



Evaluation of bite force, quality of life, and patients' satisfaction in elderly edentulous patients using implant overdentures

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PURPOSE. This study aimed to compare the bite force (BF) between complete dentures and implant overdentures (IODs) retained by two mandibular implants. Additionally, we evaluated the quality of life (QoL) and patient satisfaction among individuals using IODs. In addition, the effects of demographic parameters such as age and sex, and clinical parameters such as implant length, implant diameter, attachment height, attachment color, and interimplant distance on BF, QoL, and patient satisfaction were evaluated. **MATERIALS AND METHODS.** A total of 51 edentulous patients rehabilitated with the maxillary complete dentures and mandibular IODs retained by two implants were included in this study. BF was measured using a force meter pre- and post-implant in the same patients. Oral health-related quality of life (OHRQoL) was assessed with the Oral Health Impact Profile (OHIP-14) and patient satisfaction was assessed with the Visual Analog Scale (VAS) questionnaires. **RESULTS.** It was found that BF values were statistically higher for IODs than complete dentures ($P < .001$). In terms of attachment height of the OHIP scores, there was a significant difference in the psychological disability and social disability domains ($P < .05$). When examining the change in patient satisfaction as a function of sex, it was found that mandibular retention satisfaction differed significantly by sex ($P < .05$), but there was no significant difference in the other domains. **CONCLUSION.** Within the limitations of this study, it was observed that the BF increased after the use of IODs. Several factors, including age, interimplant distance, attachment height, and attachment color, were found to impact OHRQoL. Sex and implant diameter were identified as factors affecting patient satisfaction. [J Adv Prosthodont 2023;15:214-26]

KEYWORDS

Bite force; Complete denture; Implant overdenture; Patient satisfaction; Quality of life

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INTRODUCTION

For years, edentulous patients have been treated with conventional complete dentures. However, patients have various problems with their complete dentures. Mobility, particularly seen in mandibular dentures, leads to inefficient chewing, decreased oral health-related quality of life (OHRQoL), and patient satisfaction. There is also a decrease in maximum bite force (BF) in complete denture wearers compared to dentate patients. Recognizing these issues, the McGill consensus statement published in 2002 reported that implant overdentures (IODs) retained by 2 implants should be the first treatment option considered for the edentulous mandible. The McGill consensus statement was supported by the York consensus statement published in 2009. This treatment approach is praised for its simplicity, sustainability, minimally invasive nature, and affordability, offering benefits such as improved retention, stability, BF, masticatory efficiency, OHRQoL, and patient satisfaction.¹⁻¹⁰

BF is influenced by several factors such as age, sex, craniofacial morphology, periodontal support, temporomandibular joint disorders, and dental condition. Among these factors, dental condition is the key factor. It consists of the position and number of teeth in the dental arch, the use of dentures, and the presence of dental implants. In addition to these physiological factors, the use of different recording devices, the position of the device in the dental arch, and unilateral or bilateral measurement also influence the results.^{3,11} BF measurement serves as a widely used instrument for assessing the function and efficacy of dental prostheses, employing different devices and methods.¹²

The success of implant therapy is evaluated by clinical parameters such as implant survival, prosthetic supra structure survival, marginal bone loss, presence/absence of biological or mechanical complications, and aesthetics. However, because these clinical parameters do not fully reflect the functional and psychosocial impact on patients, a complete assessment of treatment success cannot be made. Therefore, there is increasing interest in reporting patient-related outcome measures such as OHRQoL, patient satisfaction, cleaning ability, and phonetics.¹³⁻¹⁵ OHRQoL is

assessed with standardized, validated questionnaires such as the OHIP-49, OHIP-14, OHIP-5, OHRQoL-UK, and OHIP-EDENT.^{7,9,14,16,17}

The assessment of patient satisfaction after treatment occupies an important place in the measurement of treatment success. It is assumed that the patient himself is best able to make this assessment. Questionnaires completed by the patients themselves are often used for this purpose. Patient self-completed questionnaires on overall satisfaction, speech, mastication, comfort, stability, cleanability, and aesthetics are evaluated after implant placement using visual analogue scales (VAS).^{7,17,18}

In the past 10 years, many studies have been published examining the effectiveness of IODs. However, studies evaluating the effectiveness of different parameters in different populations are still needed. To the knowledge of the authors, it is known that studies evaluating the effect of implant length, implant diameter, attachment height, attachment color, and interimplant distance on BF have not yet been conducted at the time of this study. In line with all this information, it was the aim of the present clinical study to investigate the effects of age, sex, implant length, implant diameter, attachment height, attachment color, and interimplant distance on BF, OHRQoL, and patient satisfaction in patients with IODs.

