβλητών χρησιμοποιώντας ως εξαρτημένες μεταβλητές τη μασητική επίδοση και τον βαθμό υιοθέτησης της ΜΔ αντίστοιχα. Το επίπεδο στατιστικής σημαντικότητας ορίστηκε στο $p \leq 0,05$.

Αποτελέσματα: Στη μελέτη συμμετείχαν 130 άτομα, 97 γυναίκες και 33 άνδρες (εύρος: 60–93 ετών), με μέση ηλικία τα 73,9 ± 8,5 έτη. Η πλειοψηφία ήταν είτε έγγαμοι (48,5%) είτε χήροι (46,2%). Το 46,5% είχε λάβει ≤6 χρόνια εκπαίδευσης και μόνο 41 άτομα (31,5%) είχαν λάβει περισσότερα από 12 χρόνια εκπαίδευσης. Ενεργοί καπνιστές ήταν μόνο το 12,3%. Κατανάλωναν κατά μέσο όρο 3,1 ± 2,3 διαφορετικά φάρμακα κάθε μέρα (εύρος: 0–13) και είχαν μέσο Δείκτη Μάζας Σώματος (ΔΜΣ) 28,5 ± 4,7 (εύρος: 20,3–49,9). Πενήντα εννέα συμμετέχοντες (45,4%) είχαν περισσότερα από 20 δόντια, 30 (23,1%) είχαν από 11 έως 20 δόντια και 20 (15,4%) ήταν ολικά νωδοί. Στους ενόδοντες, ο μέσος αριθμός δοντιών ήταν 18,7±8,3 (εύρος 1-31). Ο μέσος αριθμός μασητικών επαφών μεταξύ φυσικών ή προσθετικών δοντιών (συγκλίνοντα ζεύγη ανταγωνιστών δοντιών) ήταν 10,5±3,1 (εύρος: 2-16), με την πλειοψηφία των συμμετεχόντων (61,5%) να έχει περισσότερες από 10 μασητικές επαφές. Δεκαέξι συμμετέχοντες (14,6%) παρουσίασαν βαθμό κινητικότητας δοντιών #2 ή #3 σε περισσότερο από το 10% των δοντιών τους. Πενήντα οκτώ άτομα (44,6%) έφεραν διάφορους τύπους κινητών προσθετικών αποκαταστάσεων, ενώ και τα 20 ολικά νωδά άτομα έφεραν ζεύγος ολικών οδοντοστοιχιών. Εβδομήντα δύο συμμετέχοντες (55,4%) ανέφεραν ότι είχαν πολύ καλή ή καλή κατάσταση στοματικής υγείας. Συνολικά 111 (85,4%) ανέφεραν ότι είχαν «πολύ καλή» ή «καλή» μασητική ικανότητα, 14 (10,8%) μέτρια και 5 (3,9%) κακή ή πολύ κακή μασητική ικανότητα. Ο βαθμός υιοθέτησης της ΜΔ κυμαινόταν από 3 έως 9 (5,6 ± 1,4).

Οι μονομεταβλητές αναλύσεις αποκάλυψαν στατιστικά σημαντικές συσχετίσεις (p≤0,05) μεταξύ της μικρότερης μασητικής επίδοσης και της μεγαλύτερης ηλικίας, της χηρείας σε σχέση με την αγαμία, της κακής υποκειμενικής μασητικής ικανότητας, της χρήσης κινητών προσθετικών αποκαταστάσεων, της χρήσης ολικής οδοντοστοιχίας, του πόνου που προκαλείται από την οδοντοστοιχία άνω γνάθου, του μικρότερου αριθμού των δοντιών, της ολικής νωδότητας, της αυξημένης κινητικότητας των δοντιών, του μικρότερου αριθμού οπίσθιων μασητικών επαφών αλλά και όλων των μασητικών επαφών (φυσικών ή προσθετικών), της κακής συγκράτησης των κάτω μερικών οδοντοστοιχιών και της κακής σύγκλεισης οδοντοστοιχιών. Επιπλέον, οι παράμετροι που επηρέασαν θετικά το επίπεδο υιοθέτησης της ΜΔ ήταν η καλύτερη μασητική επίδοση, ο μικρότερος αριθμός φαρμάκων την ημέρα, ο χαμηλότερος ΔΜΣ και η απουσία καπνίσματος.

Οι πολυμεταβλητές αναλύσεις έδειξαν ότι ο μικρότερος αριθμός φυσικών δοντιών (95% CI: -0,02–0,01, p<0,001), η χρήση ζεύγους ολικών οδοντοστοιχιών στους ολικά νωδούς ασθενείς (95% CI: 0,09–0,35, p=0,001) και τα μεγαλύτερα ποσοστά δοντιών με μεγάλη κινητικότητα (95% CI: 0,07–0,82, p=0,020) συσχετίστηκαν με χαμηλότερη μασητική επίδοση. Ο μικρότερος βαθμός υιοθέτησης της μεσογειακής διατροφής συσχετίστηκε σημαντικά με τον υψηλότερο ΔΜΣ (95% CI: − 0,10 – 0,00, p = 0,047) και τη χαμηλότερη μασητική επίδοση (95% CI: − 2,23–0,00, p = 0,050).

