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Relationship between oral rehabilitation and nutrients intake in the independent elderly: a systematic review of the literature

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Objective. When investigating nutrients intake in ageing patients, a compromised dental status leading to impaired masticatory performance has been considered associated with nutrients deficiency. The aim of the study was to investigate the association between oral rehabilitation and nutrients intake in independent elderly.
Methods. PubMed, Web of Science, Cochrane Library e Tripdatabase were searched for eligible studies published between 1991 and 2020. The search comprised articles written in English, selected using the key words "denture" OR "mastication" AND "nutrition" OR "elderly". Samples of patients with age not inferior to 65 years and with independent life conditions were considered.
Results. Among 1362 studies found searching the databases, 10 articles referred to 4 randomized controlled trials and 8 observational studies fulfilled the inclusion criteria. The overall results of the observational studies suggested that a proper oral rehabilitation provides the elderly with a higher nutrients intake. Three RCT comparing different prosthetic treatments found no difference in the nutrients intake between the two study groups. One RCT compared the effect of nutritional advice *vs* standard advice on dentures' maintenance: at 6 months the intervention group showed a higher intake of plant protein and a higher MNA-SF score, while the control group showed a higher intake of animal protein and vitamin B12.
Conclusions. Congruous prosthetic rehabilitations alone can't assure adequate nutrients intake in the elderly, but the influence of other factors is suggested: nutritional counseling seems an important factor to improve nutrients intake and it's recommended to be associated with the prosthetic rehabilitation.

Key words: nutrients, aged, mastication, dental prosthesis, counseling

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INTRODUCTION

The increase of life expectancy, typical of the last decades, has determined a significant growth of the elderly in all developed countries. The quality of aging and the heterogeneity of the elderly population can be affected by the occurrence of two conditions: frailty and sarcopenia.
Frailty was defined "a state of reduced physiologic reserve associated

with increased susceptibility to disability [1]. According to De Jong [2], the most important factors related to frailty are physical inactivity and malnutrition, even though many other factors contribute to this condition: chronic diseases, bad lifestyle, side effects of multiple drugs intake, sudden and negative events. One of the major predictor of frailty is sarcopenia, a typical aging related process in the elderly, characterized by the loss of muscle mass and strength and physical performance decline and significantly influenced by malnutrition [3-5].
Edentulism is a condition that can determine a significant reduction of the quality of life, and its prevalence is going to increase, due to the progressive ageing of the population. In 2002, Douglass [6] predicted that in the USA, by the year 2020, the adult population needing a rehabilitation with a complete denture would increase from 33.6 millions to 37.9 millions. Always in 2002, the Mc Gill consensus [7] provided a minimum standard of care for edentulous patients, that is a conventional maxillary complete denture and a mandibular implant retained overdenture (MIR-OVD). The consensus was based on the assumption that numerous people wearing conventional dentures report that they can't eat many foods, particularly those that are hard or tough. This forces them to change their diets in unhealthy ways and causes their nutrition to be poorer than that of people with natural teeth. The consensus also reported evidence that people who receive mandibular two implants overdentures modify their diet, improving their nutritional state, thus having a strong positive impact on general health, particularly for senior adults who are vulnerable to malnutrition. With ageing, the progressive teeth loss determines a change of nutrition habits, depending on the compensation performed by the prosthetic intervention. If missing teeth are not replaced, a modification of masticatory mechanical function may occur and removable prosthetic rehabilitation is unable to fully restore the masticatory performance to that of a dentate patient, (especially when eating fibrous or hard food) regardless of the congruity of the prosthesis itself. Thus, literature [8-10] investigated the association between oral rehabilitation and nutrients intake, and when the masticatory effectiveness of these patients resulted impaired by an improper or missing rehabilitation, it was considered associated with macro and micronutrients deficiency in their diet. However, these articles don't cover completely all the literature describing this association.

AIM OF THE STUDY

The aim of the study was to perform a literature systematic review to investigate, in the population aged >= 65 years and not institutionalized, the association between oral rehabilitation and nutrients intake.