MATERIALS AND METHODS

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of the Eskişehir Osmangazi University (approval number 25403353-050.99-E.144752). The Clinical trial registration number is NCT05565261. All patients were informed of the study procedures, and their written informed consent was obtained. Inclusion/exclusion criteria from the study are given in Table 1. The inclusion criteria were based on the classification proposed by Ettinger and Beck,¹⁹ and functionally independent older adults are included. Also, mandibular bone atrophy was categorized from panoramic radiographs according to the Cawood and Howell (1988) criteria.²⁰ Patients with adequate bone height and width (Class III and IV) for implant surgery were

included.

The sample size was calculated using G*Power Software (version 3.1.9.7) and with 80% power. According to the results ($\alpha = .05$, $\beta = 0.8$), it was decided to include at least 42 patients in the study.

Firstly, complete dentures with bilateral balanced occlusion were fabricated. After the dentures were delivered, the patients were called for routine control, the pressure spots were eliminated, and occlusal adjustments were made. The OccluSense® computerized occlusion analysis system (Dr. Jean Bausch GmbH & Co. KG, Cologne, Germany) was used to control occlusion. The patients used the dentures for at least 8 weeks to allow the muscles to adapt. After all conditions are suitable, the first BF measurement has been made in complete dentures. The BF was measured with a force meter (AKSON TMF-02 Bite Force Measurement Device; Akson, Istanbul, Türkiye). There is a cylindrical strain gauge in the metal apparatus where the measurement is made. The device works with batteries. It has been reported in studies that the device makes reliable measurements.²¹ Before the study, the prosthodontist (E.N.A.) was trained for using the device. The intraoral sensor of the device was placed at the level of the maxillary and mandibular first molar. A wooden stick of the same thickness as the bite fork was placed in the opposing dental arc to

avoid imbalance. Patients were requested to bite hard for 3 sec. A total of 6 bites were recorded, 3 for the right side and 3 for the left side. To obtain a reliable value, patients rested for 1 min after each measurement. The maximum BF was accepted as the highest value among the 3 bite forces. The average of the highest bite BF obtained from the right and left sides was accepted as the mean BF.

Then, 2 dental implants (Astra Tech Implant System; Dentsply Sirona, Charlotte, NC, USA) were placed in the mandibular canine region. Although implant lengths varied between 8 - 13 mm; implant diameters were 3.5 or 4.00 mm. Following the surgical procedure, soft lining material (Mollosil; Detax, Ettlingen, Germany) was applied to the surface of the dentures in contact with the soft tissue, and the patients were enabled to use the dentures. A 3-month osseointegration period was provided to allow the implants to integrate with the surrounding bone. After the osseointegration period, a clinical examination of the dentures was performed. The examination was performed by the same prosthodontist (E.N.A.) each time. The accuracy of the dentures in terms of occlusion and vertical dimension, tissue adaptation, and the health of the soft tissue were evaluated. If cracks or fractures were present, the dentures were repaired, and if a defect in tissue adaptation was detected, the

Table 1. Inclusion/exclusion criteria for the study

Inclusion criteria	Exclusion criteria
Patients aged 45 years and older	Patients younger than 45 years
Edentulous patients who are functionally independent according to the classification made by Ettinger and Beck	Edentulous patients who are functionally dependent older adults and frail older adults according to the classification made by Ettinger and Beck
Patients who had no pathology in oral tissues	Patients with uncontrolled systemic disease (such as diabetes mellitus)
Patients who had no inflammation around the dental implant	Patients with parafunctional habits (such as bruxism)
Patients who had no implant mobility or loss until the prosthesis stage	Patients with complaints of the masticatory muscles or temporomandibular joint
Patients who did not have systemic disease that would endanger the prognosis of the dental implant	Patients with taking medication that affect muscle activity
Patients who had bilateral balanced occlusion	Patients who did not show up on time for the control session
Patients who could understand and answer the questionnaire questions	Patients who cannot place an implant due to a local bone defect in the mandible
Patients who were edentulous for at least 6 months before treatment	Patients requiring additional surgery for mandibular residual ridge

dentures were idealized by relining.

During the stage of attaching the dentures to the implants, the healing abutments were removed, the gingival heights were measured, and the appropriate resilient stud attachments (Locator; Zest Anchors LLC, Escondido, CA, USA) were selected. The dentures were connected to the attachments. Thus, the existing complete dentures was converted into IODs.

