Analysis of the relevant factors associated with oral health-related quality of life in elderly denture wearers

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Abstract

Purpose: The purpose of the present study was to explore the factors related to oral health-related quality of life (OHRQoL) in elderly patients who underwent prosthetic treatment with removable dentures through several objective and subjective examinations and to analyze their interrelationships.

Methods: The current study involved 78 denture wearers, aged 65 years or above, who underwent treatment at the clinic of prosthodontics and undertook routine checkups. The present study used eight age-matched patients with healthy dentition as controls. The following items were evaluated: OHRQoL (Oral Health Impact Profile), main occluding area, maximal occlusal force, masticatory performance, and masticatory ability. Spearman's rank correlation coefficient was used to assess the correlation between the OHIP score and each item and multiple linear regression analysis with the backward elimination method was used to analyze the factors affecting the OHIP score (α = 0.05).

Results: The OHIP summary score was significantly correlated with the number of occlusal supports, number of remaining teeth, maximal occlusal force, and the masticatory ability score. The multiple regression analysis revealed that the number of occlusal supports, the number of remaining teeth, whether the upper main occluding area was the remaining tooth or not, and the masticatory ability score were the significant independent variables that affected the OHIP summary scores.

Conclusions: The present study verified the relationship between the OHRQoL and the occlusion of remaining teeth or the items derived from the main occluding areas. The current results suggest that retaining the maxillary first molar is a key factor in the OHRQoL.

Keywords: OHRQoL, OHIP, Elderly denture wearers, Occlusion, Masticatory function

Received 17 December 2020, Accepted 15 February 2021, Available online 1 July 2021

1. Introduction

In Japan, the rate of aging exceeded 21% in the year 2007, which is the fastest rate of aging in the world, and the proportion of the elderly continues to increase in this super-aged society [1]. Consequently, the relationship between oral health and general health has been discussed by previous studies, with the extension of healthy life expectancy and the reduction of health disparities as the fundamental objectives [2-5]. Oral health is important for maintaining the pleasure of eating and speaking and it greatly contributes to the improvement of the quality of life. Thus, it has become an important item in general health [6-9].

Loss of teeth causes defects in aesthetics, mastication, pronunciation, and sensation at an early stage. If appropriate prosthetic treatment is performed immediately to rectify the defect at this stage, continuous disability can be avoided. However, if time passes without any treatment to replace the lost tooth, changes in the occlusal position can occur. Therefore, even if the prosthetic treatment is performed at the later stages, insufficient patient satisfaction is occasionally encountered in clinical practice. Conversely, some reports have stated that stomatognathic function can be ensured by treating the occlusal arch as a shortened dental arch [10-12], but this can only be achieved in a limited oral environment and early prosthetic treatment for tooth loss is necessary to stabilize the occlusion.

Objective items, such as the masticatory performance and occlusal force, are often used to evaluate the outcomes of prosthetic treatment. On the other hand, the patient's own assessment of his or her oral health-related quality of life (OHRQoL) has been proposed as a patient-oriented outcome and the importance of such assessments has been emphasized by previous studies [13-17]. Therefore, it is possible to accurately evaluate the outcomes of prosthetic treatment by combining the aforementioned items. The Oral Health Impact Profile (OHIP) [18] is widely used internationally for the evaluation of OHRQoL and the Japanese version of OHIP (OHIP-J) [19] is mainly used in Japan. The OHIP-J is a self-administered questionnaire that assesses fifty-four problems in day-to-day life, including forty-nine items in the original OHIP and five items unique to Japan. A previous study [20] that investigated the relationship between the OHRQoL, expressed as OHIP, and tooth loss reported that the linear regression analysis between the number of missing occlusal units (the presence of a pair of occluding premolars or molars with occluding premolar and molar corresponding to one and two units, respectively) and the total OHIP score showed that an increase of one missing occlusal unit was associated with an increase in the OHIP score by 2.1; that is, the OHRQoL decreased. Conversely, several studies have reported an improvement in the OHRQoL when a removable denture was inserted to replace a missing tooth [13,21-28]. A study by Al-Imam et al. [26] reported that the OHIP score decreased from an average of 48 before denture insertion to 34 after denture insertion, indicating an improvement in the OHRQoL without any change in the same during the five years of follow-up. Hence, the efficacy of a removable denture for the replacement of a missing tooth has been affirmed in terms of the OHRQoL. However, in the aforementioned study, some patients who displayed complications during follow-up tended to continue using the dentures with reduced OHRQoL.
Such situations may be the consequence of adapting oneself to problematic conditions, even in scenarios involving low OHRQoL. Considering the fact that the purpose of prosthetic treatment is to improve the OHRQoL and to maintain the oral environment of the patient, the difficulty regarding prosthetic treatment with removable dentures is evident.

It is essential to verify the factors that affect OHRQoL after wearing a denture, in order to achieve a high level of long-term patient satisfaction with removable denture treatment and for the dentists to undertake measures to improve or ensure future OHRQoL, even before the progression of tooth loss. The purpose of the present study was to explore the factors related to OHRQoL in elderly patients who underwent prosthetic treatment with removable dentures and were leading independent day-to-day lives by means of several objective and subjective examinations and to analyze their interrelationships. The null hypothesis of the present study was that each item used for the evaluation could not be a relevant factor in the assessment of the OHRQoL after wearing a denture.

