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Changes in masticatory performance and bite force after treatment with mandibular overdentures retained by four titanium–zirconium mini implants: One-year randomised clinical trial

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Abstract

Objective: This prospective study is part of a randomised clinical trial and reports the changes in masticatory performance (MP) and bite force, and explores their influential factors, 1 year after the provision of mandibular overdentures retained by four titanium–zirconium mini implants.

Methods: Edentulous patients received conventional complete dentures, followed by placement of four mini implants (Straumann® Mini Implant System) in the anterior mandible and converting the conventional prosthesis into a mandibular overdenture. Treatment protocols were randomised using a 2×2 factorial design combining different surgical (flapped vs. flapless) and loading (immediate vs. delayed) protocols. MP was assessed using a two-colour mixing ability test and a colorimetric analysis to measure the level of colour mixing (Variance of Hue–VoH). Maximum voluntary bite force (MBF) was measured by a digital gnathodynamometer in the posterior and anterior regions. Sex, age, surgical and loading protocols and ridge morphology were tested as independent variables. MP and MBF tests were performed at baseline (pre-treatment) and the 3-, 6- and 12-month after implant loading. Descriptive statistics, independent *t*-test, and linear mixed-effect model (LMM) regression were used for data analysis.

Results: Seventy-four participants were assessed and 73 completed the 1-year follow-up. Statistically significant improvements in functional parameters were observed in all follow-up periods compared to baseline ($p < .001$). The flapless protocol was associated with higher improvement in MP at the 3-month follow-up ($p = .004$), while less resorbed ridges were associated with better MP ($p = .038$) and higher MBF ($p < .001$).

Conclusion: The mandibular overdenture protocol using four titanium–zirconium mini implants was effective in improving MP and MBF of edentulous patients, compared to pre-treatment values. The findings also suggest that improvements in chewing function and bite force are impacted by clinical factors since better outcomes were observed for flapless surgeries and less resorbed edentulous ridges.

CLINICAL TRIAL REGISTRATION: ClinicalTrials.Gov ID NCT04760457.

KEYWORDS
clinical trial, dental implant, edentulous patient, mastication, overdenture

1 | INTRODUCTION

Lower stability and retention of complete mandibular dentures have been reported as a major reason for the limited masticatory function of edentulous patients.[1] However, those patients can greatly benefit from the use of dental implant-retained prosthodontics to improve oral function and comfort.[2] Improving masticatory capacity is reported as one of the main reasons why edentulous patients demand implant treatments.[3] Studies show that the maximum bite force is significantly improved after implant interventions, ranging from 60% to 200% improved values compared to conventional dentures. Improvement in bite force is also associated with better masticatory performance (MP).[4–6] Better stability and retention of the mandibular denture after implant treatment has a positive impact on the capacity to crush and break down fragmentable foodstuffs (i.e. chewing efficiency) due to increased bite force, and bolus-kneading ability (i.e. MP) as well as improved sensitivity, coordination and force of the oral musculature.[7]

MP and bite force tests are commonly used as indicators of changes in oral function following implant treatments.[8,9] The MP index can be assessed using standardised tests which analyse the ability to grind or mix food.[10,11] A suitable method for edentulous subjects is the mixing-ability test based on colorimetric technique measurement.[7] The degree of mixing of a two-colour material (usually a two-colour chewing gum) is evaluated visually on a reference scale or optoelectronically.[12] The assessment of chewing function may be complemented by bite force measurement, which is established as the maximum bite force at occlusal contacts recorded using force transducers.[6]

Improvement in functional parameters has been reported after rehabilitation with implant-retained mandibular overdentures compared to conventional complete dentures.[13–16] Although current recommendations propose a mandibular overdenture retained by two implants as the first line treatment option for an edentulous mandible,[17] alternative options with mini implants have been indicated, particularly for older patients with atrophic mandibles.[18–20]

Previous studies reported that overdentures retained by mini implants positively impact several subjective and objective outcomes, including patient satisfaction,[21] oral health-related quality of life (OHRQoL),[22–24] and functional parameters.[10,25] Increased patient satisfaction and improvements in OHrQoL could be partially attributed to the improvement in mastication and chewing efficiency.[26] However, few studies have investigated the impact of mandibular overdentures retained by 4-mini implants on MP.[18,19] Moreover, there is currently limited clinical data on a novel titanium-zirconia mini implant system, combined with a carbon-coated male attachment and a female PEEK (polyetheretherketone) retentive insert.

Therefore, this prospective clinical study evaluated the 1-year changes in MP and maximum bite force of edentulous patients following the provision of a mandibular overdenture retained by four mini-implants. In addition, the influence of independent clinical variables on treatment effects was also tested.