Patients, who had been using IODs for at least 8 weeks or more and whose first BF was measured with their complete dentures, were contacted randomly and invited to the control session program. All IODs were checked for occlusal interferences, fit of the denture base, possible damage to the acrylic material or attachment systems, and possible pressure points. Dental implants have been examined both clinically and radiographically for peri-implantitis and loosening (X-rays are taken). Relining or repair was done when necessary. If the attachments are worn, they have been replaced. Retention strengths according to the color of the attachment were black (processing male), extra light retention (blue: 1.5 lb (680 g)), light

retention (pink: 3.0 lb (1361 g)), and regular retention (clear: 5.0 lb (2268 g)).⁴ As stated by Passia *et al.*, BF measurement was performed 8 weeks after delivery in cases where repair, reline, and attachment replacement were required.⁶ The second BF values of the patients wearing complete dentures in the maxilla and IODs in the mandible were measured (Fig. 1).²²

During the control session program, patients were requested to complete the OHIP-14 forms to assess their OHRQoL and VAS forms to evaluate patient satisfaction. To assess the impact of parameters, age, sex, implant lengths, implant diameters, attachment height, attachment color, and interimplant distance were also recorded (Fig. 2).

OHRQoL was assessed using the Turkish version of the Oral Health Impact Profile (OHIP-14).^{9,23} Patients were asked to indicate how often the corresponding OHIP parameter occurred in the past month. OHIP-14 contains 14 questions related to 7 different domains. The 7 main themes are functional limitations, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and hand-

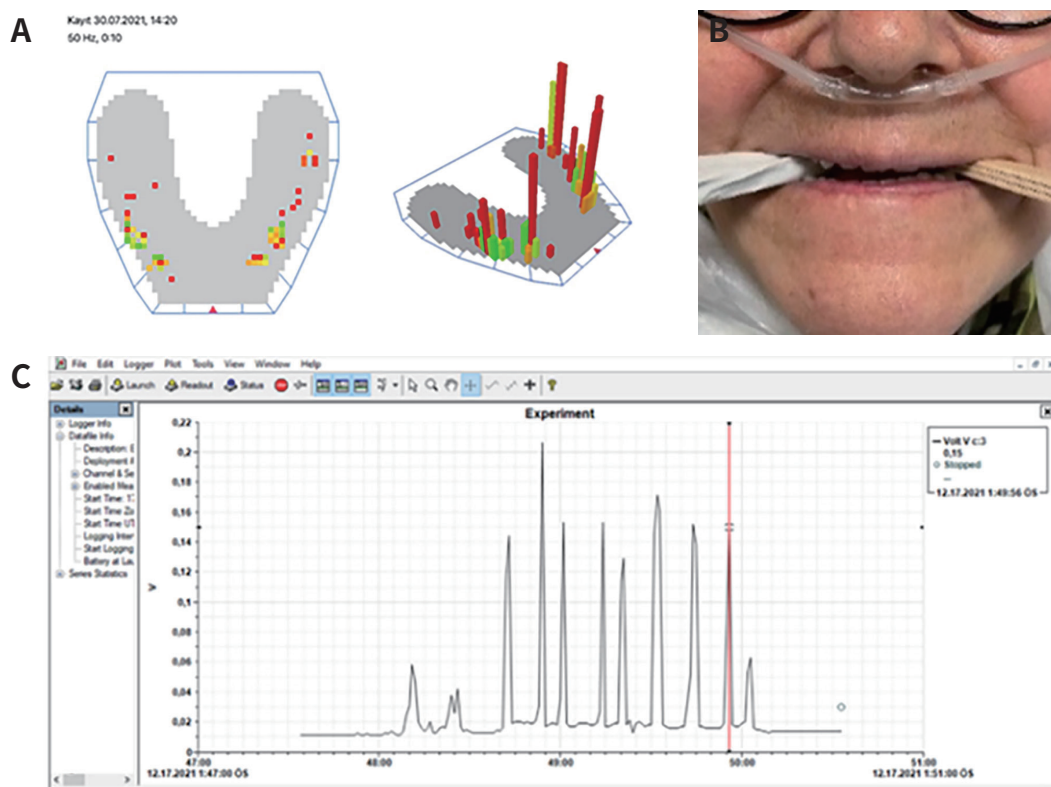


Fig. 1. (A) Occlusion analysis with the OccluSense computerized occlusal analysis system, (B, C) Bite force measurement.

