Does Prosthodontic Treatment Improve the Nutrition Status in the Elderly? Literature Review

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Abstract Prosthodontic treatment is performed to improve esthetics and oral function. That is, mastication and speech as a primary function, and finally for nutritional requirements, especially in the elderly. This literature review was conducted to evaluate the treatment outcomes of prosthodontic treatment for the elderly with two nutritional hypotheses: 1) prosthodontic intervention improves the diversity of food intake, and 2) prosthodontic intervention improves nutritional status. There is weak evidence that prosthodontic treatment can improve dietary intake; however, it could affect less the nutritional condition in comparatively healthy elderly individuals. The combination of prosthodontic treatment and nutritional guidance demonstrated nutrient intake efficiency.

Keywords: prosthodontic treatment, oral function, elderly, nutrition, food intake

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1. Introduction

The glossary of prosthodontic terms defines prosthodontics as the dental specialty pertaining to the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, comfort, appearance, and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues by using biocompatible substitutes [1]. Oral function mainly includes mastication. Mastication is the initial process of digestion and nutritional intake. Food intake from the oral cavity is also a great desire, especially in the elderly, and involves human dignity.

With the increase in the elderly population worldwide, the concept of frailty in the elderly has been proposed and has become popular [2,3]. Undernutrition/malnutrition is a key element of physical frailty and sarcopenia [4,5]. Although there are numerous causes of undernutrition/malnutrition, difficulty in mastication owing to tooth loss and denture disorder is a major factor [6,7]. Prosthodontic treatment is expected to improve masticatory disorders and facilitate the intake of various foods through the oral cavity. Several methods have been proposed as outcomes following prosthodontic treatment: subjective satisfaction using a visual analog scale, questionnaires on the ease of chewing food, maximum occlusal force, and chewing efficiency using gummy jelly [8,9,10]. Further downstream outcomes following mastication have been addressed: whether nutrient intake becomes more appropriate as a result of prosthodontic intervention and whether the nutritional requirement of the patient becomes more appropriate.

Considering the importance of undernutrition/malnutrition in the elderly, the efficacy of prosthodontic treatment needs to be discussed with outcomes such as nutrition and systemic health conditions. Although several studies on the relationship between prosthodontic interventions and nutrition have been conducted, insufficient and conflicting results have been found.

This literature review was conducted to evaluate the treatment outcomes of prosthodontic treatment for the elderly with two nutritional hypotheses: 1) prosthodontic intervention improves the diversity of food intake, and 2) prosthodontic intervention improves the nutritional condition.

2. Material and Methods

2.1. Information Sources and Search

English language articles published between January 1980 and December 2020 were reviewed using the MEDLINE database (via PubMed). Electronic database searches were performed using keywords and MeSH terms based on a search strategy used for searching MEDLINE (via PubMed): (nutrition) AND ((dental prosthesis [MeSH Terms]) or (dental implant [MeSH Terms])). In addition to these database searches, manual searches were performed.
2.2. Inclusion Criteria

The articles were selected based on the following inclusion criteria: 1) prosthodontic intervention or dental arch condition are described, 2) articles with dietary intake assessments or nutritional outcomes, such as body mass index (BMI), minimum nutrition assessment (MNA), and blood markers; 3) cross-sectional study, cohort study, randomized controlled trials (RCTs), and literature review studies; and 4) full-text articles in English. Moreover, the exclusion criteria were in vitro and animal studies.

2.3. Study Selection

A literature search was performed in this study. Two authors (T. I. and T.G.) who had previously determined the criteria, independently evaluated the literature search. First, the collected titles and abstracts were selected based on the aim and criteria. Furthermore, two reviewers confirmed that the results were the same; then, those articles underwent full-text reading to check further if detailed information was reported. Finally, the effects of both dietary intake and nutritional status were evaluated by the two authors based on the following:

“Supported” indicates that the papers support that the prosthodontic intervention/oral health is effective.

“Not supported” indicates that there is no evidence on the effect.

“Conflicting” indicates that the results on the effect are conflicting.

“Not supported” indicates that the papers support that the prosthodontic intervention/oral health is effective.