2. Materials and methods

2.1. Subjects

The subjects were recruited from the patients who underwent treatment at the Clinic of Prosthodontics, Tokyo Dental College Suidobashi Hospital, and undertook routine checkups during the time period from April 2017 to December 2019. The prosthetic treatments were performed by dentists with a minimum of three years of specialized education in prosthodontics. The inclusion criteria are stated as follows: (1) age of 65 years or above; (2) living independently with sufficient ability to understand the contents of the present study; (3) wearing removable dentures for partially or fully edentulous regions; (4) the dentures were examined and adjusted for fit and occlusion during regular checkups and used on a daily basis; and (5) prosthetic treatments for missing teeth extended up to the first molars, including implants. The exclusion criteria involved the patients with the following diseases who were under treatment in other departments: (1) severe periodontitis; (2) temporomandibular disorders; (3) orofacial pain; and (4) dry mouth. The subjects who met the inclusion criteria were included in the study and were defined as the denture-wearing group.

The present study selected the patients without removable dentures who visited the same department and had their natural dentition preserved up to the first molar as the control group. The other selection criteria were the same as the abovementioned inclusion criteria: (1) and (2) and the exclusion criteria: (1)-(4).

The study protocol was approved by the Ethics Committee of the Tokyo Dental College (#786) and written informed consent was obtained from all the subjects.

2.2. Items used for evaluation

All the examinations were performed in the outpatient clinic of the prosthodontic department by the authors or the dentist who performed the treatment. Adequate preoperative training was provided to prevent inter-operator variabilities in the examination results. All the evaluations were performed during the visits for regular checkups and the data were collected using a cross-sectional method of study.

2.2.1. Data obtained from medical records

The sex, age, and duration of denture use were obtained using the medical records.

2.2.2. Intraoral examination

The number of remaining teeth and the occlusal relationship between the upper and lower jaws (Eichner classification) were recorded by means of intraoral examination. The present study considered the pontic of the fixed bridge and the superstructure of the implant as remaining teeth. The remaining roots were considered as missing teeth. The number of occlusal units (OUs) and the number of occlusal supports (OSs: the presence of a pair of the same type of teeth in the maxillary and mandibular jaws on the ipsilateral side was considered to account for one occlusal support) were calculated from the aforementioned results.

2.2.3. OHRQoL

The OHRQoL was evaluated using the OHIP-J [19] as described above. The OHIP-J consists of fifty-four items grouped into eight domains: functional limitation (nine items), physical pain (nine items), psychological discomfort (five items), physical disability (nine items), psychological disability (six items), social disability (five items), handicap (six items), and additional Japanese items (five items). The subjects were asked how frequently they had experienced the impact pertaining to each of the 54 OHIP questions. A rating scale was applied for the responses (0, never; 1, hardly ever; 2, occasionally; 3, fairly often; 4, very often) and the summary score of the fifty-four items and the subscale score of the eight domains were used as the indices for OHRQoL. Hence, a higher score indicated an impairment in the OHRQoL.

2.2.4. Main occluding area

A specific area of the dentition, called the main occluding area, is the center of the chewing process during the mastication of hard food items. It is thought that in a healthy dentulous person, this area corresponds to the first molar where the maximum occlusal force is exerted [29]. The main occluding area was identified using a 4-mm-long piece of temporary sealing material (Temporary stopping; GC Corp., Tokyo, Japan), according to the method proposed by Kato et al. [29]. A piece of temporary stopping was placed on the subject's tongue as a test material. Subsequently, the subject was asked to chench the material at a site that was preferred during chewing. The main occluding area was determined by locating the tooth on which the temporary stopping rested during clenching. The examination was performed multiple times and at least three identical areas were selected. When the main occluding area was not on the same type of tooth in the upper and lower jaws, the upper tooth was chosen as the representative site for convenience. Based on the tooth considered as the main occluding area, the subjects were divided into a premolar group (PM) and a molar group (M). In addition, according to whether the upper and lower teeth corresponding to the main occluding area were the remaining tooth (RT) or an artificial tooth (AT), respectively, the denture-wearing group was divided into RT and AT subgroups for the upper and lower jaw separately.

2.2.5. Maximal occlusal force

In the present study, the maximal individual occlusal force in the first molar region was defined as the maximal occlusal force pertaining to the subject. Bilateral first molars were used as the site of measurement for all the subjects, even if the first molars were missing and treated with prostheses. An occlusal force-meter (Occlusal Force Meter GM10; Nagano Keki Co., Ltd., Tokyo, Japan) was used for the evaluation. The sensors were inserted between the upper and lower first molars and the patient was asked to close his or her mouth gently and to chench with maximal force for three seconds. The measurements were repeated thrice on the left and right sides with a 30-second rest period between each measurement. The mean value of the occlusal forces obtained from all six measurements was considered to be the representative value for the subjects.

2.2.6. Masticatory performance

Masticatory performance was assessed using the gummy jelly method [30]. The subjects were asked to chew glucose-containing gummy jellies (Glucolumn; GC Corp., Tokyo, Japan) on the habitual chewing side for 20 seconds. After chewing, the subjects were asked to rinse their mouths with 10 mL of distilled water and spit the contents into a cup with a filter. The glucose concentration in the filtrate (mg/dL) was measured using a glucose level measuring device (Gluco Sensor GS-II; GC Corp., Tokyo, Japan) and the estimated value was used to evaluate the masticatory performance.

2.2.7. Masticatory ability (questionnaire on food acceptance)

The subjects were provided with questionnaires in addition to the OHIP-J regarding their food intake status, which was originally designed to evaluate the self-assessed masticatory ability of the patients using complete dentures [31]. The survey included questions concerning chewing of the
following 20 types of food items arranged from hard- to easy-to-chew food items: whole apple, chewing gum, dried scallop, dried squid, fresh abalone, hard pickled radish, hard rice cracker, hard biscuit, pickled radish, peanuts, beefsteak, rice-cake cubes, burdock, potato chips, fish cake, bean sprouts, boiled carrot, boiled potato, boiled eggplant, and tofu. The subjects were asked to evaluate each of the 20 food items as “easy to chew,” “difficult to chew,” or “impossible to chew.” In the present study, the level of masticatory ability was obtained by calculating the percentage of food items judged as “easy to chew.”