MATERIALS AND METHODS

PubMed, Web of Science, Cochrane Library e Tripdatabase were searched for eligible studies published between 1991 and 2020. The search comprised articles written in English, which were selected using the following match of MeSH terms and boolean operators:"dentures" OR "mastication" AND "nutritional status" OR "aged". Two reviewers independently evaluated eligible studies and assessed the risk of bias for randomized clinical trials, applying criteria for quality assessment based on the Cochrane guidelines. Samples of patients with age not inferior to 65 years and with independent life conditions were taken into account. (Tab. I). Every article was evaluated and classified according to the author, nationality, typology of the study, samples characteristics (number, age, sex), mastication, factors associated to mastication (MAFs, including the number of teeth, number of antagonist couples, if the patient was dentate or completely edentulous, if the dentition was adequate or not and the adequateness of the prosthesis) and principal outcomes of interest. The methods chosen to evaluate mastication included self-evaluation of mastication through scales, questionnaires and food diaries and the ability of the subject to break the food into small pieces by means of masticatory efficiency tests.

RESULTS

1362 studies were found searching the four databases. After duplicates and non-original articles were removed, 1110 studies underwent a first screening, by analyzing the title and abstract, and 1035 studies were excluded. 75 potentially relevant studies were downloaded as full text and 57 of them were excluded, mostly because not fulfilling the inclusion criteria (Appendix, Table S2). 18 articles referred to 12 studies fulfilled the inclusion criteria and were included in the review (Fig. 1).
We included 10 articles referred to 4 Randomized Controlled Trials (RCT) studies on persons aged >= 65 years not institutionalized (Tab. II). RCT risk of bias assessment (Appendix, Table S1) showed that the majority of the studies have a low risk of bias, being "blinding" the criteria that scored the most unclear/ unrevealed risk of bias. Two RCT [11-13] compared the effects of two different prosthetic interventions (IOD *vs* CD); both studies did not show any differences in the intake of nutrients or related to the hematological markers between the

Table I. Inclusion and exclusion criteria for study selection.

	Inclusion criteria	Exclusion criteria
Sample	Age > 65 yrs Self-sufficient	Maxillofacial surgery Radiotherapy Institutionalized patients Systemic diseases
Outcome: nutritional status	Self-declaration or interview about nutritional intake Food diary Blood exams	Declaration regarding food intake that was not obtained
Analysis	Every association between oral status/masticatory function and food and nutrients intake	Studies that do not search for an association between oral status/masticatory function and food and nutrients intake