Table 1. Results of original papers

| No. | Authors | Year | Research type | Subjects No. | Age | Follow-up period | Intervention | Comparison | Effects | Dietary | Nutritional |
|-----|---------|------|---------------|--------------|-----|-----------------|--------------|------------|---------|---------|-------------|
| 1   | Olivier | 1995 | Cohort        | 55-74        | 55  | 3w, 6-9m        | denture relining +NG |            |         |         |            |
| 2   | Sebring | 1995 | Comparative study | 71    | around 60 | 3.5y | ID(41) | CD(30) |         |         |            |
| 3   | Moynihan | 2000 | RCTs         | 60          |     | 3m, 12m        | SDA(30)      | PD(30)    |         |         |            |
| 4   | Hamada | 2001 | Cohort       | 89          |     | diabet edentulism | 6m | IOD(52) | CD(37) |         |         |            |
| 5   | Sheiham | 2001 | Comparative study | 753 (Home), 196 (NH) | >65 | | | | | | | |
| 6   | Sheiham | 2002 | Cross-sectional | 629 | >65 | | | | | | |
| 7   | Morais  | 2003 | Cohort       | 60          | 65-75 | 6m | IOD(30) | CD(30) |         |         | |
| 8   | Bradbury | 2006 | RCTs        | 58          | 65-66 | 6w | CD(30)+DC | CD(28) |         |         | |
| 9   | Wöstemann | 2008 | Cohort      | 47(NH)      | >60 | 6m | Denture intervention | |         |         | |
| 10  | Müller  | 2008 | RCTs        | 53          | 53  | 1y | IOD | CD |         |         | |
| 11  | Lee     | 2010 | Cross-sectional | 3611 | >60 | | | | | | |
| 12  | Borges  | 2011 | Cohort       | 16          | 59-2 | 3m, 6m | CD -> IOD | before/after | | |
| 13  | McKenna | 2012 | RCTs        | 44          | >65 | 1m | SDA(23) | RPD(21) |         |         | |
| 14  | Awad    | 2012 | RCTs        | 255         | >65 | 6m, 1y | IOD(128) | CD(127) |         |         | |
| 15  | Müller  | 2013 | RCTs        | 34          | 84-85 | 1y | IOD(16 ) | CD(18) |         |         | |
| 16  | Hamdan  | 2013 | RCTs        | 217         | >65 | 1y | IOD(103) | CD(114) |         |         | |
| 17  | Tajbakhsh | 2013 | Cohort       | 32          | 58  | 5y | CD -> IFPD | before/after | | |
| 18  | McKenna | 2014 | RCTs        | 132         | >65 | 6m, 12m | RPD(65) | SDA(67) |         |         | |
| 19  | Gonçalves | 2015 | Crossover   | 12          | 62.6 | 3 days | IFPD vs RPD | before/after | | |
| 20  | Elsig   | 2015 | Cross-sectional | 29 dementia, 22 normal, 3 cognitive decline | >75 | | | | | | |
| 21  | Tanasić | 2016 | Cohort      | 200         | 68.9 | 1y | RPD | | | | |
| 22  | Amagai  | 2017 | RCTs        | 62          | 77  | 3M | CD+NG(31) | CD(31) |         |         | |
| 23  | Wallace | 2018 | RCTs        | 89          | >65 | 1y | RPD(44) | SDA(45) |         |         | |

NH: Nursing home residents
NG: nutritional guidance
RPD: Removable partial denture
CD: Complete denture
IOD: Implant-supported overdenture
IFPD: Implant fixed partial denture
SDA: Shortened dental arch

3. Results

After the initial screening of the titles and abstracts, 23 original studies [11-33] and 16 review studies [34-49] were finally selected, and the nutritional effects of the prosthodontic interventions/dental arch conditions were discussed. The results of the 23 original studies and 16 review studies are summarized in Table 1 and Table 2, respectively. The table on the original articles contains the author names, publication year, research type, subject number and age, follow-up period, prosthodontic intervention and comparison, effects on the dietary intake and nutritional status, and main suggestions. The table on the review articles contains the author names, publication year, research type, prosthodontic intervention/target, effects on dietary intake and nutritional status, and main suggestions.