2.3. Statistical analysis

2.3.1. Analysis of items used for evaluation

Each item pertaining to the denture-wearing and control groups was compared. The Mann-Whitney U test was used for the analysis of all the items, apart from the main occluding areas. In order to perform the analysis of the main occluding area, the number of subjects with PM and M groups were compared between the denture-wearing and control groups using the chi-squared test of independence.

2.3.2. Relationship between the OHIP score and each item

The Spearman's rank correlation coefficient was used to assess the correlation between the OHIP score and each item in the denture-wearing group. The items used for evaluation included the age, number of OUs, number of OSs, number of remaining upper and lower teeth, duration of denture use, maximal occlusal force, masticatory performance score, and the masticatory ability score. The Mann-Whitney U test was used to compare the scores between PM and M groups and between the RT and AT groups, in order to analyze the relationship between the OHIP summary scores and the main occluding area.

2.3.3. Analysis of the factors affecting the OHIP score

Multiple linear regression analysis with the backward elimination method was used to analyze the factors affecting the OHIP summary score in the denture-wearing group. The OHIP summary score was set as the dependent variable and the various items used for the evaluation were set as the independent variables. Among the independent variables, age, number of OS, number of remaining upper and lower teeth, duration of denture use, maximal occlusal force, masticatory performance score, and masticatory ability score were selected as the continuous variables. In addition, the sex, the location of the main occluding area was the M or not, and RT or not (upper and lower jaw separately) were considered as categorical data; therefore, these items were converted into dummy variables.

The level of significance for all statistical tests was set at $\alpha = 0.05$. Statistical analysis was performed using the SPSS Statistics ver. 22 (IBM Corporation, Armonk, NY, USA).

3. Results

3.1. Subjects (Table 1)

The current study involved eighty-six patients. Among these, seventy-eight patients were in the denture-wearing group and eight were in the control group. The denture-wearing group consisted of 30 males and 48 females with age ranging from 65 to 93 years (mean: 77.1 years, median: 76.0 years). The control group consisted of one male and seven female patients with age ranging from 65 to 92 years (mean: 79.3 years, median: 82.0 years). There was no statistically significant difference between the two groups with regard to the age (Mann-Whitney U test; $p = 0.49$).

The duration of denture use, number of remaining teeth, Eichner classification, number of OUs, and number of OSs are shown in Table 1.

3.2. Items used for evaluation (Table 1)

3.2.1. OHRQoL

The OHIP summary score was higher in the denture-wearing group, compared to the control group, which indicated an impairment in the OHRQoL. However, there was no statistically significant difference between the two groups (Mann-Whitney U test; $p = 0.09$). The denture-wearing group showed higher values, compared to the control group, for each subscale score in all the eight domains. Moreover, there were statistically significant differences between the two groups with regard to the subscale scores pertaining to the two domains of physical disability and social disability (Mann-Whitney U test; $p < 0.05$).

3.2.2. Main occluding area

The most common site of the main occluding area was the first molar in both the denture-wearing and control groups. A comparison of the number of subjects with main occluding area in the PM and M between the two groups did not reveal any statistically significant difference (chi-squared test of independence; $p = 0.28$).

3.2.3. Maximal occlusal force

The maximal occlusal force was lower in the denture-wearing group, compared to the control group, and there was a statistically significant difference between the two groups (Mann-Whitney U test; $p < 0.05$).

3.2.4. Masticatory performance

The masticatory performance score with regard to the denture-wearing group was similar to that of the control group and there was no statistically significant difference between the two groups (Mann-Whitney U test; $p = 0.86$).

3.2.5. Masticatory ability

The masticatory ability score was higher in the denture-wearing group, compared to the control group. However, there was no statistically significant difference between the two groups (Mann-Whitney U test; $p = 0.41$).

3.3. Relationship between the OHIP score and each item

The correlation between the OHIP score and each item (Spearman's rank correlation coefficient) in the denture-wearing group is shown in Table 2. The OHIP summary score was significantly correlated with the number of remaining teeth, the number of OSs, the maximal occlusal force, and the masticatory ability score. All of the aforementioned factors displayed negative correlations and the higher the value for each item, the lower the OHIP score, that is, the higher the OHRQoL. Within each domain, the number of significantly correlated items on the four subscales of physical disability, psychological disability, social disability, and handicap scores was equal to or greater than the summary score. These additional items included the number of OUs and the number of remaining teeth in each upper and lower jaw.

A comparison of the OHIP summary scores between the PM and M groups with reference to the main occluding areas showed that M group had lower scores. However, there were no statistically significant differences between the two groups (Mann-Whitney U test; $p = 0.09$) (Table 3). A comparison of the OHIP summary scores between the subjects with RT in both the upper and lower jaws and those with AT in one or both jaws showed that the former score was significantly lower (Mann-Whitney U test; $p < 0.05$) (Table 3).