Συμπεράσματα: Λαμβάνοντας υπόψιν τους περιορισμούς της παρούσας μελέτης, σε ένα δείγμα λειτουργικά ανεξάρτητων ηλικιωμένων Ελλήνων που ζούσαν σε αστική περιοχή. ο μεγαλύτερος βαθμός υιοθέτησης της μεσογειακής διατροφής συσχετίστηκε με την υψηλότερη μασητική επίδοση και τον χαμηλότερο ΔΜΣ. Επιπρόσθετα, η χαμηλότερη μασητική επίδοση συσχετίστηκε με μικρότερο αριθμό δοντιών, αυξημένο επιπολασμό δοντιών με μεγάλη κινητικότητα και με τη χρήση ζεύγους ολικών οδοντοστοιχιών από τους ολικά νωδούς ασθενείς. Η διατήρηση ή η βελτίωση της μασητικής επίδοσης με έγκαιρες προληπτικές παρεμβάσεις για τη διατήρηση των φυσικών δοντιών και την αποτελεσματική αντιμετώπιση της περιοδοντικής νόσου μπορεί να είναι ωφέλιμη για τη βελτίωση της ποιότητας της διατροφής στους ηλικιωμένους ενήλικες.

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APPENDICES

Appendix 1. Data collection records

Interview

NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS SCHOOL OF DENTISTRY

EXAMINATION SHEET IN OPEN CARE COMMUNITY CENTERS FOR OLDER PEOPLE

Date: …….. ID……
Place of examination……
Patient information

1. Name …….
2. Gender M ☐ F ☐
3. Age ……..
4. Marital status: married ☐ widowed ☐ unmarried ☐ divorced ☐
5. Are you living alone? Yes ☐ No ☐
6. Profession ……..
7. Level of education: ≤6 years ☐ 6-12 years ☐ >12 years ☐
8. Family monthly income: ≤590 euros ☐ 591-1200 euros ☐ >1200 euros ☐
9. Do you follow a special diet? Yes ☐ No ☐

9.1 If yes, please explain …….

10. Do you currently smoke? Yes ☐ No ☐
11. Coexisting pathology (ICD-10): Certain infectious and parasitic diseases ☐ Neoplasms ☐ Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism ☐ Endocrine, nutritional and metabolic diseases ☐ Mental and behavioural disorders ☐ Diseases of the nervous system ☐ Diseases of the eye and adnexa ☐ Diseases of the ear and mastoid process ☐ Diseases of the circulatory system ☐ Diseases of the respiratory system ☐ Diseases of the digestive system ☐ Diseases of the skin and subcutaneous tissue ☐ Diseases of the musculoskeletal system and connective tissue ☐ Diseases of the genitourinary system ☐ Certain conditions originating in the perinatal period ☐ Congenital malformations, deformations and chromosomal abnormalities ☐ Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified ☐ Injury, poisoning and certain other consequences of external causes ☐ External causes of morbidity and mortality ☐ Factors influencing health status and contact with health services ☐
12. Medications (HTC): Alimentary tract and metabolism ☐ Blood and blood forming organs ☐ Cardiovascular system ☐ Dermatologicals ☐ Genito-urinary system and sex hormones ☐ Systemic hormonal preparations, excluding sex hormones and insulins ☐ Antiinfectives for systemic use ☐ Antineoplastic and immunomodulating agents ☐ Musculo-skeletal system ☐ Nervous system ☐ Antiparasitic products, insecticides and repellents ☐ Respiratory system ☐ Sensory organs ☐ Various ☐
13. Number of drugs/day ……..

14. Height.....m, Weight…….kg, BMI……..

15. How do you describe your oral health?

Very poor ☐ Poor ☐ Moderate ☐ Good ☐ Very good ☐

16. Do you have an oral problem right now?

Yes ☐ No ☐

17. Does your mouth dry out?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

18. Can you chew your food well?

Not at all ☐ Poorly ☐ Moderately ☐ Well ☐ Very well ☐

19. Can you chew: steak ☐ almonds ☐ oranges ☐ no answer ☐

20. When was the last time you visited a dentist?

≤1year ☐ 1-5 years ☐ 6-10 years ☐ >10 years ☐ never ☐ can't remember ☐

21. Generally, how often do you visit the dentist?

More often than once per year ☐ every year ☐ every 2-3 years ☐ when needed ☐ never ☐ don't remember ☐ other……

22. How often do you brush your teeth?

More often than once/day ☐ once/day ☐ not every day ☐ never ☐ other……

23. Do you have dentures (partial or complete)?

No ☐ complete maxillary ☐ complete mandibular ☐ partial maxillary ☐ partial mandibular ☐

24. How old is (are) the denture(s)? (years)

maxillary..... mandibular……. Can't remember ☐

25. Are the dentures displaced during speech?

Maxillary: never ☐ sometimes ☐ always ☐

Mandibular: never ☐ sometimes ☐ always ☐

26. Do your dentures hurt?

Maxillary: never ☐ sometimes ☐ always ☐

Mandibular: never ☐ sometimes ☐ always ☐

27. Are the dentures displaced during mastication?

Maxillary: never ☐ sometimes ☐ always ☐

Mandibular: never ☐ sometimes ☐ always ☐

Xerostomia Inventory / XI

How often do you experience the following problems?