BMI, MNA, and some blood biomarkers are often used in nutritional assessments, and dietary intake is used as an indirect nutritional assessment. The Oral Health Impact Profile (OHIP), masticatory efficiency, and masticatory satisfaction were used to assess oral health and masticatory ability. The relationship between the missing teeth number/functional teeth number and nutritional status was examined in a cross-sectional study. Cohort studies were also conducted to compare the nutritional outcomes before and after prosthodontic treatment. Randomized controlled trials (RCTs) were used to compare the outcomes between the implant prostheses and conventional removable dentures.
| No. | Authors          | Year | Nutritional results                                                                                                                                 |
|-----|------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Olivier          | 1995 | Reduce the presence of digestive symptoms. Fiber intake from vegetables was significantly increased.                                                |
| 2   | Sebring          | 1995 | No significant differences in intake of calories or of 27 nutrients were noted between the two groups.                                                  |
| 3   | Moynihan         | 2000 | Prosthetic rehabilitation did not result in any other change in the intake of nutrients or in the amount of fruits and vegetables consumed.            |
| 4   | Hamada           | 2001 | The replacement of old dentures with new dentures that included either a mandibular CD or IOD did not alter patient diets such that the patients improved their nutritional intakes of essential micronutrients and macronutrients. |
| 5   | Sheiham          | 2001 | The presence, number and distribution of natural teeth are related to the ability to eat certain foods, affecting nutrient intakes and two biochemical measures of nutritional status. |
| 6   | Sheiham          | 2002 | People without teeth were significantly more likely to be underweight than those with 11 or more teeth.                                               |
| 7   | Morais           | 2003 | Significant increases were seen in concentrations of serum albumin, hemoglobin, and B12. No significant between-group differences were found. Body measurements were improved in IOD. |
| 8   | Bradbury         | 2006 | Greater increase in fruit/vegetable consumption                                                                                                      |
| 9   | Wöstmann         | 2008 | Despite the highly significant improvement in masticatory ability, no general improvement regarding the nutritional status was observed since the albumin, zinc and MNA values remained unchanged and pre-albumin even decreased. |
| 10  | Müller           | 2008 | CD wearers reported having more difficulty in chewing hard foods, both groups appeared to have a similar nutritional status (Body composition, plasma parameters, food intake) |
| 11  | Lee              | 2010 | Systolic blood pressure, CHOL, FPG, and BMI in males were statistically significant after adjusting for age and smoking. In females, systolic blood pressure, CHOL, FPG, and BMI were positively associated with the number of missing teeth. |
| 12  | Borges           | 2011 | Improvement in masticatory performance and nutritional condition.                                                                                     |
| 13  | McKenna          | 2012 | Both prosthetic rehabilitation resulted in an improvement in MNA score. Blood markers did not illustrate a clear picture of improvement in nutritional status. |
| 14  | Awad             | 2012 | No positive effect on the nutritional state (blood plasma levels of homocysteine (tHcy), vitamin B12, vitamin B6, albumin, serum folate, and C-reactive protein). |
| 15  | Müller           | 2013 | BMI decreased in both groups, but the decline tended to be smaller in the intervention group; blood markers and the MNA did not confirm this tendency.IODs are significantly more likely to take in their nutrients through fresh, whole fruits and vegetables. |
| 16  | Hamdan           | 2013 | Total dietary fiber (TDF), macronutrients, 9 micronutrients, and energy in diets. No significant between-group differences were found.               |
| 17  | Tajbakhsh        | 2013 | Vegetable intake and ability to masticate raw, hard, and fibrous food improved                                                                      |
| 18  | McKenna          | 2014 | Biochemical markers (serum Albumin and Cholesterol, Ferritin, Folate, Vitamin B12 and D). The only measure which illustrated consistent significant improvements in nutritional status for either group were Vitamin D. No difference was recorded between two groups. |
| 19  | Gonçalves        | 2015 | Higher intake of fiber, calcium, and iron and lower consumption of cholesterol-rich food                                                             |
| 20  | Elsig            | 2015 | Neither dental state nor chewing efficiency was related to the nutritional state.                                                                     |
| 21  | Tanasić          | 2016 | Adequate oral rehabilitation with symmetric positioning of the functional tooth units can improve the nutritional status (MMA, BMI) of partially edentulous patients. |
| 22  | Amagai           | 2017 | Simple dietary advice combined with complete denture treatment could improve food intake of edentulous patients.                                  |
| 23  | Wallace          | 2018 | Masticatory performance may only have minor associations with nutritional status for this patient group. No difference of nutritional status (MNA, blood marker) was found in two groups. Further research is required to determine the impact of oral rehabilitation coupled with nutritional counseling for this patient population. |