2 | MATERIALS AND METHODS

This article reports a prospective study nested within a randomised clinical trial comparing the outcomes of different surgical and loading protocols after treatment with a mandibular overdenture retained by 4-mini implants. This report assesses the before-after changes in MP and maximum bite force 1 year after implant loading. The study hypothesis was that the functional parameters of masticatory function and bite force would be positively impacted by the provision of mandibular overdentures retained by 4-mini implants when compared with pre-treatment conditions.

The study was conducted in the School of Dentistry of the Federal University of Goias, Brazil, between April 2021 and December 2022. The local research ethics committee approved by the original research protocol (CAAE 24833219.4.0000.5083—Report 3.702.392), and all participants signed a written consent form indicating their willingness to participate in the study. The trial was registered before initiating patient recruitment (NCT04760457). The study had four groups representing the combination of two surgical protocols (flapped vs. flapless) and two loading protocols (immediate vs. delayed/6-week loading), defined by simple randomization.

Eligible participants were fully edentulous patients wearing conventional maxillary and mandibular dentures and referred to the School of Dentistry of the Federal University of Goias, Brazil, for mandibular overdenture treatment with implants. The inclusion and exclusion criteria and the methods for patient assessment and implant planning, as well as detailed methodological aspects of the study, were described in detail elsewhere.[20,27,28]

The participants in this clinical trial received four titanium–zirconium mini implants (Straumann® Mini Implant System) equally distributed in the interforaminal region of the mandible, at a minimum distance of 5 mm between implants and 7 mm from the mental foramen. A minimum of 35 Ncm insertion torque was planned for all implants, regardless of the implant loading protocol.

The implant surgery planning was performed using CBCT images of the anterior mandible. The mandibular denture was duplicated, and two 2mm gutta-percha points were inserted in the fitting surface of the denture at the canine position, bilaterally to serve as reference landmarks for the surgical planning. The duplicated denture was also prepared to serve as a surgical guide.

The implant surgery protocol was performed according to the randomised groups:

- Flapped: a crestal incision was created using a 15C disposable scalpel blade, followed by a full reflection of a mucoperiosteal flap, implant bed preparation, implant insertion and suture.
- Flapless: the mini implants were inserted through the mucosal tissues without raising a flap.

The two most distally-sited implants were prepared first, and then the others were inserted towards the midline with the aid of the surgical guide. Implant site preparation was initially performed using the needle drill, followed by a 2.2mm BLT Pilot Drill. Paralleling posts were used to place the implants as parallel as possible.

The prosthodontic procedures included the conversion of the mandibular denture into an overdenture through the insertion of female PEEK matrix housing (Straumann® Optiloc® Retentive System) into the fitting surface using self-curing acrylic resin. The participants were randomly assigned into two groups according to the loading protocol:

- Immediate loading: chairside incorporation immediately after surgery, when a minimum of 35Ncm final insertion torque was achieved for all implants.
- Delayed loading: the same procedure was performed after a 6-week healing period, irrespective of the final insertion torque.

In cases assigned to the immediate loading group where any of the mini implants did not achieve the minimum 35 Ncm final insertion torque, the patient was moved into the delayed loading group, as per the study protocol.[28]

2.1 | Masticatory performance assessment with a two-coloured chewing gum

MP was assessed using a mixing ability test with a two-coloured chewing gum (Hue-Check Gum®, University of Bern, Bern, Switzerland) as the test specimen. To perform the test, the two gums, one blue and one pink, were manually pressed together after being wetted with water. Two tests were performed with 20 and 50 chewing cycles with each patient.[7] A delay of 1min was allowed between tests to avoid patient fatigue. After each chewing cycle, the gum was collected and rinsed with water. Each specimen was sealed in a transparent plastic bag and labelled with an identification code. To analyse the mixture level between the two colours, the specimens were assessed by the electronic colorimetric method (flattened chewed gum).

The colorimetric analysis was performed using the freeware ViewGum© software (dHAL Software, Greece, www.dhal.com). The specimens were flattened to a wafer of 1mm thickness by pressing with a glass plate under manual pressure. Then, the two sides of the flattened specimens were scanned (HP Photosmart Scanner C4780, Hewlett Packard Corp., Brazil) into JPEG files with 300dpi resolution and combined as a single image file.[7] The combined image was processed to provide a measure of the circular variance of the hue (VoH). The detailed procedure for delimitation of the images and VoH calculation is described elsewhere.[29] VoH values range from 0 to 1 with lower VoH values representing the greater mixing of the two layers of the chewed gum, and therefore better MP.[11]