1	I sip liquids to aid in swallowing food	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
2	My mouth feels dry when eating a meal	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
3	I get up at night to drink some water	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
4	My mouth feels dry	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
5	I have difficulty in eating dry foods	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
6	I suck sweets or cough lollies to relieve dry mouth	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
7	I have difficulties swallowing certain foods	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
8	The skin of my face feels dry	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
9	My eyes feel dry	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**
10	My lips feel dry	**Neve**	**Rarely**	**Sometimes**	**Often**	**Very often**
11	The inside of my nose feels dry	**Never**	**Rarely**	**Sometimes**	**Often**	**Very often**

The Mediterranean Diet Index (MDI_BNC4H index)

Source: Hellenic Health Foundation

1. How often do you consume olive oil in a given day (including cooked meals, salads, snacks)?
    a. Always
    b. Mostly
    c. Moderate
    d. Rare
    e. Never
2. How many servings of fish or shellfish/seafood do you consume per week?

    ☐

3. How many servings of fruit (including natural fruit juices and dried fruits) do you consume per day?

    ☐

4. How many vegetable servings (raw or cooked excluding potatoes) do you consume per day?

    ☐

5. How many servings of legumes do you consume per week?

    ☐

6. How many servings of cereals (bread, pasta, rice) do you consume per day?

    ☐

7. How many servings of nuts and seeds do you consume per week?
    a. Unsalted ☐
    b. Salted ☐

8. How many servings of olives do you consume per week?
    a. Low salted ☐
    b. Regular ☐

9. How many servings of dairy (milk, yoghurt, cheese) do you consume per day?

    ☐

10. How many servings of red meat (beef, veal, pork, mutton, goat meat), game, hamburger, or meat products (ham, sausages, cured meat, etc) do you consume per week?

    ☐

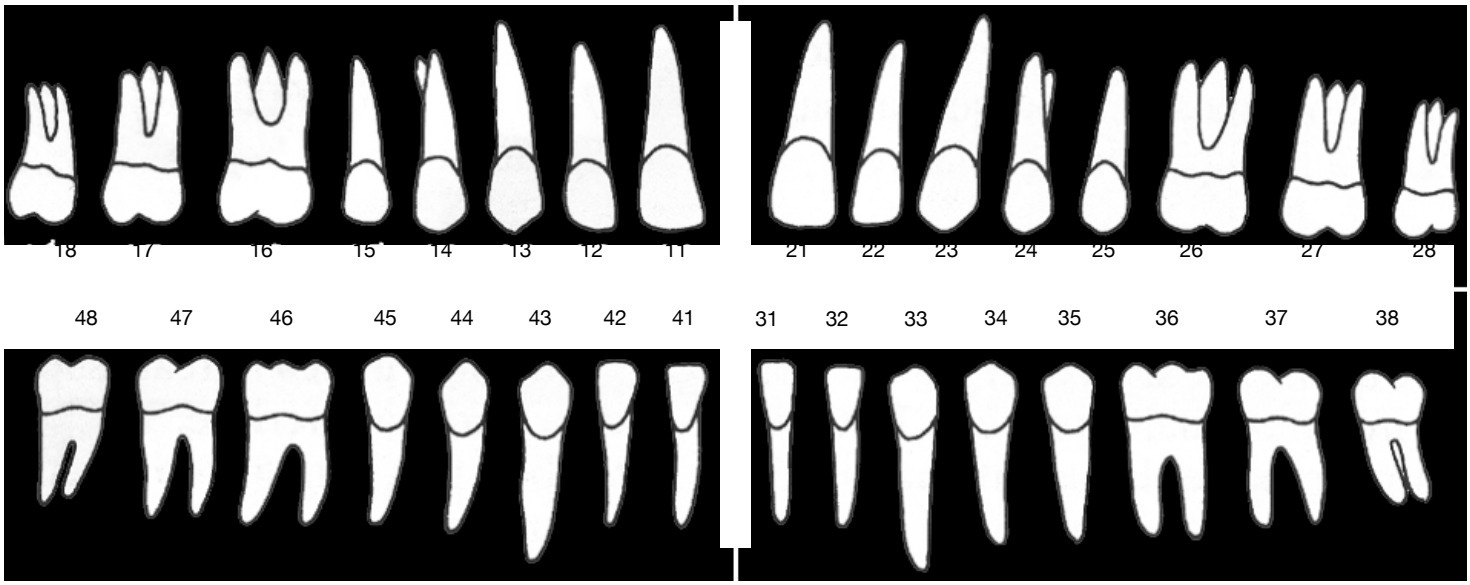
11. How many servings of white meat (chicken, turkey, rabbit, fowl game, etc) do you consume per week?