**Table 2. Results of review papers**

| No. | Authors                  | Year | Intervention/Target | Effects | Dietary intakes | Nutritional status | Suggestions                                                                 |
|-----|--------------------------|------|---------------------|---------|-----------------|--------------------|-----------------------------------------------------------------------------|
| 1   | Budtz-Jørgensen          | 2000 | Prosthetic intervention |         |                 |                    | There is no evidence that the provision of prosthetic therapies can markedly improve dietary intakes. |
| 2   | Budtz-Jørgensen          | 2001 | Prosthetic intervention |         |                 |                    | Maintenance or re-establishment of masticatory function is an integral part of the medical health care of these patients, with the aim of improving their nutritional status and quality of life. |
| 3   | Ritchie                  | 2002 | Oral health         |         |                 |                    | Tooth loss affects dietary quality and nutrient intake in a manner that may increase the risk for several systemic diseases, but there is a paucity of well-designed studies addressing oral health and nutrition. |
| 4   | Sánchez-Ayala           | 2010 | IOD vs RPD          |         |                 |                    | The effect on the nutritional state in edentulous subjects treated with implant therapy is similar to the one obtained with conventional removable dentures. |
| 5   | Preshaw                  | 2011 | RPD                 |         |                 |                    | There is no evidence to support a negative impact on nutritional status.     |
| 6   | Van Lancker              | 2012 | Oral health in elderly |         |                 |                    | Tentative evidence indicates an independent association between oral health status and malnutrition in the elderly residing in a long-term care facility. |
| 7   | Tamura                   | 2013 | Oral health         |         |                 |                    | In 16 studies. MNA, BMI, other standard measures of malnutrition. Potentially modifiable factors consistently associated with increased likelihood of weight loss, low BMI, or poor nutrition included depression, impaired function, and poor oral intake. |
| 8   | Tada                     | 2014 | Oral health         |         |                 |                    | In 22 of 28 studies, elderly persons with better mastication and dentition reported significantly higher consumption of foods and intake of some nutrients than those with poorer oral health; 6 studies showed no such differences. 5 of the 7 intervention studies did not show significant improvement in food and/or nutrient intake. |
| 9   | Boven                    | 2015 | IOD vs CD           |         |                 |                    | Chewing efficiency, maximum bite force, and satisfaction are improved. The effect on QoL is uncertain, and there is no effect on nutritional status. |
In the original study, the first hypothesis was supported by many studies, especially how the combination of prosthodontic treatment and nutritional guidance improved the diversity of food intake. The second hypothesis was supported by some older studies but more recent studies tended to be less supportive.

In this review, there were many articles in which oral health status was related to the conditions of nutrition and frailty, which supported our hypothesis. However, the findings do not always show that it is the cause (chicken) or the effect (egg) with oral health status and the conditions of nutrition and frailty. Considering the effects of prosthodontic treatment, the first hypothesis is almost accepted; however, the second hypothesis is not.

4. Discussion

In this review, original papers and review papers were extracted since many conflicting opinions on the hypotheses were anticipated. It was intended to increase the reliability when providing answers to the hypotheses. Several studies have investigated the effects of prosthodontic intervention on nutritional conditions, including the diversity of food intake. This includes whether prosthodontic treatments provide diversity in food intake, whereby individuals can eat any food to obtain the appropriate nutrients and thus improve their nutritional status.

Most reports have shown improvements in satisfaction, quality of life, and chewing ability following conventional prosthodontic treatments and implant-supported denture delivery. Although such prosthodontic treatments facilitated diversity in food intake, patients wearing conventional dentures did not necessarily avoid specific types of food compared to patients wearing implant-supported dentures with higher masticatory efficiency [12,20,26]. This may be supported by the results of Fujimoto et al. [50], who reported that subjective masticatory satisfaction rather than objective masticatory efficiency reflected a higher BMI. This may be because the patients consumed any type of food through appropriate cooking methods.