3.4. Analysis of the factors affecting the OHIP score (Table 4)

The multiple regression analysis revealed that the number of remaining upper teeth, the number of OSs, whether the upper main occluding area was RT or not, and the masticatory ability score were the significant independent variables that affected the OHIP summary scores.
In the present study, the average number of remaining teeth was 14.1, which is approximately half of the total number of teeth, as the inclusion criteria were limited to the subjects of age 65 years or above. A comparison with the data from the Survey of Dental Diseases (2016) [32] revealed that the subjects in the present study had fewer remaining teeth, compared to those in all the age groups. This may be attributed to the high number of difficult cases among the patients visiting the university hospitals. When the distribution of subjects was observed on the basis of the Eichner classification, there were more subjects in the B and C categories, compared to the A category. In addition, the 12 OUs and 14 OSs in those with all remaining teeth were reduced to 1.8 and 4.2, respectively, in the subjects. Specifically, the occlusal contacts between the upper and lower jaws that are necessary for the occlusal stability were lost in many cases, indicating that these cases require oral rehabilitation by dentists with specialized training in prosthodontics.

In the present study, the OHIP-J was used to evaluate the OHRQoL. Yamazaki et al. [19] have reported the reliability and validity of the OHIP-J. The OHIP developed by Slade et al. [18] was translated into Japanese, revised by a Japanese dentist, back-translated into English, and rechecked in English. In addition, five new items were added to fit the Japanese spiritual climate. The test-retest reliability was 0.81, as measured using the intra-class correlation coefficients (ICC), and the ICC of each domain ranged from 0.37 to 0.83, which is clinically sufficient. Internal consistency (Cronbach’s alpha) was validated with values ranging from 0.89 to 0.98 for each domain.

The OHIP summary score of 32.5 in the denture-wearing group in the

| Table 1. Results of examination items. |
|---------------------------------------|
| **Denture wearing group** | **Control group** | **p value** |
| Number of subjects | Median | Q25 | Q75 | Number of subjects | Median | Q25 | Q75 |
| Total number of subjects | 78 | | | | 8 | | |
| Sex | | | | | | | |
| Male | 30 | | | | 1 | | |
| Female | 48 | | | | 7 | | |
| Age (y) | 76.0 | 72.0 | 82.0 | 82.0 | 70.5 | 85.8 | 0.489 a |
| Denture wearing duration (mo) | 46.0 | 18.3 | 80.8 | | | |
| Number of remaining teeth | | | | | | | |
| Total | 15.0 | 6.3 | 22.0 | 28.0 | 27.8 | 28.0 | |
| Upper | 5.0 | 0.0 | 11.0 | 14.0 | 13.8 | 14.0 | |
| Lower | 8.0 | 5.0 | 11.0 | 14.0 | 14.0 | 14.0 | |
| Eichner classification | | | | | | | |
| A | 5 | 8 | |
| B | 39 | 0 | |
| C | 34 | 0 | |
| Number of OU | 0.0 | 0.0 | 3.8 | 12.0 | 11.5 | 12.0 | |
| Number of OS | 2.5 | 0.0 | 8.0 | 14.0 | 13.8 | 14.0 | |
| OHIP | | | | | | | |
| Summary score | 32.5 | 13.0 | 54.8 | 19.0 | 12.0 | 25.3 | 0.086 a |
| Functional limitation | 8.5 | 5.0 | 11.8 | 6.0 | 3.5 | 8.3 | 0.252 a |
| Physical pain | 6.0 | 3.0 | 9.0 | 6.0 | 1.8 | 6.5 | 0.508 a |
| Psychological discomfort | 3.0 | 1.0 | 5.0 | 1.5 | 0.8 | 3.8 | 0.466 a |
| Physical disability | 7.0 | 1.0 | 9.0 | 1.5 | 0.8 | 3.8 | 0.016 * a |
| Psychological disability | 1.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.3 | 0.099 a |
| Social disability | 0.5 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.049 * a |
| Handicap | 1.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.3 | 0.086 a |
| Additional Japanese items | 4.0 | 2.0 | 6.0 | 1.5 | 0.8 | 3.5 | 0.074 a |
| Main occluding area | | | | | | | |
| PM | 9 | 2 | | | 0.278 b |
| M | 69 | 6 | |
| Upper RT; Lower RT | 12 | | |
| Upper RT; Lower AT | 19 | | |
| Upper AT; Lower RT | 17 | | |
| Upper AT; Lower AT | 30 | | |
| Maximal occlusal force (N) | 173.8 | 109.9 | 278.8 | 273.7 | 235.9 | 392.9 | 0.020 * a |
| Masticatory performance (mg/dL) | 150.0 | 126.0 | 179.8 | 145.5 | 127.0 | 169.0 | 0.858 a |
| Masticatory ability (%) | 70.0 | 55.0 | 85.0 | 60.0 | 53.8 | 71.3 | 0.405 a |

Q25: first quartile, Q75: third quartile
a: Mann-Whitney’s U test; *p < 0.05
b: Chi-square test of independence

4. Discussion

In the present study, the average number of remaining teeth was 14.1, which is approximately half of the total number of teeth, as the inclusion criteria were limited to the subjects of age 65 years or above. A comparison with the data from the Survey of Dental Diseases (2016) [32] revealed that the subjects in the present study had fewer remaining teeth, compared to those in all the age groups. This may be attributed to the high number of difficult cases among the patients visiting the university hospitals. When the distribution of subjects was observed on the basis of the Eichner classification, there were more subjects in the B and C categories, compared to the A category. In addition, the 12 OUs and 14 OSs in those with all remaining teeth were reduced to 1.8 and 4.2, respectively, in the subjects. Specifically, the occlusal contacts between the upper and lower jaws that are necessary for the occlusal stability were lost in many cases, indicating that these cases require oral rehabilitation by dentists with specialized training in prosthodontics.