    ☐

12. How many glasses of wine do you drink per week?

    ☐

2.Clinical oral examination



1. Number of teeth: …….
2. Number of teeth with mobility: #1 …… #2 …… #3 ……..
3. Number of chewing pairs: anterior …….. posterior……..
4. **Maxillary denture**: complete☐ partial☐
5. Retention: not at all☐ poor☐ fair☐ good☐ very good☐ excellent☐
6. Stability: not at all☐ poor☐ fair☐ good☐ excellent☐
7. Neuromuscular control poor☐ good☐
8. **Mandibular denture**: complete☐ partial☐
9. Retention: not at all☐ poor☐ fair☐ good☐ very good☐ excellent☐
10. Stability: not at all☐ poor☐ fair☐ good☐ excellent☐
11. Vertical dimension: correct☐ reduced☐ increased☐
12. Central relationship: correct☐ poor☐
13. Occlusion: correct☐ poor☐

Appendix 2. List of tables

Table 1.1 The association between sociodemographic factors and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Sociodemographic factors							
Gender							0.438
Female	97 (74.6%)	0.28	0.21	0.21	0.09	0.41	
Male	33 (25.4%)	0.23	0.18	0.17	0.06	0.39	
All	130 (100%)	0.27	0.21	0.19	0.09	0.40	
Age (years)							**0.002**
60-74	69 (53.1%)	0.22	0.19	0.14	0.08	0.33	
75-84	43 (33.1%)	0.28	0.20	0.25	0.12	0.40	
≥85	18 (13.8%)	0.41	0.23	0.36	0.20	0.66	
Marital status							**0.004****
Married	63 (48.5%)	0.23	0.19	0.16	0.08	0.36	
Widowed	60 (46.2%)	0.32	0.22	0.27	0.14	0.47	
Unmarried	3 (2.3%)	0.04	0.01	0.04	0.03	0.05	
Divorced	4 (3.1%)	0.19	0.10	0.15	0.11	0.29	
Education (years)							0.315
≤6	60 (46.5%)	0.32	0.22	0.24	0.14	0.47	
7-12	29 (22.3%)	0.25	0.22	0.17	0.08	0.41	
>12	41 (31.5%)	0.20	0.17	0.15	0.05	0.34	
Income (euros)							0.511
≤590	24 (18.5%)	0.27	0.22	0.22	0.09	0.33	
591-1200	77 (59.2%)	0.28	0.21	0.21	0.10	0.41	
>1200	29 (22.3%)	0.22	0.18	0.16	0.05	0.33	
Living alone							0.300
Yes	53 (40.8%)	0.29	0.21	0.22	0.10	0.42	
No	77 (59.2%)	0.25	0.20	0.17	0.09	0.39	

* p-value derived from univariate quantile regression

** p-value derived from Kruskal-Wallis test

Table 1.2 The association between medical factors and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Medical factors (ICD-10 Version:2019)							
Neoplasms							0.683
Yes	11 (8.5%)	0.20	0.18	0.17	0.08	0.28	
No	119 (91.5%)	0.27	0.21	0.21	0.09	0.41	
Diseases of the blood and blood-forming organs							0.188
Yes	8 (6.2%)	0.29	0.14	0.32	0.17	0.35	
No	122 (93.8%)	0.25	0.21	0.19	0.09	0.40	
Endocrine, nutritional or metabolic diseases							0.813
Yes	90 (69.2%)	0.27	0.21	0.20	0.09	0.38	
No	40 (30.8%)	0.26	0.21	0.19	0.09	0.41	
Mental and behavioural disorders							0.372
Yes	16 (12.3%)	0.33	0.26	0.24	0.11	0.62	
No	114 (87.7%)	0.26	0.20	0.19	0.09	0.39	
Diseases of the nervous system							0.501
Yes	13 (10%)	0.27	0.25	0.14	0.07	0.51	
No	117 (90%)	0.26	0.20	0.20	0.10	0.40	
Diseases of the eye and adnexa							0.329
Yes	7 (5.4%)	0.24	0.15	0.31	0.06	0.40	
No	123 (94.6%)	0.27	0.21	0.19	0.09	0.40	
Diseases of the ear and mastoid process							0.369
Yes	4 (3.1%)	0.31	0.26	0.25	0.09	0.58	
No	126 (96.9%)	0.26	0.21	0.19	0.09	0.40	
Diseases of the circulatory system							0.385
Yes	86 (66.2%)	0.28	0.22	0.21	0.09	0.42	
No	44 (33.8%)	0.23	0.18	0.17	0.08	0.33	
Diseases of the respiratory system							0.332
Yes	8 (6.2%)	0.15	0.12	0.14	0.06	0.21	
No	122 (93.8%)	0.23	0.21	0.21	0.09	0.41	

Diseases of the digestive system							0.455
Yes	22 (16.9)	0.22	0.21	0.16	0.08	0.31	
No	108 (83.1)	0.27	0.21	0.21	0.09	0.41	
Diseases of the skin and subcutaneous tissue							0.942
Yes	1 (0.8%)						
No	129 (99.2%)	0.27	0.21	0.19	0.09	0.04	
Diseases of the musculoskeletal system and connective tissue							0.557
Yes	33 (25.4%)	0.26	0.21	0.17	0.09	0.43	
No	97 (74.6%)	0.27	0.21	0.21	0.09	0.40	
Diseases of the genitourinary system							0.285
Yes	8 (6.2%)	0.30	0.19	0.28	0.11	0.41	
No	122 (93.8%)	0.26	0.21	0.19	0.09	0.39	
BMI (kg/m^2)							0.352
<18.5	0						
18.5-24.9	27 (20.8%)	0.28	0.22	0.22	0.09	0.42	
25.0-29.9	67 (51.5%)	0.25	0.19	0.20	0.10	0.36	
≥30	36 (27.7%)	0.29	0.23	0.17	0.08	0.41	
Smoking							0.272
Yes	16 (12.3%)	0.16	0.11	0.14	0.09	0.41	
No	114 (87.7%)	0.28	0.21	0.21	0.07	0.26	