Considering the improvement of nutritional status following prosthodontic interventions, some studies reported improvements [17,22,23,31,33]; however, most studies did not always report significant improvement [14,19,20,24,25,26,28,30,33,37,38,42,43,45,46]. Patients who have undergone prosthodontic treatment, including implant treatments, generally have good general health conditions without any hyponutrition/malnutrition, and prosthodontic treatments might be needed to obtain higher satisfaction with mastication. Consequently, the treatment might have had less effect on the nutritional condition of the elderly.

When prosthodontic treatment was combined with dietary guidance, both eating habits and nutritional conditions were reported to have improved. [11,18,32,33,41,46]. Bradbury et al. [18] reported that prosthodontic treatment combined with dietary counseling by a nutritionist resulted in a significant increase in fruit and vegetable consumption compared to the control group at six weeks following complete denture placement. Another study also reported that nutritional guidance improved nutrient intake using either conventional complete dentures or implant-supported overdentures, and the improvement was greater in patients with implants [18]. Similar results were reported by Amagai et al. in Japan [32].

Many reports suggest that the nutritional status is affected by the number of missing teeth and dental status in elderly patients requiring nursing care and patients in nursing homes [15,16,21,36,39,40,47,48,49], and our results were in agreement. In other words, for those who are unable to consider the method of food preparation and cooking for themselves, the maintenance of oral function, that is, masticatory ability, would be necessary at a minimum. There are many causes of low nutrition in the elderly, and it is important to clarify first the primary cause. Thus, the assessment of masticatory ability and diversity of food intake is warranted. If the patients report difficulty in mastication, the combination of prosthodontic treatment and nutritional guidance is considered effective.
Author Contributions
Conceptualization, T.I.; literature search, T.I., T.K. and T.G.; analysis and table preparation, T.I., T.K. and T.G.; original draft preparation, T.I.; review and editing, T.G., M.W., Y.I. and T.I.; funding acquisition, T.I. Authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

References
[1] The Glossary of Prosthodontic Terms: Ninth Edition, The Journal of Prosthetic Dentistry, 2017: 117(58): e1-e105.

[2] Fried, L.P., Tangen, C.M., Walston, J., Newman, A.B., Hirsch, C., Gott diener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., McBurnie M.A., Cardiovascular Health Study Collaborative Research Group, Frailty in older adults: evidence for a phenotype. The Journals of Gerontology: Series A, 2001: 56(3), M146-56.

[3] The Japan Geriatrics Society. 2014. Statement on the frailty from the Japan Geriatrics Society. (accessed 11.1.2021, at http://www.jpn-geriat-soc.or.jp/info/topics/pdf/20140513_01_01.pdf) (in Japanese).

[4] Bales, C.W., Ritchie, C.S., Sarco penia, weight loss, and nutritional frailty in the elderly, Annual Review of Nutrition, 2002: 22, 309-323.

[5] Cruz-Jentoft, A.J., Bahat, G., Bauer, J., Bauer, J., et al., Revised European consensus on definition and diagnosis, Age and Ageing, 2019: 48(1), 16-31.

[6] Akpata, E., Otoh, E., Enwonwu, C., Adeleke, O., Joshipura, K., Tooth loss, chewing habits, and food choices among older Nigerians in Plateau State: a preliminary study, Community Dentistry and Oral Epidemiology, 2011: 39(5), 409-415.

[7] Poisson, P., Laffond, T., Campos, S., Dupuis, V., Bourdel-Marchasson, I. Relationships between oral health, dysphagia and undernutrition in hospitalised elderly patients, Gerodontology, 2016: 33(2), 161-168.

[8] Hirai, T., Ishijima, T., Koshino, H., Anazai, T., Age-related change of masticatory function in complete denture wearers: Evaluation by a sieving method with peanuts and a food intake questionnaire method, International Journal of Prosthodontics, 1994: 5, 454-460.

[9] Awad, M.A., Feine, J.S., Measuring patient satisfaction with mandibular prostheses, Community Dentistry and Oral Epidemiology, 1998: 26(6), 400-405.

[10] Okiyama, S., Ikebe, K., Nokubi, T., Association between masticatory performance and maximal occlusal force in young men, Journal of Oral Rehabilitation, 2003: 30(3), 278-282.