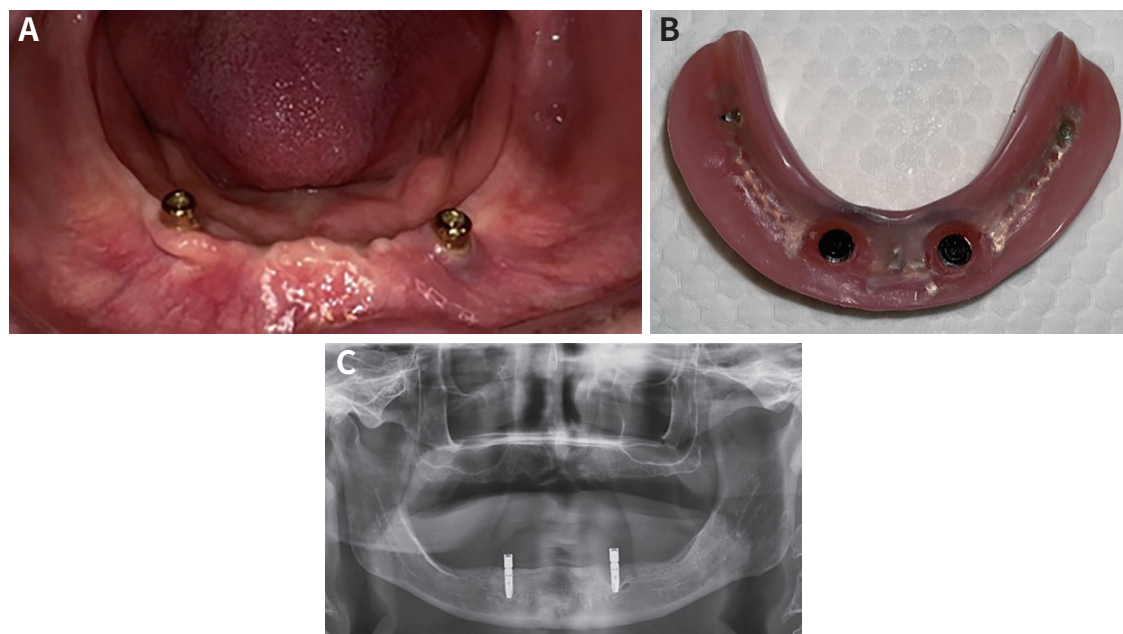


Fig. 2. (A) Intraoral view of attachments after 3 years of use, (B) The metal framework was placed in order to prevent fractures that may occur in all dentures, (C) Panoramic radiographic view of two dental implants.

icap. Patients answered the questions as 0 = Never, 1 = Rarely, 2 = Occasionally, 3 = Quite often, and 4 = Frequently. Scoring was based on 7 main categories and 8 data as the sum of all these categories. The total score of the OHIP-14 is at least 0 and the highest score is 56. A lower score indicates a better OHRQoL, while a higher score indicates a negative impact on OHRQoL.^{16,23} OHIP-14 is frequently used in studies evaluating IODs.^{7,9,16,17}

Patient satisfaction was assessed using the VAS questionnaire.^{7,17,24} The questions in the questionnaires evaluated the comfort of the prosthesis, convenience in chewing, aesthetics, speech, stability, and ease of cleaning. Patients answered the questions with 5 = Totally satisfied, 4 = Satisfied, 3 = Adequate, 2 = Not satisfied and 1 = Not at all satisfied. Higher scores indicate higher patient satisfaction.¹⁸

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 20.0 software (SPSS Inc.; Chicago, IL, USA) with a confidence level of 95%. Kolmogorov-Smirnov and Shapiro-Wilks test was used to determine whether the measurements were in accordance with the normal distribution. The significance of the difference between bite forces was examined with the *t*-test in

dependent groups. Whether the bite force and OHIP scale sub-dimensions and patient satisfaction differed significantly according to various parameters were examined by *t*-test and one-way analysis of variance in independent groups. The significance level was set at $P < .05$.

RESULTS

Fifty-one patients (32 women, 19 men) with mean age of 64 ± 7 years (range 47 - 80 years) were included in this study. Mean observation period was 43 ± 18 months (Table 2).

While BF values ranged from 31 N to 88 N (mean 57 N) for complete dentures, BF values varied from 50 N to 172 N (mean 94.3 N) for IODs. The maximum BF was statistically significantly higher for IODs than for complete dentures ($P < .001$) (Table 3).

The maximum BF was not affected by age, sex, implant lengths, implant diameters, attachment height, attachment color, and interimplant distance ($P > .05$) (Fig. 3, Fig. 4, Fig. 5).

There was no statistically significant difference among OHIP scores according to age, sex, implant diameters, and interimplant distance ($P > .05$). The

Table 2. The distribution of the patients included in the study according to different parameters is given

		n	%
Sex	Women	32	62.7
	Men	19	37.3
Age (year)	47 - 64	24	47.1
	65 and above	27	52.9
Dental implant diameter (mm)	3.5	86	84.3
	4.00	15	15.7
Dental implant height (mm)	8 - 9	14	13.7
	10 and above	88	86.3
Attachment height (mm)	2	44	43.1
	3	48	47.1
	4	4	3.9
	5	6	5.9
Attachment color	Black	8	7.8
	Blue: 1.5 lb (680 g)	8	7.8
	Pink: 3.0 lb (1361 g)	76	74.5
	Clear: 5.0 lb (2268 g)	10	9.8
Observation period (month)	0 - 36	23	45.1
	37 - 48	11	21.6
	49 - 72	12	23.5
	73 and above	5	9.8

mean total OHIP scores are shown in Table 4. However, it was observed that OHIP scores were higher in individuals aged 65 years and older. According to the attachment height of the OHIP scores, there was a significant difference in the psychological disability and social disability domains ($P < .05$). According to the results of the Tukey test performed to determine which group the difference originates from; for psychological disability and social disability subdimensions, the scores of those with an attachment height of 4 mm were significantly higher than those of all other groups. In this case, it can be thought that the increase in the height of the attachment negatively affects the QoL.