In the present study, the OHIP-J was used to evaluate the OHRQoL. Yamazaki et al. [19] have reported the reliability and validity of the OHIP-J. The OHIP developed by Slade et al. [18] was translated into Japanese, revised by a Japanese dentist, back-translated into English, and rechecked in English. In addition, five new items were added to fit the Japanese spiritual climate. The test-retest reliability was 0.81, as measured using the intra-class correlation coefficients (ICC), and the ICC of each domain ranged from 0.37 to 0.83, which is clinically sufficient. Internal consistency (Cronbach’s alpha) was validated with values ranging from 0.89 to 0.98 for each domain.

The OHIP summary score of 32.5 in the denture-wearing group in the
Table 2. Correlation coefficients for the relationship between OHIP summary score and each examination item.

| Examination item                | rs  | p value |
|---------------------------------|-----|---------|
| Age                             | -0.076 | 0.508 |
| Denture wearing duration        | 0.020 | 0.863 |
| Number of remaining teeth       |     |         |
| Total                           | -0.247 | 0.029 * |
| Upper                           | -0.207 | 0.069 |
| Lower                           | -0.194 | 0.088 |
| Number of OS                    | -0.190 | 0.095 |
| Maximal occlusal force          | -0.300 | 0.008 ** |
| Masticatory performance         | -0.027 | 0.815 |
| Masticatory ability             | -0.497 | 0.000 ** |

Spearman’s rank correlation coefficient; *p < 0.05, **p < 0.01

Table 3. OHIP summary scores for each group based on the main occluding area.

| PM                          | M              | p value |
|-----------------------------|----------------|---------|
| Median                      | Q25  | Q75  | Median | Q25  | Q75  |
| AT in both upper and lower jaws |     | 52.0 | 37.0  | 61.0 | 30.0  | 12.0 | 51.0 | 0.091 |
| RT in both upper and lower jaws |     | 52.0 | 37.0  | 61.0 | 30.0  | 12.0 | 51.0 | 0.091 |
| Median                      | Q25  | Q75  | Median | Q25  | Q75  |
| AT in one or both jaws      |     | 11.0 | 7.8   | 21.8 | 35.5  | 21.0 | 55.0 | 0.018* |

Mann–Whitney’s U test; *p < 0.05

Table 4. Multiple linear regression analysis to analyze factors affecting OHIP summary score.

| Dependent variables | Independent variables | B     | β     | t value | VIF | p value |
|---------------------|-----------------------|-------|-------|---------|-----|---------|
| OHIP summary score  | Intercept             | 68.914| 8.062 |         |     |         |
|                     | Number of remaining teeth (upper) | 3.493 | 0.765 | 2.670   | 9.025 | 0.009 |
|                     | Number of OS          | -3.967| -0.737| -2.942  | 6.892 | 0.004 |
|                     | Main occluding area (upper: RT or not) | -13.894| -0.291| -2.121  | 2.063 | 0.037 |
|                     | Masticatory ability   | -0.479| -0.405| -3.979  | 1.140 | 0.000 |

B: partial regression coefficient
β: standardized partial regression coefficient
VIF: Variance Inflation Factor

The present study was comparable to the post-treatment OHIP score of denture wearers reported by previous studies [21-28,31,33]. This score in the present was higher, compared to the OHIP summary score of the control group, which was similar to the scores reported by a previous study [34] that stated that the subjects above the age of 60 years with dentures tended to report more impairments in the OHRQoL. On the other hand, the subscale scores that differed significantly between the two groups were the scores pertaining to the domains of physical disability and social disability. In a report by Al-Imam et al. [26], the most frequent problem encountered during the follow-up was the functional limitation, which was different from the results of the present study. This may be partly due to the fact that the dentures provided to the subjects in the present study were either fabricated directly by the prosthodontic specialists or under their guidance. Hence, they were functionally satisfactory. In addition, the average age of the subjects was higher by about 10 years, compared to the subjects in the abovementioned article, which may be a reason for the difference in the criteria for satisfaction. This can be derived from the fact that when the denture-wearing group in the present study was divided into two groups, that is, sixty-five to seventy-four years of age and above seventy-five years of age, and the median values of the scores of functional limitation were lower in denture wearers, despite the similarity in the occlusal condition, as per the Eichner classification. Therefore, it is considered that there were no statistically significant differences in the number of PM and M between the two groups of subjects. Considering that the mandible of the first molar region has been reported to be an adequate mechanical environment, due to its stable macrostructure [37], it is reasonable to assume that the main occluding area on the denture base would still exist, even if the first molar is replaced by an artificial tooth, as long as the patient is provided with a denture fabricated by a dentist with specialized training in prosthodontics.

The maximal occlusal force was lower in the denture-wearing group, compared to the control group, which is similar to the results reported by previous studies [38-41] that analyzed the relationship between the occlusal force and the number of remaining teeth. Although there is a difference in the site of evaluation of the occlusal force, whether the occlusal force is measured on the first molar or the entire dentition, it is reasonable to expect a smaller value for the dentures with mucosal support. However, a comparison of the masticatory function between the denture-wearing and control groups revealed that there was no statistically significant difference between the two groups. Therefore, it was suggested that although the denture-wearing group in the present study did not exhibit the same occlusal force as the force exhibited prior to the tooth loss, their masticatory function may be compensated by the increased coordination of other motor and sensory functions [40,42]. It is also suggested that the elimination of the difference in masticatory function between the two groups may be attributed to the decline in the dexterity of jaw movements with age [43], even though the teeth and muscles of the control group were in a healthy condition.