* p-value derived from univariate quantile regression

Table 1.3 The association between medications and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Medications ATC classification system							
Alimentary tract and metabolism							0.714
Yes	56 (43.1%)	0.28	0.22	0.21	0.09	0.44	
No	74 (56.9%)	0.25	0.20	0.19	0.09	0.36	
Blood and blood forming organs							0.735
Yes	29 (22.3%)	0.23	0.15	0.19	0.09	0.37	
No	101 (77.7%)	0.23	0.22	0.21	0.09	0.41	
Cardiovascular system							0.442
Yes	95 (73.1%)	0.28	0.21	0.21	0.09	0.41	
No	35 (26.9%)	0.24	0.19	0.16	0.08	0.34	
Dermatologicals							
Yes	0						
No	130 (100%)						
Genito urinary system and sex hormones							0.409
Yes	5 (3.8%)	0.41	0.24	0.31	0.20	0.65	
No	125 (96.2%)	0.26	0.21	0.19	0.09	0.40	
Systemic hormonal preparations, excluding sex hormones and insulins							0.142
Yes	40 (30.8%)	0.27	0.20	0.27	0.09	0.37	
No	90 (69.2%)	0.26	0.21	0.19	0.09	0.41	
Antiinfective for systemic use							0.633
Yes	2 (1.5%)	0.20	0.04	0.11	0.08	0.11	
No	128 (98.5%)	0.27	0.21	0.20	0.09	0.20	
Antineoplastic and immunomodulating agents							0.651
Yes	2 (1.5%)	0.36	0.43	0.36	0.05	0.66	
No	128 (98.5%)	0.26	0.21	0.19	0.09	0.19	

Musculo-skeletal system							0.473
Yes	20 (15.4%)	0.29	0.24	0.22	0.08	0.49	
No	110 (84.6%)	0.26	0.20	0.19	0.09	0.39	
Nervous system							0.149
Yes	30 (23.1%)	0.30	0.22	0.27	0.21	0.42	
No	100 (76.9%)	0.26	0.21	0.19	0.09	0.39	
Antiparasitic products, insecticides and repellents							
Yes	0						
No	130 (100%)						
Respiratory system							0.510
Yes	5 (3.8%)	0.17	0.15	0.11	0.05	0.31	
No	125 (96.2%)	0.27	0.21	0.20	0.09	0.40	
Sensory organs							
Yes	0						
No	130 (100%)						
Number of drugs per day							0.774
0	14 (10.8%)	0.21	0.19	0.14	0.07	0.30	
1-4	88 (97.7%)	0.28	0.21	0.21	0.09	0.41	
≥5	27 (20.8%)	0.25	0.20	0.18	0.10	0.38	

* p-value derived from univariate quantile regression

Table 1.4 The association between subjective oral health indicators and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Subjective oral health indicators							
Subjective oral health							0.725
Very good/ good	72 (55.4%)	0.28	0.21	0.21	0.10	0.41	
Moderate/ poor/very poor	58 (44.6%)	0.25	0.20	0.17	0.09	0.37	
Current oral problem							0.336
Yes	38 (29.2%)	0.22	0.20	0.15	0.08	0.34	
No	92 (70.8%)	0.28	0.21	0.22	0.11	0.41	
Xerostomia Index							0.202
≤75th percentile	98 (75.4%)	0.25	0.19	0.19	0.09	0.38	
>75th percentile	32 (24.6%)	0.31	0.26	0.23	0.06	0.56	
Chewing ability							**0.001**
Very good/ good	111 (85.4%)	0.24	0.19	0.17	0.09	0.36	
Moderate/ poor/very poor	19 (14.6%)	0.40	0.23	0.37	0.21	0.65	
Chewing steak							**0.024**
Yes	113 (86.9%)	0.25	0.19	0.18	0.09	0.36	
No	17 (13.1%)	0.40	0.25	0.38	0.17	0.67	
Chewing almonds							**0.015**
Yes	116 (89.2%)	0.24	0.19	0.17	0.09	0.37	
No	14 (10.8%)	0.44	0.20	0.41	0.24	0.63	
Chewing oranges							
Yes	130 (100%)						
No	0						

* p-value derived from univariate quantile regression

Table 1.5 The association between dental visitations and oral hygiene habits, and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Dental visitations and oral hygiene habits							
Last dental visit							0.073
Less than 12 months	59 (45.4%)	0.24	0.19	0.17	0.08	0.34	
12 months and over	71 (54.6%)	0.29	0.22	0.22	0.09	0.42	
Dental visitation habits							0.393
More often than every 2 years	33 (25.4%)	0.19	0.15	0.16	0.06	0.34	
Less often than every 2 years	97 (74.6%)	0.29	0.22	0.22	0.10	0.42	
Oral hygiene frequency							0.373
At least once per day	115 (88.5%)	0.27	0.21	0.20	0.09	0.40	
Less often than once per day	15 (11.5%)	0.22	0.19	0.18	0.07	0.31	