When the results of OHIP are examined according to the color of the attachment, the domain of psychological discomfort differs significantly according to color ($P < .05$). The level of the domain of psychological discomfort was significantly higher in the blue group than in the pink group (Table 5). In the presence of an interimplant distance of 25 mm or more, OHIP scores are observed to be lower, except for the functional limitation domain. However, when the scale scores are examined, it is seen that the OHIP scores

Table 3. Bite force (BF) means and *t*-test results in dependent groups to determine whether the difference among these averages is significant or not

	Mean	SD	t	P
Complete Dentures	57.0	13.6	-13.819	.000*
Implant Overdentures	94.3	26.5		

There is a significant difference between the BF ($P < .001$). The BF values measured in IODs are significantly higher than the values measured in complete dentures.

* Significant difference $P < .001$.

Fig. 3. Values of bite force (BF) by attachment color (Mean \pm Standard Deviation).

Attachment colors were black (processing male), extra light retention (blue: 1.5 lb (680 g)), light retention (pink: 3.0 lb (1361 g)), and regular retention (clear: 5.0 lb (2268 g)), ($P > .05$).

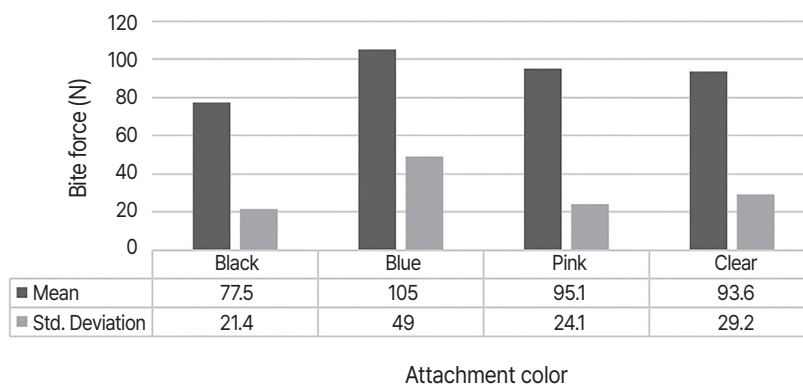


Fig. 4. Values of bite force (BF) by interimplant distance (10 to 24 mm or 25 mm and above) (Mean ± Standard Deviation).

The relationship between interimplant distance and BF was examined by correlation analysis and the Pearson correlation coefficient was obtained. Accordingly, there was no significant correlation between the inter-implant distance and the BF ($P > .05$).

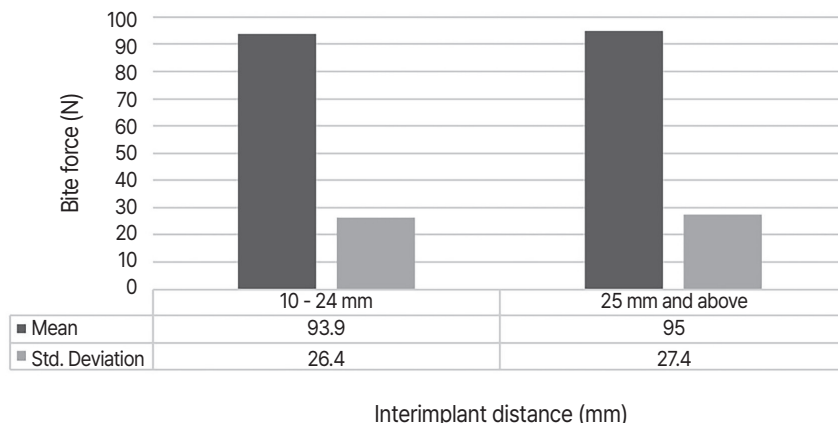


Fig. 5. Values of bite force (BF) according to observation period (Mean ± Standard Deviation) ($P > .05$). It is observed that the BF can be maintained unchanged in long-term use.