Most of the previous studies [27,40,42,44] have reported the relationship between each item used in the evaluation and the masticatory performance, suggesting correlations with the number of remaining teeth, maximal occlusal force, and the OHIP score. On the other hand, in the present study, one of the items that correlated particularly well with the OHIP summary score and subscale score was the masticatory ability. However, there were no correlations with the masticatory performance and it was found that the subjective factors, such as the ability to eat certain foods, were more important for the OHRQoL of elderly denture wearers, compared to the objective factors, such as the extent to which they could crush and grind food. For instance, one subject above the age of 90 years showed a low masticatory performance, but his OHRQoL was well maintained with no problems in his dietary lifestyle. However, the present study has the limitation that the OHRQoL was analyzed using a cross-sectional design [45] and future cohort studies [27] are required to clarify these points. Within each domain, the number of significantly correlated examination items on the four subscales of physical disability, psychological disability, social disability, and handicap scores was equal to or greater than the summary score, indicating that many items used for evaluation in the
The present study was strongly related to the OHRQoL. The number of OSs was also judged as highly significant among the items used for the evaluation, thereby confirming that the occlusal support of the remaining teeth is an important requirement for OHRQoL. This result is concurrent with other reports [46-50], thereby depicting the importance of occlusal support and the number of remaining teeth in OHRQoL.

The present study performed the multiple linear regression analysis with the OHRQoL score as a dependent variable. As a result, the number of remaining upper teeth, the number of OSs, whether the upper main occluding area was RT or not, and the masticatory ability score were observed to be the significant independent variables related to the OHRQoL summary scores. Certain previous studies [33,51] have performed the multivariate analysis with OHP scores in denture wearers as the dependent variable. However, no previous study has demonstrated the relationship between the OHRQoL and occlusion of the remaining teeth or the items derived from the main occluding areas, which is the novelty of the present study. The present results clearly indicated that the OHRQoL was higher when the upper main occluding area was located on the remaining teeth. Combined with the fact that the main occluding area was located on the first molar in a majority of the subjects, the retaining maxillary first molar is considered to be an important factor in the OHRQoL. Therefore, the null hypothesis of the present study, which stated that each item used for the evaluation could not be a relevant factor in the assessment of the OHRQoL after wearing a denture, was rejected.

In the analysis of the Spearman’s rank correlation coefficient, all the variables that were correlated with the OHRQoL summary score had negative correlation coefficients and higher values for each item were associated with higher OHRQoL. However, in the multiple linear regression analysis, the partial regression coefficient of the number of remaining upper teeth as an independent variable was positive. This suggests that the number of remaining upper teeth may be a suppressor variable [52]. Although multicollinearity is denied by the variance inflation factors (VIF), the involvement of the number of OSs in the OHRQoL score includes the influence of the number of remaining upper teeth. Hence, in the cases with the same number of OSs, it can be interpreted that the balance of the number of remaining teeth in the upper and lower jaws worsens and the OHRQoL decreases as the number of remaining upper teeth increases.

The present study has certain limitations. With regard to the ratio of the male to female subjects, the proportion of females was high. However, a statistical comparison of each of the items used for the evaluation between the males and females revealed no significant differences. Hence, it is unlikely that the sex differences will have a significant impact on the conclusions of the present study. Conversely, it is a limitation that the quality of the denture was not fully ensured, owing to the fact that multiple dentists were in charge of the treatment. Moreover, the small number of subjects in the control group is another limiting factor, as very few patients with higher OHRQoL. However, in the multiple linear regression analysis, the partial regression coefficient of the number of remaining upper teeth as an independent variable was positive. This suggests that the number of remaining upper teeth may be a suppressor variable [52]. Although multicollinearity is denied by the variance inflation factors (VIF), the involvement of the number of OSs in the OHRQoL score includes the influence of the number of remaining upper teeth. Hence, in the cases with the same number of OSs, it can be interpreted that the balance of the number of remaining teeth in the upper and lower jaws worsens and the OHRQoL decreases as the number of remaining upper teeth increases.

The present study performed the multiple linear regression analysis with the OHIP score as a dependent variable. As a result, the number of remaining upper teeth, the number of OSs, whether the upper main occluding area was RT or not, and the masticatory ability score were observed to be the significant independent variables related to the OHRQoL summary scores. Certain previous studies [33,51] have performed the multivariate analysis with OHP scores in denture wearers as the dependent variable. However, no previous study has demonstrated the relationship between the OHRQoL and occlusion of the remaining teeth or the items derived from the main occluding areas. The current results suggest that retaining the maxillary first molar is a key factor in the OHRQoL.

Acknowledgements

The authors would like to thank the subjects for their cooperation in this study. The authors also thank the members of the Department of Removable Partial Prostodontics, Tokyo Dental College, for helpful discussions.

Declaration of Competing Interest

The authors have no conflicts of interest to declare with respect to this study.

References

[1] Current Population Estimates as of October 1, 2007, Statistics Bureau of Japan, http://www.stat.go.jp/english/data/jmsu/2007np/index.html. 2020 [accessed 30 July 2020].

[2] Hironaka M, Kayama Y, Misaka Y, Akifusa S. Relationship between self-rated masticatory ability and independent life in community-dwelling older adults. Gerontol Geriatr Med 2015. https://doi.org/10.1177/2337321415603193.

[3] Matsuyama Y, Aida J, Watt RG, Tsuboa T, Koyama S, Sato Y, et al. Dental status and compression of life expectancy with disability. J Dent Res 2017;96:1006-13. https://doi.org/10.1177/0022034517713166.

[4] Müller F, Shimazaki Y, Kuhaltka F, Schimmel M. Oral health for an ageing population: the importance of a natural dentition in older adults. Int Dent J 2017;67:7-13. https://doi.org/10.1111/idj.12329.

[5] Kato H, Takahashi Y, Teikai T, Igarashi Y, Satoh S, Hato S, et al. Tooth loss-associated cognitive impairment in the elderly: a community-based study in Japan. Intern Med 2019;58:1411-16. https://doi.org/10.2169/internalmedicine.1896-18.