* p-value derived from univariate quantile regression

Table 1.6 The association between removable dentures use and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Removable dentures use							
Use of removable dentures**							**<0.001**
Yes	58 (44.6%)	0.38	0.22	0.36	0.20	0.53	
No	72 (55.4%)	0.17	0.15	0.14	0.07	0.22	
Use of complete denture(s)**							**<0.001**
Yes	32 (24.6%)	0.50	0.20	0.49	0.32	0.68	
No	98 (75.4%)	0.19	0.14	0.16	0.08	0.27	
Use of partial denture(s)**							0.066
Yes	31 (23.8%)	0.27	0.18	0.27	0.10	0.38	
No	99 (76.2%)	0.26	0.22	0.18	0.09	0.41	
Maxillary complete denture**							**<0.001**
Yes	27 (20.8%)	0.51	0.20	0.51	0.32	0.68	
No	103 (79.2%)	0.20	0.16	0.16	0.08	0.31	
Mandibular complete denture**							**<0.001**
Yes	25 (19.2%)	0.54	0.18	0.59	0.40	0.70	
No	105 (80.8%)	0.20	0.15	0.16	0.08	0.31	
Maxillary partial denture**							0.205
Yes	22 (16.9%)	0.28	0.19	0.27	0.10	0.36	
No	108 (83.1%)	0.26	0.21	0.18	0.09	0.41	

Mandibular partial denture**							0.107
Yes	19 (14.6%)	0.29	0.17	0.31	0.12	0.41	
No	111 (85.4%)	0.26	0.21	0.19	0.09	0.40	
Pair of complete dentures							**<0.001**
Yes	20 (15.4%)	0.56	0.16	0.62	0.45	0.71	
No	110 (84.6%)	0.21	0.17	0.16	0.08	0.33	

* p-value derived from univariate quantile regression

** May include dentate people and denture wearers

Table 1.7 The association between dental status and masticatory performance

		Masticatory performance					
	n (%)	**Mean**	**SD**	**Median**	**25%**	**75%**	**p-value***
Dental status							
Dentate status							**<0.001**
Dentate	110 (84.6%)	0.21	0.17	0.16	0.08	0.33	
Edentulous	20 (15.4%)	0.55	0.16	0.55	0.44	0.68	
Number of teeth							**<0.001**
0	20 (15.4%)	0.54	0.17	0.55	0.44	0.68	
1-10	21 (16.2%)	0.31	0.21	0.31	0.12	0.41	
11-20	30 (23.1%)	0.28	0.18	0.23	0.13	0.37	
>20	59 (45.4%)	0.15	0.12	0.11	0.06	0.19	
Tooth mobility							**0.011**
>10% mobility II+III	16 (14.5%)	0.33	0.23	0.26	0.16	0.53	
≤ 10% mobility II+III	94 (85.5%)	0.19	0.15	0.16	0.08	0.31	
Anterior chewing pairs							0.952
<3	19 (14.6%)	0.26	0.20	0.18	0.09	0.41	
≥3	111 (85.4%)	0.27	0.21	0.20	0.09	0.40	
Posterior chewing pairs							**0.005**
≤4	26 (20%)	0.34	0.21	0.31	0.17	0.53	
5-6	49 (37.7%)	0.27	0.21	0.25	0.09	0.37	
7-10	55 (42.3%)	0.22	0.20	0.16	0.07	0.41	
Chewing contacts (natural and prosthetic)							**0.013**
≤6	14 (10.8%)	0.37	0.23	0.35	0.17	0.62	
7-10	36 (27.7%)	0.28	0.20	0.25	0.11	0.40	
>10	80 (61.5%)	0.24	0.20	0.17	0.08	0.35	

* p-value derived from univariate quantile regression

Table 1.8. Multivariable Quantile Regression Derived Coefficients (β) and P values for masticatory performance (variance of the hue) as dependent variable.

	Masticatory performance				
Predictor variables	**β**	**SE**	***P*-value**	**95% Conf. Interval**	
Natural Teeth (number)	-0.01	0.00	$<10^{-3}$	-0.02	-0.01
Full Dentures					
No	Reference				
Yes	0.21	0.06	0.001	0.09	0.35
Mobility (%)	0.44	0.18	0.020	0.07	0.82

*Final multivariable model resulting by backward elimination of nonsignificant predictors (deletion criterion P>0.10)