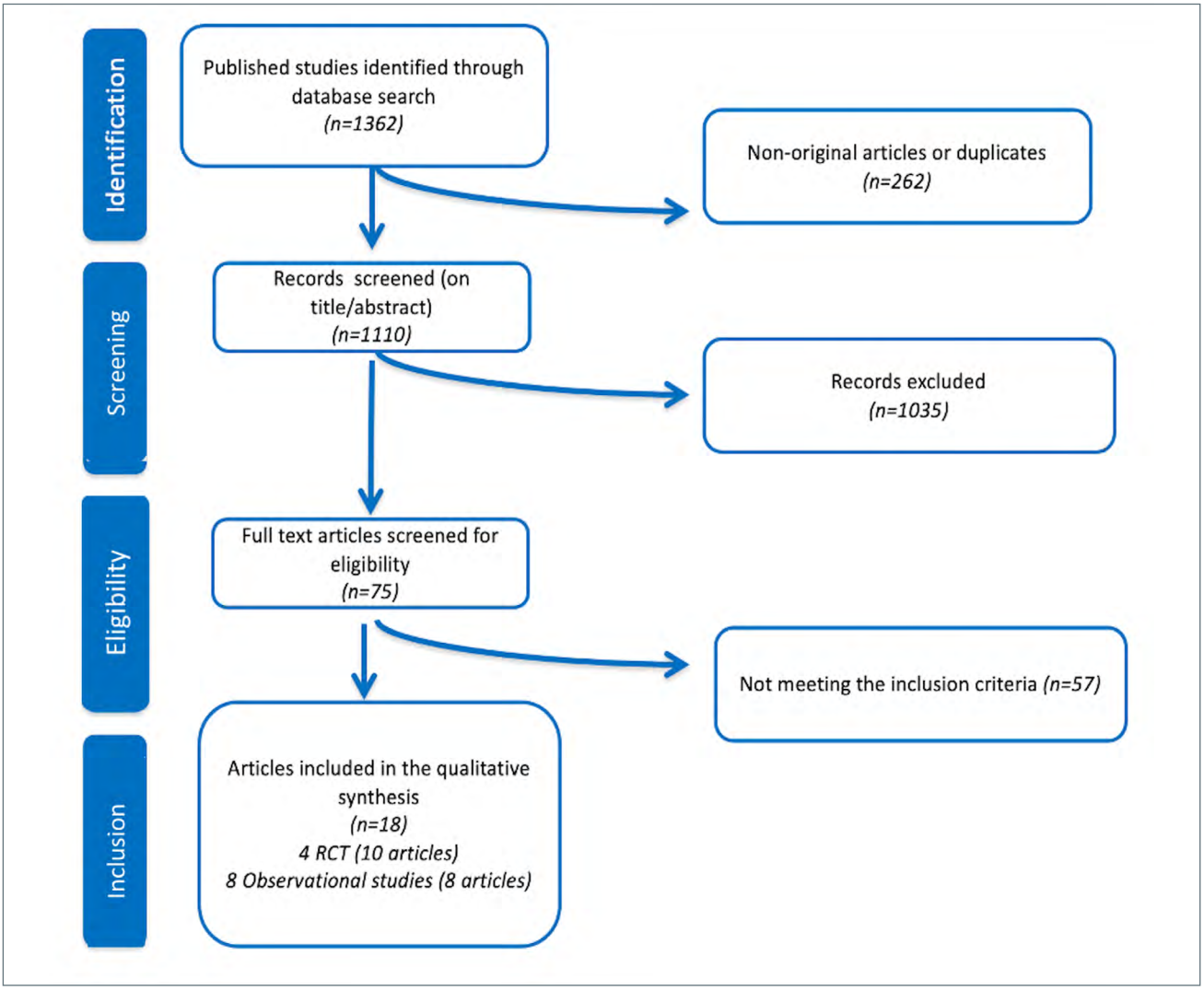

Figure 1. Flow-chart of the screening process (adapted from PRISMA).

two study groups and found some inconsistent results over time within each group. One RCT [14-16] compared a functionally oriented treatment *vs* RPD, founding no differences in the intake of nutrients or hematological markers between the two study groups, and with some improvement over time in both groups. One RCT [17-20]

Table II. Characteristics and main results of included Randomized Controlled Trials.

Author (year)	Participants, location	Intervention (IG)/comparator (CG)	Outcomes and measurements	Synthesis of main results	Comments
Amagai (2017)/ Suzuki (2018)/ Kanazawa (2019)/ Suzuki (2019)	edentulous elderly patients requiring new complete dentures IG: 75.3 yrs CG: 78.6 yrs 70 randomized, 62 finished the trial at 3 months 59 finished the trial at 6 months Location: Tokyo (Japan) Period: 2015-2016	IG: (n.31 at 3 months, 30 at 6 months) complete denture treatment + dietary advice in a pamphlet form (indicating "what" and "how much" should be eaten in a day) CG: (n.31 at 3 months, 29 at 6 months) complete denture treatment + advice pertaining to the care and maintenance of the dentures	Food intake: brief-type self-administered diet history questionnaire (BDHQ). Self reported MNA-SF Oral health related quality of life: Japanese version of the Oral Health Impact Profile for edentulous people (OHIP-EDENT-J) Masticatory function:color-changeable chewing gum and a test gummy jelly Outcome assessment at baseline, at 3 and 6 months post-treatment	*Between groups* At 3 months: - Greater intake of chicken, fish with bones, carrots, pumpkins, and in the intake of protein in IG - Intake of proteins, magnesium and vitamin B1 higher in the IG - No differences in MNA-SF score - No difference in the OHIP-EDENT-J scores and in masticatory function At 6 months: - Plant protein intake higher in the IG; - Animal protein and vitamin B12 intakes higher in the CG. - Higher MNA-SF score in the IG *Within groups* At 3 months: Both groups improved in the OHIP-EDENT-J scores and in masticatory function	At baseline, protein intake met the recommended dietary reference intakes for Japanese in both groups Incomplete blinding Nutrient intake based on self-reported questionnaire
Awad (2012)	Edentulous for a minimum of 5 years, aged > 65 yrs 255 randomized, 219 completed 12 months follow up Location: Montreal (Canada) Period: NR	IG: (n.110) IOD and maxillary CD CG: (n.109) CD	Primary outcome: blood serum concentration of homocysteine Secondary outcomes: a range of haematological markers, BMI. Self reported chewing ability (Likert scale questionnaire) Outcome assessment at baseline and at 12 months post-treatment	*Between groups* - No differences at 12 months in the primary and secondary nutritional outcomes - Significant differences in the individuals' ability to chew a variety of foods *Within groups* - Decrease of some nutrients (B12, folate) from baseline to 6 and 12 months, in both groups - BMI stable over time in both groups	Self-reported chewing ability Incomplete blinding