[11] Olivier, M., Laurin, D., Brodeur, J.M., Boivin, M., Leduc, N., Lévy, M., Taché, R.H., Prosthetic relining and dietary counselling in elderly women, Journal of the Canadian Dental Association, 1993: 61(10), 882-886.

[12] Sebring, N.G., Guckes, A.D., Li, S.H., McCarthy, G.R., Nutritional adequacy of reported intake of edentulous subjects treated with new conventional or implant-supported mandibular dentures. Journal of Prosthetic Dentistry, 1995: 74, 358-363.

[13] Moynihan, P.J., Butler, T.J., Thomason, J.M., Jepson, N.J., Nutrient intake in partially dentate patients: the effect of prosthesis rehabilitation, Journal of Dentistry, 2000: 28(8), 557-563.

[14] Hamada, M.O., Garrett, N.R., Roumanas, E.D., Kapur, K.K., Freymiller, E., Han, T., Diener, R.M., Chen, T., Levin, S., A randomized clinical trial comparing the efficacy of mandibular implant-supported overdentures and conventional dentures in diabetic patients. Part IV: Comparisons of dietary intake, Journal of Prosthetic Dentistry, 2001: 85(1), 53-60.

[15] Sheiham, A., Steele, J., Does the condition of the mouth and teeth affect the ability to eat certain foods, nutrient and dietary intake and nutritional status amongst older people?, Public Health Nutrition, 2001: 4, 797-803.

[16] Sheiham, A., Steele, J.G., Marce nes, W., Finch, S., Walls, A.W., The relationship between oral health status and Body Mass Index among older people: A national survey of older people in Great Britain, British Dental Journal, 2002: 192, 703-706.

[17] Morais, J.A., Heydecke, G., Pawliuk, J., Lund, J.P., Feine, J.S., The effects of mandibular two-implant overdentures on nutrition in elderly edentulous individuals, Journal of Dental Research, 2003: 82(1), 53-58.

[18] Bradbury, J., Thomason, J.M., Jepson, N.J., Walls, A.W., Allen, P.F., Moynihan, P.J., Nutrition counseling increases fruit and vegetable intake in the edentulous, Journal of Dental Research, 2006: 85(5), 463-468.

[19] Wöstmann, B., Michel, K., Brinkert, B., Melchheimer-Weiskott, A., Rehmann, P., Balkenhohl, M., Influence of denture improvement on the nutritional status and quality of life of geriatric patients, Journal of Dental Research, 2008: 36(10), 816-821.

[20] Muller, K., Morais, J., Feine, J.S., Nutritional and anthropometric analysis of edentulous patients wearing implant overdentures or conventional dentures, Brazilian Dental Journal, 2008: 19(2), 145-150.

[21] Lee, H.K., Lee, K.D., Merchant, A.T., Lee, S.K., Song, K.B., Lee, S.G., Choi, Y.H., More missing teeth are associated with poorer general health in the rural Korean elderly, Archives of Gerontology and Geriatrics, 2010: 50, 30-33.

[22] Borges, Tânia de Freitas, M., Mendes, F.A., de Oliveira, T.R., do Prado, C.J., das Neves, F.D., Overdenture with immediate load: mastication and nutrition. British Journal of Nutrition, 2011: 105(7), 990-994.

[23] McKenna, G., Allen, P.F., Flynn, A., O'Mahony, D., DaMata, C., Cronin, M., Woods, N., Impact of tooth replacement strategies on the nutritional status of partially-dentate elders, Gerodontology, 2012: 29(2), e883-90.

[24] Awad, M.A., Morais, J.A., Wollin, S., Khalil, A., Gray-Donald, K., Feine, J.S., Impl ant overdentures and nutrition: a randomized controlled trial, Journal of Dental Research, 2012: 91(1), 39-46.

[25] Müller, F., Duvernay, E., Loup, A., Vazquez, L., Herrmann, F.R., Schimmel, M., Implant-supported mandibular overdentures in very old adults: a randomized controlled trial, Journal of Dental Research, 2016: 92(12 Suppl), 154S-60S.

[26] Hamdan, N.M., Gray-Donald, K., Awad, M.A., Johnson-Down, L., Wollin, S., Feine, J.S., Do implant overdentures improve dietary intake? A randomized clinical trial, Journal of Dental Research, 2013: 92(12 Suppl), 146S-53S.