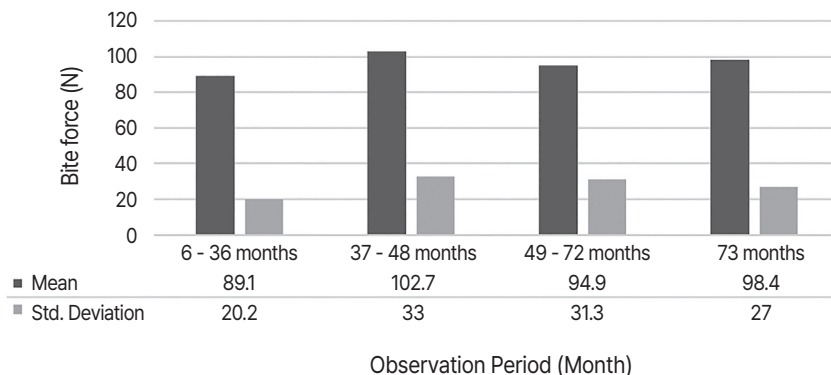


Table 4. Evaluation of OHIP-14 scores by sex

	Sex		Total	P
	Men (n = 19) Mean ± SD	Women (n = 32) Mean ± SD		
OHIP total	5.3 ± 5.7	7.9 ± 6.7	7.0 ± 6.4	.160
Functional limitation	0.8 ± 0.7	1.1 ± 1.1	1.0 ± 1.0	.231
Physical pain	1.1 ± 1.0	1.5 ± 1.2	1.4 ± 1.2	.164
Psychological discomfort	1.2 ± 1.5	1.3 ± 1.7	1.3 ± 1.6	.774
Physical disability	0.9 ± 1.0	1.4 ± 1.3	1.2 ± 1.2	.181
Psychological disability	0.6 ± 1.1	1.2 ± 1.6	1.0 ± 1.5	.155
Social disability	0.3 ± 0.9	0.6 ± 0.9	0.5 ± 0.9	.362
Handicap	0.5 ± 1.0	0.8 ± 1.1	0.7 ± 1.1	.286

OHIP total score and 7 subscores are seen. When the satisfaction of IODs is compared according to sex, there is no significant difference between men and women ($P > .05$). OHIP = Oral Health Impact Factor, SD = Standard deviation.

Table 5. Correlation results between OHIP scores and attachment colors

		N	Mean	SD	P
Functional limitation	Black	4	0.00	0.00	.115
	Blue	4	0.75	0.96	
	Pink	38	1.16	1.00	
	Clear	5	0.80	0.45	
	Total	51	1.00	0.96	
Physical pain	Black	4	2.00	1.83	.521
	Blue	4	1.25	1.50	
	Pink	38	1.24	1.02	
	Clear	5	1.80	1.64	
	Total	51	1.35	1.18	
Psychological discomfort	Black	4	2.50	2.08	.039*
	Blue	4	2.75	1.50	
	Pink	38	0.95	1.35	
	Clear	5	1.80	2.05	
	Total	51	1.29	1.58	
Physical disability	Black	4	1.25	2.50	.713
	Blue	4	1.25	1.89	
	Pink	38	1.11	0.95	
	Clear	5	1.80	1.64	
	Total	51	1.20	1.23	
Psychological disability	Black	4	0.75	1.50	.233
	Blue	4	1.25	1.89	
	Pink	38	0.79	1.19	
	Clear	5	2.20	2.68	
	Total	51	0.96	1.47	
Social disability	Black	4	0.25	0.50	.140
	Blue	4	1.25	1.89	
	Pink	38	0.34	0.71	
	Clear	5	1.00	1.41	
	Total	51	0.47	0.92	
Handicap	Black	4	0.50	1.00	.623
	Blue	4	1.25	1.89	
	Pink	38	0.61	1.00	
	Clear	5	1.00	1.22	
	Total	51	0.69	1.09	
OHIP total	Black	4	7.25	8.34	.440
	Blue	4	9.75	10.69	
	Pink	38	6.18	5.20	
	Clear	5	10.40	9.84	
	Total	51	6.96	6.41	

* $P < .05$. When the change of OHIP scores according to attachment color is examined; the psychological discomfort sub-dimension differs significantly according to color ($P < .05$). For the psychological discomfort sub-dimension that differs significantly; The psychological discomfort sub-dimension level of the blue-colored is significantly higher than the pink-colored.

of the patients with implants with a diameter of more than 4 mm are lower. In this case, it can be thought that the OHRQoL of patients with larger implants is more positively affected.

When examining the change in patient satisfaction as a function of sex, it was found that mandibular retention satisfaction differed significantly by sex ($P < .05$), but there was no significant difference in the other domains. The mean retention rate in the mandible is significantly higher in men than in women. Patient satisfaction was not found to differ significantly according to other parameters ($P > .05$).