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Table II. *continues.*

Author (year)	Participants, location	Intervention (IG)/comparator (CG)	Outcomes and measurements	Synthesis of main results	Comments
Hamdan (2013)	Same population as Awad 2012 255 randomized, 217 finished the trial for the investigated outcome at 12 months. Same Location and period as Awad 2012	IG: (n.103) IOD and maxillary CD CG: (n.114) complete CD	Three standard 24-hour dietary recalls by telephone interview Outcome assessment at baseline and at 12 months post-treatment	*Between groups* - No differences in the intake of total dietary fiber (TDF), energy, macronutrients and 9 micronutrient	Nutrient intake based on self-reported questionnaire Incomplete blinding Same Trial Registration Number as Awad 2012
McKenna (2014 and 2015)/Wallace (2018)	Partially dentate patients aged >65 yrs 132 randomized, 89 finished the trial at 12 months Location: Cork (Ireland) Period: NR	IG: (n.45) functionally orientated treatment (shortened dental arch) CG: (n.44) (conventional treatment) removable partial dentures	Food intake: self reported MNA and MNA-SF A range of haematological markers Chewing ability: two coloured chewing gum. Outcome assessment at baseline and at 1,6 and 12 months post-treatment	*Between groups* - No differences for all haematological markers, for MNA score and for chewing ability *Within groups* - Improvement in Vit.D levels and MNA score at 12 months in both groups. - Improvement in chewing ability at 12 months in both groups.	Self-reported dietary intake Incomplete blinding
Morais (2003)	Edentulous for a minimum of 5 years, aged 65-75 yrs 60 randomized, 56 finished the trial at 6 months Location: Montreal (Canada) Period: NR	IG: (n.29) IOD and maxillary CD CG: (n.27) conventional CD	Food diary. BMI, various anthropometric measures A range of haematological markers. Self reported chewing ability Outcome assessment at baseline and at 1and 6 months post-treatment	*Between groups* - No differences for all haematological markers, nutrient intake and anthropometric data *Within groups* Some hematological markers (B12, Albumin), some anthropometric measures and some questions on masticatory functions improved post-treatment, more frequently in the IG	Self-reported dietary intake Incomplete blinding

NR: not reported; IOD: mandibular implant overdenture; CD: complete denture; MNA: mini nutritional assessment; MNA-SF: mini nutritional assessment-short form; BMI: body mass index; SDA: shortened dental arch; RPD: removable partial denture.

compared the effect of a nutritional advice vs standard advice on dentures' maintenance in people with new complete dentures; both groups improved masticatory function at 3 months; at 6 months the intervention group showed a higher intake of plant protein and a higher MNA-SF score, while the control group showed a higher intake of animal protein and vitamin B12.

8 observational studies were included (Tab. III); the 2 prospective cohorts evaluated the effects of a prosthetic rehabilitation alone [21] or coupled with a dietary counseling [22] with a "before/after" design; both studies show an improvement in some food and nutrient intake after prosthetic rehabilitation, although one of them did not adjust for potential confounders [21]. We included 6 cross sectional surveys [23-28], more frequently performed on subset of subjects form larger population surveys or cohorts, aiming to evaluate the association between oral status (e.g. number of teeth, wearing denture, occlusal force) and nutritional intake, in two studies both self-reported by subjects. Overall results suggest that a better masticatory performance provides the elderly with a higher micro and macro-nutrients intake, in particular vegetables. Due to the heterogeneity in the definitions of outcomes, exposures and covariates controlled for in the statistical analyses in the observational studies included in the review we did not perform a formal meta-analysis. We also did not perform a formal meta-analysis of RCT results due to the small number of available studies for each specific clinical question.