[6] Mirau H, Araki Y, Umemai T. Chewing activity and activities of daily living in the elderly. J Oral Rehabil 1997;24:457-60. https://doi.org/10.1046/j.1365-2842.1997.00530.x.

[7] Avlund K, Holm-Pedersen P, Schroll M. Functional ability and oral health among older people: a longitudinal study from age 75 to 80. J Am Geriatr Soc 2001;49:954-62. https://doi.org/10.1111/j.1532-5415.2001.49187.x.

[8] Shimazaki Y, Soh I, Sato T, Yamashita Y, Koga T, Miyazaki H, et al. Influence of dentition status on physical disability, mental impairment, and mortality in institutionalized elderly people. J Dent Res 2001;80:340-5. http://doi.org/10.1177/0022034510800010801.

[9] Sun W, Watanabe M, Tamamoto Y, Shihubiti T, Kono R, Saito M, et al. Factors associated with good self-rated health of non-disabled elderly living alone in Japan: a cross-sectional study. BMC Public Health 2007;7:297. https://doi.org/10.1186/1471-2458-7-297.

[10] Käyser AF. Shortened dental arches and oral function. J Oral Rehabil 1981;8:457-62. https://doi.org/10.1111/j.1365-2842.1981.00659.x.

[11] Kanno T, Carlsson GE. A review of the shortened dental arch concept focusing on the work by the Käyser/Nijmegen group. J Oral Rehabil 2006;33:850-62. https://doi.org/10.1111/j.1365-2842.2006.01625.x.

[12] McKenna G, Allen PF, O’Mahony D, Cronin M, DaMata C, Woods N. The impact of rehabilitation using removable partial dentures and functionally orientated treatment on oral health-related quality of life: a randomised controlled clinical trial. J Dent 2015;43:63-71. https://doi.org/10.1016/j.jdent.2014.06.006.

[13] John MT, Slade GD, Szentesery A, Setz JM. Oral health-related quality of life in patients treated with fixed, removable, and complete dentures 1 month and 6 to 12 months after treatment. Int J Prosthodont 2004;17:503-11.

[14] Bae KH, Kim C, Paik DI, Kim JB. A comparison of oral health related quality of life between complete and partial removable denture-wearing older adults in Korea. J Oral Rehabil 2006;33:317-22. https://doi.org/10.1111/j.1365-2842.2005.01565.x.

[15] Gjengedal H, Berg E, Boe OE, Trovik TA. Self-reported oral health and denture satisfaction in partially and completely edentulous patients. Int J Prosthodont 2011;24:9-15.

[16] Yen YY, Lee HE, Wu YM, Lan SJ, Wang WC, Du JK, et al. Impact of removable dentures on oral health-related quality of life among elderly adults in Taiwan. BMC Oral Health 2015;15:1. https://doi.org/10.1186/1472-6831-15-1.

[17] Jenei A, Sándor J, Hegedüs C, Bágyi K, Nagy L, Kiss C, et al. Oral health-related quality of life after prosthetic rehabilitation: a longitudinal study with the OHIP questionnaire. Health Qual Life Outcomes 2015;13:99. https://doi.org/10.1186/s12955-015-0289-2.

[18] Slade GD, Spencer AJ. Development and evaluation of the Oral Health Impact Profile. Community Dent Health 1994;11:3-11.

[19] Yamazaki M, Inukai M, Baba K, John MT. Japanese version of the Oral Health Impact Profile (OHIP-J). J Oral Rehabil 2007;34:159-68. https://doi.org/10.1111/j.1365-2842.2006.01693.x.

[20] Baba K, Igarashi Y, Nishiyama A, John MT, Akagawa Y, Ikebe K, et al. The relationship between missing occlusal units and oral health-related quality of life in patients with shortened dentures. Int J Prosthodont 2008;21:72-4.
[21] Wolfart S, Heydecke G, Luthardt RG, Marré B, Freesmeyer WB, Stark H, et al. Effects of prosthetic treatment for shortened dental arches on oral health-related quality of life, self-reports of pain and jaw disability: results from the pilot-phase of a randomized multicentre trial. J Oral Rehabil 2005;32:815-22. https://doi.org/10.1111/j.1365-2842.2005.01522.x.

[22] Hadzipsas-Nadraje A. Quality of life with removable dentures. Mater Sociomed 2011;23:214-20. https://doi.org/10.5455/msm.2011.23.214-220.

[23] Ozahay EB, Gotfredsen K. Effect of treatment with fixed and removable dental prostheses. An oral health-related quality of life study. J Oral Rehabil 2012;39:28-36. https://doi.org/10.1111/j.1365-2842.2011.02245.x.

[24] Wolfart S, Müller F, Gerß J, Heydecke G, Marré B, Böning K, et al. The randomized shortened dental arch study: oral-health-related quality of life. Clin Oral Investig 2014;18:525-33. https://doi.org/10.1007/s00784-013-1090-6.

[25] Fueki K, Igarashi Y, Maeda Y, Baba K, Koyano K, Sasaki K, et al. Effect of prosthetic restoration on oral health-related quality of life in patients with shortened dental arches: a multicentre study. J Oral Rehabil 2015;42:701-8. https://doi.org/10.1111/joor.12297.

[26] Al-Imam H, Özahay EB, Benetti AR, Pedersen AM, Gotfredsen K. Oral health-related quality of life after complications with treatment with partial removable dental prosthesis. J Oral Rehabil 2016;43:23-30. https://doi.org/10.1111/joor.12338.

[27] Yamamoto S, Shiga H. Masticatory performance and oral health-related quality of life before and after complete denture treatment. J Prosthodont Res 2018;62:370-4. https://doi.org/10.1111/jpor.12525.