DISCUSSION

The conventional treatment approach for edentulism is treatment with a complete denture. However, patients often complain about issues such as mobility, especially in mandibular dentures. In contrast, IODs have shown to be a more successful treatment option, providing improved masticatory function, retention, stability, and comfort.^{1,2} The BF is an important parameter in evaluating the effectiveness of treatments. Comparing BF measurements between complete dentures and subsequent IODs in the same patient helps standardize patient and denture factors, making the BF measurements more reliable.^{7,25} Therefore, in this study, the BF values were measured with both a complete denture and an IODs in the same patient. The findings of the study were that BF values were significantly higher in IODs than in complete dentures ($P < .001$). Additionally, age, sex, implant lengths, implant diameters, attachment height, attachment color, and interimplant distance did not have a significant effect on BF ($P > .05$).

van Kampen *et al.*²⁶ examined the effects of 3 different attachments (magnet, bar, and ball) and reported that maximum BF nearly doubled after implant treatment in all 3 designs and that there was no significant difference in maximum BF among the attachment types. Similarly, in this study, BF values increased by 60.4% after the use of IODs. The difference in BF values observed between the 2 studies could be due to the average age, sex distribution, and the use of different devices.

Rismanchian *et al.*²⁷ evaluated the maximum BF in

3 different groups. BF values were 55.4 ± 14.31 N in subjects wearing complete dentures for 6 months, 68.74 ± 20.59 N in subjects wearing complete dentures for 10 years or more, and 119.84 ± 26.47 N in subjects wearing IODs in the mandible and complete dentures in the maxilla. In the present study, the BF values were 57 ± 13.6 N for complete dentures and 94.3 ± 26.5 N for IODs. In agreement with the results obtained, the 2 studies are compatible. In the study by Rismanchian *et al.*,²⁷ it was reported that the mean BF values were significantly higher in men than in women. In the study comparing 2 groups of patients with IODs and complete dentures, Geçkili *et al.*³ reported that BF values were significantly higher in the IODs group (mean 127.23 N) than in the complete denture group (mean 53.09 N). BF values were found to be significantly higher in men than in women. Consistent with these results in this study, while the BF values in men (102.7 ± 32.2 N) were higher than in women (89.3 ± 21.4 N), this value was not statistically significant ($P > .05$). However, it should be noted that the number of men and women patients was not evenly distributed. The high number of women patients might have influenced the statistical significance of this difference.

Increased BF has been associated with improved stability of IODs. After the IODs are attached to the attachments, an increase in muscle strength occurs. It is believed that the lack of stabilization with complete dentures prevents the jaw muscles from reaching their full potential.²⁸ Müller *et al.*²² reported an increase in BF and masseter muscle thickness after IODs use in functionally dependent older adults. OHRQoL and patient satisfaction increased with the increase in stability in the IODs group. Caloss *et al.*²⁹ investigated the effects of denture stabilization on BF in patients with complete dentures in the maxilla and IODs in the mandible. In one of the 2 measurements performed for this purpose, a bite block was used to stabilize the opposing arc, whereas it was not used in the other measurement. Higher values were obtained in the measurements performed without a bite block. The researchers reported that in this situation, the force is transferred to both the transducer and the bite block when the bite block is used, which does not fully reflect the BF of the person. The BF value was re-

ported to be 103 ± 48.4 N for the measurements with the bite block at the level of the first molar.²⁹ In the present study, a bite block was placed on the opposite arc of the measured arc in order to provide stabilization. The results obtained were found to be compatible with their study.

In the study by Schimmel *et al.*,²⁴ the BF of 4 different groups was evaluated and it was found that the BF was the highest in individuals with natural teeth. In addition, there was no significant difference between complete dentures and IOD in terms of BF scores. However, the study noted that pain during biting could be a limiting factor because both groups used mucosa-supported prostheses in the maxilla. However, the study reported that the younger mean age in the complete denture group could affect the outcome. It is known that age has a negative effect on BF because muscle atrophy occurs with aging. Atrophy of the masticatory muscles in geriatric patients leads to a decrease in BF. However, muscle loss can be compensated for with implant support.^{30,31} In the present study, age was found to have no significant effect on BF. This may be attributed due to the limited sample size.

In this study, the Turkish OHIP-14 questionnaire was preferred due to its validity and reliability. The OHIP-14 contains more questions than other questionnaires to assess the effects on the QoL of the geriatric population.^{9,16,23} In the study by Geçkili *et al.*, it was found that the physical disability scores of patients older than 65 years were significantly higher than those of patients younger than 65 years.³² This suggests that the QoL of patients over 65 years of age is lower. The OHIP-14 domain of physical disability includes questions on meal interruption and malnutrition due to retention and stability. Additionally, the low scores obtained in the OHIP-14 social disability and handicap area scores of the patients using the locator attachment indicate that they have a better OHRQoL.³² In the present study, total OHIP scores were found to be higher in individuals aged 65 years and older, although this was not significant. This indicates that increasing age has a negative effect on OHRQoL.

Patient satisfaction is influenced by denture retention. In edentulous patients, both OHRQoL and patient satisfaction increase with increasing retention as

a result of the attachment of dentures to implants.³³ Users of IODs reported high overall satisfaction as well as comfort, stability, mastication, speech, and aesthetics 6 months after starting to use dentures.³⁴ In the present study, it is hypothesized that the higher patient satisfaction in men is due to the fact that the average mandibular retention rate is significantly higher in men than in women. Moreover, the OHIP-14 scores obtained in the present study are consistent with the study evaluating the QoL of IODs.⁹ Similarly, men patients in the present study had a higher QoL. This may be due to older women patients being very attentive to and concerned about the accuracy of dentures.