Table 2.1 The association between sociodemographic factors and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Sociodemographic factors				
Gender				0.465
Female	97 (74.6%)	5.58	1.35	
Male	33 (25.4%)	5.78	1.34	
All	130 (100%)	5.70	1.40	
Age (years)				0.930
60-74	69 (53.1%)	5.59	1.42	
75-84	43 (33.1%)	5.84	1.34	
≥85	18 (13.8%)	5.33	1.08	
Marital status				0.288**
Married	63 (48.5%)	5.67	1.38	
Widowed	60 (46.2%)	5.53	1.36	
Unmarried	3 (2.3%)	6.67	0.58	
Divorced	4 (3.1%)	6.25	0.96	
Education (years)				0.649
≤6	60 (46.5%)	5.62	1.30	
7-12	29 (22.3%)	5.52	1.24	
>12	41 (31.5%)	5.76	1.51	
Income (euros)				0.491
≤590	24 (18.5%)	5.38	1.35	
591-1200	77 (59.2%)	5.71	1.34	
>1200	29 (22.3%)	5.66	1.42	
Living alone				0.590
Yes	53 (40.8%)	5.72	1.38	
No	77 (59.2%)	5.58	1.34	

*p-value derived from univariate linear regression

** Kruskal-Wallis One Way Analysis of Variance on Ranks

Table 2.2 The association between medical factors and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Medical factors (ICD-10 VERSION:2019)				
Neoplasms				0.639
Yes	11 (8.5%)	5.45	1.13	
No	119 (91.5%)	5.66	1.37	
Diseases of the blood and blood-forming organs				0.977
Yes	8 (6.2%)	5.63	1.77	
No	122 (93.8%)	5.64	1.33	
Endocrine, nutritional or metabolic diseases				0.838
Yes	90 (69.2%)	5.62	1.33	
No	40 (30.8%)	5.68	1.42	
Mental and behavioural disorders				**0.043**
Yes	16 (12.3%)	5.00	1.03	
No	114 (87.7%)	5.73	1.37	
Diseases of the nervous system				0.355
Yes	13 (10%)	5.31	1.49	
No	117 (90%)	5.68	1.34	
Diseases of the eye and adnexa				0.194
Yes	7 (5.4%)	6.29	1.38	
No	123 (94.6%)	5.60	1.35	
Diseases of the ear and mastoid process				0.868
Yes	4 (3.1%)	5.75	0.50	
No	126 (96.9%)	5.63	1.37	
Diseases of the circulatory system				0.990
Yes	86 (66.2%)	5.64	1.32	
No	44 (33.8%)	5.64	1.43	
Diseases of the respiratory system				0.437
Yes	8 (6.2%)	6.00	1.07	
No	122 (93.8%)	5.61	1.37	

Diseases of the digestive system				0.305
Yes	22 (16.9)	5.91	1.11	
No	108 (83.1)	5.58	1.40	
Diseases of the skin and subcutaneous tissue				0.637
Yes	1 (0.8%)	5.00		
No	129 (99.2%)	5.64	1.36	
Diseases of the musculoskeletal system and connective tissue				0.890
Yes	33 (25.4%)	5.67	1.45	
No	97 (74.6%)	5.63	1.33	
Diseases of the genitourinary system				0.811
Yes	8 (6.2%)	5.75	1.04	
No	122 (93.8%)	5.63	1.37	
BMI (kg/m^2)				**0.043**
<18.5	0			
18.5-24.9	27 (20.8%)	6.11	1.42	
25.0-29.9	67 (51.5%)	5.58	1.33	
≥30	36 (27.7%)	5.39	1.29	
Smoking				**0.053**
Yes	16 (12.3%)	5.55	1.36	
No	114 (87.7%)	6.25	1.26	

*p-value derived from univariate linear regression

Table 2.3 The association between medications and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Medications (ATC classification system)				
Alimentary tract and metabolism				0.720
Yes	56 (43.1%)	5.59	1.28	
No	74 (56.9%)	5.68	1.42	
Blood and blood forming organs				0.818
Yes	29 (22.3%)	5.69	1.26	
No	101 (77.7%)	5.62	1.38	
Cardiovascular system				0.595
Yes	95 (73.1%)	5.60	1.29	
No	35 (26.9%)	5.74	1.52	
Dermatologicals				
Yes	0			
No	130 (100%)			
Genito urinary system and sex hormones				0.200
Yes	5 (3.8%)	6.40	1.52	
No	125 (96.2%)	5.61	1.34	
Systemic hormonal preparations, excluding sex hormones and insulins				0.439
Yes	40	5.50	1.20	
No	90	5.70	1.42	
Antiinfective for systemic use				0.503
Yes	2 (1.5%)	5.00	1.42	
No	128 (98.5%)	5.65	1.36	
Antineoplastic and immunomodulating agents				0.503
Yes	2 (1.5%)	5.00	0	
No	128 (98.5%)	5.65	1.36	

Musculo-skeletal system				0.115
Yes	20 (15.4%)	5.20	1.32	
No	110 (84.6%)	5.46	1.35	
Nervous system				0.160
Yes	30 (23.1%)	5.33	1.30	
No	100 (76.9%)	5.73	1.36	
Antiparasitic products, insecticides and repellents				
Yes	0			
No	130 (100%)			
Respiratory system				0.346
Yes	5 (3.8%)	6.20	1.10	
No	125 (96.2%)	5.62	1.36	
Sensory organs				
Yes	0			
No	130 (100%)			
Number of drugs per day				**0.056**
0	14 (10.8%)	6.50	1.56	
1-4	88 (67.7%)	5.59	1.33	
≥5	27 (20.8%)	5.37	1.21	