Table III. Characteristics and results of included observational studies (Prospective cohort or Cross-sectional survey).

Author (year)	Participants, location and period	Objective	Outcomes and measurements	Synthesis of main results	Comments
Prospective cohort studies					
Nabeshima (2018)	Partially dentate patients scheduled to receive new removable partial dentures (RPD) at a dental hospital N.38 selected, 32 analysed Mean age 73.2 yrs (SD 7.7) Women: 65.8% Location: Tokyo (Japan) Period: 2015-2017	Evaluate if a dietary counselling (aimed at increasing dietary fruit and vegetable intake and improving dietary habits) administered in conjunction with RPDs would increase fruit and vegetable intake. Patients received dietary counseling provided by a dentist twice, directly after treatment and at 1 month follow-up evaluation	Included only patients who were scheduled to receive RPD and were currently eating < 350 g of vegetables per day (i.e.the daily intake recommended in Japan). Food and nutrient intake: estimated from self-administered BDHQ Blood samples: carotenoids and vitamin C in 6-hour fasting blood samples Questionnaire and blood samples at baseline (before RPD), and at 1 and 3 months after RPD	At univariate analysis: - mean vegetable intake increased significantly at 3 months after treatment, from 249 to 323 g/day - mean fruit intake did not change substantially, from 162 to 173 g/day at 3 months (univariate analysis) - serum carotenoids and vitamin C levels measured with 6-hour fasting blood samples remained constant	Self-reported food intake Small sample size The authors report that at baseline mean fruit intake (162 g/day) of the study population was greater than in the Japanese population as a whole (109 g/day)
Tanasić (2017)	Patients partially or completely edentulous with a need for rehabilitation, aged >= 65 yrs N.150 analyzed Location: Belgrade (Serbia) Period: 2011-2015	To test if prosthetic restorations improve the nutritional status of patients	BMI and MNA recorded before and at 6 and 12 months after prosthetic rehabilitation 34.7% and 30.7% of patients received an implant supported maxillary and mandibular overdentures, respectively; 65.3% and 69.3% of patients received maxillary and mandibular RDB, respectively	At baseline: - 47.3% underweight (BMI < 18.5), - 32.7% at risk of malnutrition (MNA score 17-23.5) and 16.7% malnourished (MNA score < 17) At the univariate analysis, improvement in the MNA and BMI after 6 and 12 months from prosthetic rehabilitation	Self-reported dietary intake Information on comorbidities, educational level, socio-economic status not collected

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Table III. *continues.*

Author (year)	Participants, location and period	Objective	Outcomes and measurements	Synthesis of main results	Comments
Cross-sectional surveys					
Choi (2014)	Subjects aged >= 65 years N. 722 Median age: nr Women: 58.2 Location: Korea Period: 2007	To examine the relationship between the oral health and nutritional intake of people aged 65 and older	Study based on the results from 4th Korea National Health and Nutrition Examination Survey (KNHANES), for subjects aged >= 65 yrs and who answered both the health check-up and nutrition questionnaire 24-h dietary recall method Prosthodontic status evaluated during health examination	At a multivariate analysis adjusted for gender and income, daily nutritional intakes of energy, protein, fat, ash, calcium, phosphorus and thiamine were decreased significantly in elderly with partial or full dentures compared with those with no prosthesis or with a fixed prosthesis	Self-reported dietary intake
Inomata (2017)	Individuals 79-81 yrs residing close to the visit venue, from an ongoing cohort study N.760 Age 79-81 yrs Women: 52.1% Location: two regions of Japan Period: 2011-2012	To determine the association of dietary intake with the number of teeth and occlusal force in community dwelling 80-y-old Japanese people	Data obtained from the baseline visit of Japanese octogenarians included in the prospective cohort study "SONIC" Oral examination to evaluate: -number of teeth - bilateral maximal occlusal force (grouped by tertiles) in the intercuspal position using pressure-sensitive sheets Food intake (Diet during the preceding month): brief-type self-administered diet history questionnaire (BDHQ)	Response rate = 17.5% (941/5378) 181 subjects further excluded (extremely low or high reported energy intake, those currently receiving dietary counseling, or with intentional dietary change during the preceding year) In multivariate analysis adjusted for gender, educational level, financial status, area of residence, family structure and BMI: - the number of teeth was not associated with the energy-adjusted intake of any food group examined - a decline in occlusal force was significantly associated with a lower intake of vegetables, fish and shellfish, protein, polyunsaturated fatty acids, dietary fiber and most vitamins and minerals	The average number of teeth of the study participants (15.2) was higher than the data for Japanese aged 80 y to 84 y (12.2) Self-reported dietary intake

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Table III. *continues*.