The implant length is an important factor affecting the success and failure of dental implants. It was found that the success rates of dental implants with a length of more than 10 mm were higher. Increasing the diameter and length of the implant increases the surface area, resulting in better contact between the implant-bone and a more stable connection.³⁵ In the present study, no effects of implant lengths were found on BF, OHRQoL, and patient satisfaction. However, when the scale scores are examined, it is seen that the OHIP scores of the patients with implants with a diameter of more than 4 mm are lower. In this case, it can be assumed that the OHRQoL of patients with large diameter implants is more positively influenced.

In IODs retained by 2 implants, implants can be placed in the lateral incisors, canines, and premolars.³⁵ The effects of interimplant distance on attachment retention properties, attachment surface wear, marginal bone loss, OHRQoL, and patient satisfaction have been investigated in previous studies.³⁵⁻³⁸ However, due to the limited number of published studies, it should be noted that these effects are inconclusive. In addition, it was noted that at the time of this study, there was no study examining the effect of interimplant distance at BF. The study, published in 2019, found that increasing interimplant distance increased retention matrix surface changes and wear in both attachment systems used in the study. While the implants were placed at 19 mm intervals in one group, they were placed at 25 mm intervals in the other group. It was observed that higher wear occurred in

2 different attachment groups that were placed at 25 mm intervals.³⁸ In the study that compared the retention values of different attachments at interimplant distances of 19 mm, 23 mm, and 29 mm, it was reported that the retention values of ball attachments were the highest at 29 mm.³⁶ It was reported that longer interimplant distance may positively affect the OHRQoL and patient satisfaction. Increased interimplant distance was associated with a significantly lower social disability and handicap scores. This may be due to the increased retention of more posteriorly placed implants, especially when sticky foods are consumed.³⁵ However, Mumcu and Dereci reported no significant effect of interimplant distance on marginal bone loss around the attachments.³⁹ In the present study, no significant association was found between interimplant distance and BF, OHRQoL, and patient satisfaction ($P < .05$). However, OHIP-14 scores were observed to be lower at 25 mm and above interimplant distance in all subsections except for functional limitation ($P < .05$).

The height of the attachment is an important factor to consider in attachment selection. Lower attachments result in less lateral force transfer to the implants and less displacement of the prosthesis. The selection of attachment height is crucial for protecting the implants, preventing marginal bone loss, determining denture base thickness, and preventing denture fracture susceptibility. However, the presence of a thick mucosa requires the use of higher attachments.⁴⁰⁻⁴² Mumcu and Dereci reported that attachment height may affect marginal bone loss.³⁹ The 4-mm attachments were associated with greater distal and mesial marginal bone loss compared with the 2-mm and 3-mm attachments. No statistically significant difference in marginal bone loss was reported between the 2- and 3-mm locator attachments. This result may indicate that 2- and 3-mm attachments produce similar stresses in peri-implant bone tissue, whereas stress accumulation in peri-implant tissues is higher with 4-mm attachments. When the attachment is higher, prostheses tend to rotate on an axis connecting implants. This leads a decrease in stability. The lower stability leads to undesirable loads on the implants and increases marginal bone loss. Higher abutments carry a much greater load during masti-

cation.³⁹ In this study, it was observed that the BF values were higher for 2- and 3-mm attachment lengths, although this was not significant ($P < .05$). According to the attachment height of the OHIP questionnaire, there was a significant difference in the psychological disability and social disability subdimensions of the cases ($P < .05$). For the subdimensions of psychological disability and social disability, the scores of those with an attachment height of 4 mm were significantly higher than those of the other groups. In this case, it could be assumed that the increase in attachment height has a negative effect on OHRQoL.

The possibility of using complete dentures in the maxilla and IODs in the mandible to cause combination syndrome may be one of the limitations of the study. However, this situation can be prevented by frequent control of occlusal contacts and the need for relining.

CONCLUSION

In conclusion, the study investigated the impact of various denture characteristics on BF, OHRQoL, and patient satisfaction. Higher BF values were observed in patients treated with IODs than in patients treated with complete dentures. It was found that the parameters of age, sex, implant diameter, attachment height, attachment color, and interimplant distance may have influenced OHRQoL and patient satisfaction. Age did not significantly affect BF, contrary to the expected negative impact of age-related muscle atrophy. The OHIP-14 questionnaire demonstrated that increasing age negatively affects OHRQoL. However, further studies with larger sample sizes are needed to evaluate the efficacy of fixed and removable implant-supported dental prostheses in geriatric patients.

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