[27] Tajbakhsh, S., Rubenstein, J.E., Faine , M.P., Mancl, L.A., Raigrodski, A.J., Selection patterns of dietary foods in edentulous participants rehabilitated with maxillary complete dentures opposed by mandibular implant-supported prostheses: a multicenter longitudinal assessment, Journal of Prosthetic Dentistry, 2011: 110(4), 252-258.

[28] McKenna, G., Allen, P.F., O'Mahony, D., Flynn, A., Cronin, M., DaMata, C., Woods, N., Comparison of functionally oriented tooth replacement and removable partial dentures on the nutritional status of partially dentate older patients: a randomised controlled clinical trial, Journal of Dental Research, 2014: 42(6), 653-659.

[29] Gonçalves, T.M., Campos, C.H., Garcia, R.C., Effects of implant-based prostheses on mastication, nutritional intake, and oral health-related quality of life in partially edentulous patients: a paired clinical trial, The International Journal of Oral & Maxillofacial Implants, 2015: 30(2), 391-396.

[30] Elsig, F., Schimmel, M., Duvernay, E., Giesannelli, S.V., Graef, C.E., Carlier, S., Herrmann, F.R., Michel, J.P., Gold, G., Zekry, D., Tooth loss, chewing efficiency and cognitive impairment in geriatric patients, Gerodontology 2015: 32, 149-156.

[31] Tanasić, I., Radaković, T., Stojić, L.T., Lemić, A.M., Soldatović, I., Association Between Dentition Status and Malnutrition Risk in Serbian Elders, The International Journal of Prosthodontics, 2016: 29(5), 484-486.

[32] Amagai, N., Komagamine, Y., Kanazawa, M., Iwaki, M., Jo, A., Suzuki, H., Minakuchi, S., The effect of prosthetic rehabilitation and simple dietary counseling on food intake and oral health.
related quality of life among the edentulous individuals: A randomized controlled trial, *Journal of Dentistry*, 2017: 65, 899-909.

[33] Wallace, S., Samietz, S., Abbas, M., McKenna, G., Woodside, J.V., Schimmel, M., Impact of prosthetic rehabilitation on the masticatory performance of partially dentate older patients: Can it predict nutritional state? Results from a RCT. *Journal of Dentistry*, 2018: 68, 66-71.

[34] Budtz-Jørgensen, E., Chung, J.P., Mojon, P., Successful aging—the case for prosthetic therapy, *Journal of Public Health Dentistry*, 2000: 60(4), 308-312.

[35] Budtz-Jørgensen, E., Chung, J.P., Rapin, C.H., Nutrition and oral health. *Best Practice & Research: Clinical Gastroenterology*, 2001: 15(6), 885-896.

[36] Ritchie, C.S., Joshipura, K., Hung, H.C., Douglass, C.W., Nutrition as a mediator in the relation between oral and systemic disease: associations between specific measures of adult oral health and nutrition outcomes, *Critical Reviews in Oral Biology & Medicine*, 2002; 13(3), 291-300.

[37] Sánchez-Ayala, A., Lagravère, M.O., Gonçalves, T.M., Lucena, S.C., Barbosa, C.M., Nutritional effects of implant therapy in edentulous patients—a systematic review, *Implant Dentistry*, 2010: 19(3), 196-207.

[38] Preshaw, P.M., Walls, A.W., Jakubovics, N.S., Moynihan, P.J., Jepson, N.J., Loewy, Z., Association of removable partial denture use with oral and systemic health, *Journal of Dentistry*, 2011: 39(11), 711-719.

[39] Van Lancker, A., Verhaeghe, S., Van Hecke, A., Vanderwee, K., Goossens, J., Beeckman, D., The association between malnutrition and oral health status in elderly in long-term care facilities: A systematic review, *International Journal of Nursing Studies*, 2012: 49, 1568-1581.

[40] Tanura, B.K., Bell, C.L., Masaki, K.H., Amella, E.J., Factors associated with weight loss, low BMI and malnutrition among nursing home patients: A systematic review of the literature, *Journal of the American Medical Directors Association*, 2013: 14, 649-655.

[41] Tada, A., Miura, H., Systematic review of the association of mastication with food and nutrient intake in the independent elderly, *Archives of Gerontology and Geriatrics*, 2014: 59, 497-505.

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