Author (year)	Participants, location and period	Objective	Outcomes and measurements	Synthesis of main results	Comments
Natapov (2018)	Individuals > 65 yrs living in the community and insured medically with two of the four health funds. N.1776 Mean age NR Women: NR Location: Israel Period: 2005-2006	To assess the impact of dental status and visits on dietary intake of the Israeli elderly	Study based on data collected from those interviewed for the first National Health and Nutrition Survey of the Elderly (Mabat Zahav), carried out in 2005-6. Patients interviewed in their homes by trained interviewers.Food intake: 24 h dietary recall method. Questionnaire: demographic, socio-economic, behavioral and general health conditions, and subjective dental health status, including owning removable (partial or full) dentures	Response rate (questionnaire filled) = 96% (1776/ 1852) At a multivariate analysis adjusted for education, interest in association between nutrition and health and reading nutrition labels: - elderly who had no dentures had significantly better intakes of 4 out of 5 parameters - energy, fiber, protein and vegetables than the elderly with dentures	Self-report of both outcomes and main exposures (nutritional status, eating habits, dental status)
Okamoto (2019)	Volunteers from the Nara prefecture aged >= 65 years at the baseline survey, who were living in their own homes and were able to walk independently N. 3134 Median age:71.0 yr Women: 49.2 Location: Japan Period: 2007	Hypotheses tested: (i) A smaller number of teeth is associated with lower maximum occlusal force, fewer masticable foods, lower serum albumin levels, and a lower BMI. (ii) Among people with approximately the same numbers of teeth, people without occlusal support in the molar region have a lower masticatory ability, serum albumin levels, and BMI than people with such support	Data retrieved from the baseline data of the 2007 Fujiwara-kyo study (prospective cohort study on elderly), for subjects with available data on occlusal force The baseline health examination included a dental examination, measurement of occlusal force, measurement of height and body weight, blood collection, and a questionnaire about lifestyle Nutritional indices: serum albumin and BMI	At multivariate analyses with serum albumin levels below the lower quartile (< 4.4g/dL) and a BMI below the lower quartile (< 21 kg/m^2) as dependent variables, and number of teeth, maximal occlusal force, age, education length, alcohol consumption, smoking status, grip strength, and disease history as explanatory variables - among males, no association between reduced number of teeth and maximum occlusion force and the nutritional indices -among females: a maximum occlusal force of 100 to 300 N or less than 100 N were associated with serum albumin levels below 4.4 g/dL, not with BMI below lower quartile. No consistent association between number of teeth and nutritional indices No differences in nutritional indices for people with or without occlusal support in the molar region In both males and females, the maximum occlusal force decreased significantly with the number of teeth	

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Table III. *continues*.

Author (year)	Participants, location and period	Objective	Outcomes and measurements	Synthesis of main results	Comments
Stoffel (2018)	Individuals 65-74 yrs residing in households N.287 Mean age 69.3 yrs (SD 3.52) Women: 64.5% Location: Cruz Alta (Brasil) Period: July-August 2016	To assess nutritional status and associated factors in elderly individuals	Nutritional status: self reported MNA Demographic, socio-economic, behavioral and general health conditions: self completed questionnaire (PCA Tool-SB Brazil) Clinical visit: dental status (including need of prosthesis), anthropometric measurements	48.4% at nutritional risk (45.3% at risk of malnutrition and 3.1% malnourished) In a multivariate analysis including as predictors the use of prosthesis and access to a dentist, compared to persons complete or partially dentate, those edentulous wearing no or only one prosthesis were at higher nutritional risk, while no increased nutritional risk was observed for those edentulous wearing two prosthesis. A higher nutritional risk was also observed for those reporting no access to a dentist in the previous 12 months	Self-reported dietary intake
Su (2020)	Attendees of two elderly welfare centers aged ≥ 65 years, able to walk without help N.294 Mean age 75.8 yrs (SD 5.8) Women: 71.1% Location: Sapporo (Japan) Period: August-September 2018	To determine if older adults wearing complete or partial dentures have a higher risk of malnutrition	Nutritional status: self reported MNA-SF Demographic characteristics, eating habits, dental status (complete denture:CD, partial denture: PD, no denture:ND) and health status: self completed questionnaire Taste sensitivity: salt-impregnated taste paper test BMI and protein mass: bioelectrical impedance analysis	Response rate = 95% (294/310) 64.3% wore PD, 9.9% wore CD 23.5% at risk of malnutrition (MNA-SF < 12) At the multivariate analysis, including age, gender, suspected dysphagia, frailty, protein mass, and awareness of salt restriction, the risk of malnutrition was positively associated with suspected dysphagia and frailty, and negatively associated with protein mass, awareness of salt restriction and wearing PD compared to ND (OR 0.39, 95% CI, 0.20-0.77); wearing a CD compared to ND showed a lower risk of malnutrition, although not statistically significant (OR 0.63, 95% CI 0.22-1.83)	Small number of persons wearing a CD Self-report of both outcomes and main exposures (nutritional status, eating habits, dental status)