[28] Myint Oo KZ, Fueki K, Yoshida-Kohno E, Hayashi Y, Inamochi Y, Wakabayashi N. Minimal clinically important differences of oral health-related quality of life after removable partial denture treatments. J Dent 2020;92:103246. https://doi.org/10.1016/j.jdent.2020.103246.

[29] Kato H, Furuki Y, Hasegawa S. Observation on the main occluding area and occlusal support in denture wearers. J Prosthet Dent 1989;62:50–3. https://doi.org/10.1016/j.jor.1989.05219.

[30] Esugui H, Shiga H. Relationship between masticatory performance using a gummy jelly and masticatory movement. J Prosthodont Res 2017;61:419–25. https://doi.org/10.5243/jsswr.2017.01.001.

[31] Satô Y, Minagi S, Aikaga Y, Nagasawa T. An evaluation of chewing function of complete denture wearers. J Prosthet Dent 1989;62:50–3. https://doi.org/10.1016/j.or.2016.00022-3913.8900947-4.

[32] Survey of Dental Diseases (2016), Ministry of Health, Labour and Welfare, https://www.mhlw.go.jp/toukei/list/62-17b.html; 2020 [accessed 30 July 2020].

[33] Hassel AJ, Koke U, Schmitter M, Rammelsberg P. Factors associated with oral health-related quality of life in institutionalized elderly. Acta Odontol Scand 2006;64:9-15. https://doi.org/10.1080/00016350500326211.

[34] John MT, LeRésche L, Koenig TD, Højoo P, Migliorelli DL, Micheels W. Oral health-related quality of life in Germany. Eur J Oral Sci 2003;111:483-91. https://doi.org/10.1111/j.1600-0528.2003.00079.x.

[35] Aras K, Hasaneiossoğlu U, Shinogaya T. Masticatory performance, maximum occlusal force, and occlusal contact area in patients with bilaterally missing molars and distal extension removable partial dentures. Int J Prosthodont 2009;22:204-9.

[36] Ikebe K, Matsuoka K, Kagawa R, Enoki K, Yoshida M, Maeda Y, et al. Association of masticatory performance with age, gender, number of teeth, occlusal force and salivary flow in Japanese older adults: is ageing a risk factor for masticatory dysfunction?. Arch Oral Biol 2011;56:991-6.

[37] Inomata C, Ikebe K, Kagawa R, Okubo H, Sasaki S, Okada T, et al. Significance of occlusal force for dietary fibre and vitamin intake in independently living 70-year-old Japanese: from SONIC Study. J Dent 2014;42:556-64. https://doi.org/10.1016/j.jdent.2014.02.015.

[38] Morita K, Ishida K, Kato K, Mori T, Nishimura R, Yoshida M, et al. Factors related to masticatory performance in healthy elderly individuals. J Prosthet Dent 2018;62:432-5. https://doi.org/10.1016/j.jpor.2018.03.007.

[39] Lewis GR. Mandibular positioning skills with respect to age. N Z Dent J 2001;97:4-8.

[40] Kosaka T, Kida M, Kiku M, Hashimoto S, Fujii K, Yamamoto M, et al. Factors influencing the changes in masticatory performance: the Suita study. JDR Clin Trans Res 2018;3:405-12. https://doi.org/10.1177/2380084418783863.

[41] Cho MJ, Kim EK. Subjective chewing ability and health-related quality of life among the elderly. Gerodontology 2019;36:99-106. https://doi.org/10.1111/gor.12385.

[42] Brennan DS, Spencer AJ, Roberts-Thomson KF. Tooth loss, chewing ability and quality of life. Qual Life Res 2008;17:227-35. https://doi.org/10.1007/s11136-007-9293-2.

[43] Ikebe K, Hazeyama T, Enoki K, Murai S, Okada T, Kagawa R, et al. Comparison of GOHAI and OHIP-14 measures in relation to objective values of oral function in elderly Japanese. Community Dent Oral Epidemiol 2012;40:406-14. https://doi.org/10.1111/j.1600-0528.2012.00683.x.

[44] Kimura M, Watanabe M, Tanimoto Y, Kusabiraki T, Komiyama M, Hayashida I, et al. Occlusal support including that from artificial teeth as an indicator for health promotion among community-dwelling elderly in Japan. Geriatr Gerontol Int 2013;13:539-46. https://doi.org/10.1111/j.1477-0594.2012.00931.x.

[45] Dhingra S, Rajesh R, Rao A, Pai UT, Shenoy R, Pai M. Impact of occlusal support and perceived chewing ability on oral health-related quality of life among patients attending a private dental institution in India. J Indian Prosthodont Soc 2017;17:15-21. https://doi.org/10.4103/jips.jips.2014.00943.

[46] Komiyama T, Ohn T, Miyoshi Y, Murakami T, Tsaboo A, Tomata Y, et al. Relationship between status of dentition and incident functional disability in an elderly Japanese population: prospective cohort study of the Tsurgaoy project. J Prosthodont Res 2018;62:443-8. https://doi.org/10.1016/j.jpor.2018.04.003.

[47] Nagawara T, Takeyama Y, Ishida K, Yokoyama A. Comparison of treatment outcomes in partially edentulous patients with implant-supported fixed prostheses and removable partial dentures. Int J Oral Maxillofac Implants 2016;31:736-83. https://doi.org/10.11607/jomi.4605.

[48] Pansey S, Elliot W. Suppressor variables in social work research: ways to identify in multiple regression models. J Soc Social Work Res 2010;1:28-40. https://doi.org/10.5243/sswr.2010.2.