*p-value derived from univariate linear regression

Table 2.4 The association between subjective oral health indicators and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Subjective oral health indicators				
Subjective oral health				0.890
Very good/ good	72 (55.4%)	5.65	1.35	
Moderate/ poor/very poor	58 (44.6%)	5.65	1.37	
Current oral problem				**0.042**
Yes	38 (29.2%)	5.26	1.11	
No	92 (70.8%)	5.79	1.42	
Xerostomia Index				0.340
≤75th percentile	98 (75.4%)	5.70	1.37	
>75th percentile	32 (24.6%)	5.44	1.29	
Chewing ability				0.090
Very good/ good	111 (85.4%)	5.72	1.33	
Moderate/ poor/very poor	19 (14.6%)	5.16	1.43	
Chewing steak				0.870
Yes	113 (86.9)	5.65	1.38	
No	17 (13.1%)	5.59	1.18	
Chewing almonds				0.541
Yes	116 (89.2%)	5.66	1.35	
No	14 (10.8%)	5.43	1.40	
Chewing oranges				
Yes	130 (100%)			
No	0			

*p-value derived from univariate linear regression

Table 2.5 The association between dental visitations and oral hygiene habits, and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Dental visitations and oral hygiene habits				
Last dental visit				0.471
Less than 12 months	59 (45.4%)	5.36	1.27	
12 months and over	71 (54.6%)	5.87	1.38	
Dental visitation habits				0.190
More often than every 2 years	33 (25.4)	5.55	1.50	
Less often than every 2 years	97 (74.6%)	5.67	1.30	
Dental hygiene frequency				0.770
At least once per day	115 (88.5%)	5.63	1.35	
Less often than once per day	15 (11.5%)	5.73	1.39	

*p-value derived from univariate linear regression

Table 2.6 The association between removable dentures use and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Removable dentures use				
Use of removable dentures				0.990
Yes	58 (44.6%)	5.64	1.36	
No	72 (55.4%)	5.64	1.36	
Use of complete denture(s)				0.830
Yes	32 (24.6%)	5.59	1.39	
No	98 (75.4%)	5.65	1.35	
Use of partial denture(s)				0.905
Yes	31 (23.8%)	5.61	1.28	
No	99 (76.2%)	5.65	1.38	
Maxillary complete denture use				0.405
Yes	27 (20.8%)	5.44	1.40	
No	103 (79.2%)	5.69	1.34	
Mandibular complete denture use				0.865
Yes	25 (19.2%)	5.68	1.49	
No	105 (80.8%)	5.63	1.32	
Maxillary partial denture use				0.118
Yes	22 (16.9%)	5.23	1.19	
No	108 (83.1%)	5.72	1.37	
Mandibular partial denture use				0.480
Yes	19 (14.6%)	5.84	1.30	
No	111 (85.4%)	5.60	1.36	
Pair of complete dentures use				0.621
Yes	20 (15.4%)	5.50	1.54	
No	110 (84.6%)	5.66	1.32	

*p-value derived from univariate linear regression

Table 2.7 The association between dental status and masticatory performance, and adherence to the Mediterranean Diet

	Mediterranean Diet Index (MDI_BNC4H)			
	n (%)	**Mean**	**SD**	**p-value***
Dental status & masticatory performance				
Dentate status				
Dentate	110 (84.6%)	5.66	1.32	0.620
Edentulous	20 (15.4%)	5.50	1.54	
Number of teeth				0.650
0	20 (15.4%)	5.50	1.54	
1-10	21 (16.2%)	5.81	1.25	
11-20	30 (23.1%)	5.43	1.33	
>20	59 (45.4%)	5.73	1.35	
Tooth mobility				0.670
>10% mobility II+III	16 (14.5%)	5.50	1.15	
≤ 10% mobility II+III	94 (85.5%)	5.69	1.35	
Anterior chewing pairs				0.749
<3	19 (14.6%)	5.84	1.21	
≥3	111 (85.4%)	5.60	1.38	
Posterior chewing pairs				0.264
≤4	26 (20%)	5.69	1.23	
5-6	49 (37.7%)	5.43	1.27	
7-10	55 (42.3%)	5.80	1.47	
Chewing contacts (natural and prosthetic)				0.541
≤6	14 (10.8%)	5.71	1.27	
7-10	36 (27.7%)	5.50	1.11	
>10	80 (61.5%)	5.69	1.47	
Masticatory performance				**0.050**
High (≤ median)	65 (50.0%)	5.81	1.39	
Low (> median)	65 (50.0%)	5.46	1.30	

*p-value derived from univariate linear regression

Table 2.8 Multivariable analysis between the Mediterranean Diet Index (MDI_BNC4H) and independent variables

	Multivariate Model*				
	Mediterranean Diet Index (MDI_BNC4H)				
Predictor variables	**β**	**SE**	**P-value**	**95% Conf. Interval**	
BMI	-0.05	0.02	0.047	-0.10	-0.00
Masticatory performance	-1.12	0.56	0.050	-2.23	-0.00

*Final multivariable model resulting by backward elimination of nonsignificant predictors (deletion criterion P>0.10)