NR: not reported; IOD: mandibular implant overdenture; CD: complete denture; MNA: mini nutritional assessment; MNA-SF: mini nutritional assessment-short form; BMI: body mass index; RPD: removable partial denture.

DISCUSSION

Cross-sectional studies included in the review mostly indicate a positive association between oral rehabilitation and nutrients intake. However, when approaching cross-sectional studies, some limitations should be acknowledged; first of all, the cross-sectional design does not allow to investigate the temporality of the association, i.e.to explain if food intake variations occurred before mastication impairment or as a consequence of it; this aspect could be better addressed with an observational prospective study design. However, in a recent systematic review [29] that took into account 8 longitudinal studies in 4 different countries (without age selection of participants), the authors pointed out that most results were contradictory and the quality of the evidence was weak, leading to the conclusion that there is no strong evidence on the effect of tooth loss on diet and nutrition, with inconsistent results among the few studies identified (Tab. S3). The observational studies included in this review often included small samples of subjects, and the association with confounding factors, such as comorbidities, educational level and socio-economic status, was sometimes not considered. As regards the randomized clinical trials the three trials [11-16] comparing the effects of two different prosthetic interventions did not show any differences in the intake of nutrients or in the hematological markers between the two study groups; when performed, the analysis of within groups variations shows mostly an improvement in masticatory functions/chewing ability in both groups, but inconsistent results regarding nutritional intake over time within each group. One RCT [17-20] compared the effect of a nutritional advice vs standard advice on dentures' maintenance in people with new complete dentures: both groups improved masticatory function at 3 months; at 6 months the intervention group showed a higher intake of plant protein and a higher MNA-SF score, although the control group showed a higher intake of animal protein and vitamin B12. Therefore, the outcomes of the RCTs overall indicate that a congruous prosthetic rehabilitation alone can't assure adequate nutrients intake, so that the diet in the elderly doesn't depend only on the use of an adequate prosthesis: the influence of other factors is suggested, among which salivary flux and multiple drug intake, social and economic factors, phycological factors, physical activity and alcohol consumption. First of all, when approaching an ageing population it is important to remind that the decline of nutrition and the loss of appetite, which can be disease related or drug induced [30] is somehow expected and that might result in a gradual malnutrition [31,32]. Psychological disorders, among which depression is the most frequent, are often associated with loss of appetite [33]. Other psychological factors contributing to malnutrition and anorexia are traumatic life events such as loneliness, death of a spouse, or social factors such as social isolation, loss of independence and socio-economic inequality [34]. Impaired vision can affect food access making food preparation, cooking and reading food labels more difficult [35]. Moreover, the sense of smell and taste decreases with age and this contributes to diminished food intake in the elderly and has a negative impact on the type of food ingested, typically resulting in a less varied diet [36]. With age, there is an increasing susceptibility to various pathological conditions such as Candidal infections, burning mouth syndrome, and denture-related lesions, that contribute to maintain the vicious cycle of malnutrition. Furthermore, the decline in saliva secretion during aging causes xerostomia, which adversely affects masticatory function making the food bolus formation difficult [37] and impairing taste sensitivity [38]. Nutrient intake is also affected by excessive alcohol consumption, which decreases the appetite, discouraging caloric intake from food, with a corresponding reduction in other nutrients and compromising the absorption of nutrients [39]. The impact of different factors, other than mastication and prosthetic status, has been discussed and confirmed by recent reviews. (Appendix, Table S3) In his systematic review, Bezerra [40] questions if the real impact of dental implant-supported prostheses on the nutritional status of partially and complete edentulous patients. Patients wearing implant overdentures presented better masticatory function in comparison to conventional complete denture wearers, but bioavailability of several nutrients remained within the same range, especially on the long-term. Therefore, the authors concluded that oral rehabilitation should be planned using a multidisciplinary approach, in order to enhance food choices and promote health benefits to the patients. Yamazaki et al. [41] came to the same conclusion, stating that the modifying effect of implant retained overdenture treatment on nutritional status might be limited and that further studies are needed to evaluate the effectiveness and efficacy of denture treatments. One RCT included in our review [20] suggests some improvement of the nutritional intake only when the prosthetic treatment was associated with proper dietary advice. The narrative synthesis of a recent systematic review [42] (Tab. S3) also indicates support for dietary intervention coupled with oral rehabilitation on diet. In this context, a key role can be played by nutritional counselling, that should be encouraged and combined with the prosthetic treatment to improve food intake. When treating elderly patients, especially after completing a prosthetic rehabilitation, the treatment should be finalized by giving simple dietary advice,orally or by means of a pamphlet, and possibly further reinforced by

proper nutritional counseling performed by nutritionists in order to improve nutrients intake of healthy elderly and those at risk of malnutrition, and to prevent the occurrence and the progression of systemic conditions such as sarcopenia, osteoporosis and cardiovascular diseases.

The exposure to nutritional counseling is crucial and depends on several variables. Even if nutritionists are the most prepared professionals to monitor food consumption and train eating habits, access to these professionals might be limited, especially among the lower income population. A recent study [43] pointed out that undergoing medical consultation in the previous year increased the probability by three of having received nutritional counseling, thus enlightening the role of the physicians as promoters of nutritional counseling, based on their frequent and direct contact with patients. According to Antoniadu [44], the actual needs of independent elderly adults suggest that health research and oral health care should learn to design and manage olistic and personal treatment plans, including lifestyle, psychological and nutritional approaches: therefore, the professionals working in the field of gerodontology should be educated on the nutritional needs of the elderly. In this context, the strategy to improve nutrients intake in the elderly population should take into account the fortification of food products with selected ingredients, such as vitamins and minerals [45] and providing food with adequate sensory values and optimal nutritional quality [46]. In particular, dietary indications should be focused on increasing protein intake [47], in order to maintain muscular mass and reduce the occurrence and severity of sarcopenia, meaning that it is necessary to take high-quality protein during each meal in order to reach an optimal daily intake of of 1.0-1.2 g/kg [48,49]. Meals should also be balanced by introducing nutrients that prevent osteoporosis occurrence, not only calcium and vitamin D, but also iron, copper, vitamin K, phosphorus, manganese, boron, potassium and selenium: in this context, bone remodeling and bone mineral density can be successfully sustained by introducing a balanced amount of fruit, dried fruits, fibre, vegetables, probiotic and dairy foods [50-54].

CONCLUSIONS

Based on the available data, there aren't enough studies to draw definitive conclusions, but further research is required to improve current knowledge of these associations and to acquire uniform and comparable results. These data will be useful to develop welfare politics customized for an ageing population even when independent. Healthy nutrition, together with congruous prosthetic solutions and increased masticatory function, is necessary to change and improve diet habits. Nutritional counselling seems an important factor to improve nutrients intake in the elderly and it is recommended to be associated with the prosthetic rehabilitation treatment. The multidisciplinary cooperation of dental professionals, dietetics practitioners, and primary care providers to improve dietary habits and nutritional intake seems therefore mandatory.

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Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

BE: contributed to study design, data acquisition and interpretation and drafted the manuscript; MC: designed the research strategy, coordinated the data-analysis and interpretation; NV: contributed to study design and critically revised the manuscript; PC: contributed to study conception and critically revised the manuscript; BF: contributed to study conception and design and critically revised the manuscript.

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