2.2 | Bite force measurement

The maximum voluntary bite force (MBF) was measured in Newtons (N) using a digital gnathodynamometer (DMD® Kratos, Kratos Equipamentos Industriais Ltda., Brazil). The device has a bite fork with a strain gauge transducer which uses sensitive elastic elements and strain gauges to convert the measured pressure into a corresponding change in resistance value. When the bite fork is placed between the teeth and the bite force is applied, an electric signal is generated and transmitted to the digital monitor.[9]

MBF was measured between the upper and lower first molar, separately on the right and left sides and in the incisal region. For each bite test, the participant was asked to bite as hard as possible on the force gauge and maintain the clenching position until feeling uncomfortable. A 2-min resting interval was adopted between each bite test. A contra-lateral stabilising device with identical thickness was used to prevent dislodgement of the dentures. The peak force of three consecutive recordings on each side was registered, and the mean MBF of the right and left sides was calculated to represent a single MBF for the posterior region for each patient. Similar procedures were performed for the assessments in the incisal region.

2.3 | Independent variables

Age and gender were tested as predictive variables of MP and MBF, as well as the influence of the surgical and loading protocols on the functional parameters. In addition, the morphology of the edentulous mandibular ridge was assessed using the Cadwood & Howell classification,[30] based on the analysis of tomographic sections of the implant regions by two independent raters.[28] The typical aspect of the anterior mandibular ridge was classified as: Class I–dentate; Class II–immediately post extraction; Class III–well-rounded ridge form, adequate in height and width; Class IV–knife-edge ridge form, adequate in height and inadequate in width; Class V–flat ridge form, inadequate in height and width; Class VI–depressed ridge form, with some basalar loss evident.[30] For subgroup analyses, Classes III and IV and V and VI were grouped to represent a dichotomous variable with less and more resorbed edentulous ridges, respectively.

2.4 | Time points for longitudinal analysis

Functional tests were performed at the pre-treatment stage during the implant surgery planning (baseline), and at the 3-, 6- and 12-month follow-up following overdenture insertion (post-treatment stages). The longitudinal changes due to implant treatment were assessed by comparing follow-up measurements to baseline.

2.5 | Sample size estimation

Sample size estimation was based on the primary randomised clinical trial.[20] For this study, a post hoc calculation (G*Power 3.1.9.4) was performed considering the difference between two dependent means (matched pairs in before-after analysis) for a one-sided test, 0.05 alpha (Type I error) and a large effect size (0.50). The calculated power was 0.99 for a sample of 74 participants, which means this study was powerful enough to detect a true treatment effect in the follow-up periods.

2.6 | Data analysis

Descriptive analyses were used to summarise the outcome measures in terms of mean and standard deviations. Independent *t*-tests and paired *t*-tests were used for bivariate between- and within-group comparisons. The magnitude of before-after outcome changes was expressed as the effect size (ES) estimation. ES was calculated using *t*-test statistics (paired *t*-test), number of cases (n), and the correlation between the two measures in matched subjects (r). The formulae for Cohen's d effect size calculation was: $d = t\,\frac{\sqrt{2(1-r)}}{n.}$

Longitudinal changes and repeated measures within subjects, were assessed using a linear mixed-effect Model (LMM) regression which modelled the changes in the functional parameters due to the dependent data structure. Patient-specific MP and MBF at different time points were treated as repeated outcome measures, and each model had a random intercept for each individual. The number of chewing cycles (20 vs. 50) and bite region (anterior vs. posterior) were also considered as within-subject repeated-measures for MP and MBF, respectively. Two regression models were constructed for MP and MBF as dependent variables. Time points, age, gender, ridge form, number of chewing cycles (MP) and occlusal region (MBF) were tested as independent variables. The introduction of independent variables in the regression models was performed using the enter method with backward elimination. The model parameter estimates were expressed as regression coefficients and their standard errors. The significance level was set at $p < .05$, and the IBM-SPSS software (version 24.0) was used for data analysis.

3 | RESULTS

Seventy-four participants were included in the study, 64.9% female, with ages ranging from 35 to 80 years (mean = 64.0; SD = 8.2) at baseline. The final distribution of participants in the study groups according to the combinations of surgery and loading protocols were: immediate/flapless = 17 (23.0%); immediate/flapped = 18 (24.3%); delayed/flapless = 20 (27.0%); and delayed/flapped = 19 (25.7%). During the 1-year follow-up period, one patient did not attend any visits thus only 73 patients were included in the data analysis Three patients did not attend the 3-month visit, two did not attend the 6-month visit and one did not attend the 12-month visit. Patients with partially missing data were included in the statistical analyses.

Figure 1 shows the changes of MP and MBF over time. Significant improvements in both functional parameters were observed in all follow-up periods compared to baseline ($p < .001$). The differences between baseline (CD) and overdenture (3 months) were, in fact, significant not only for 50 cycles (MP) and posterior region (MBF) but also for 20 cycles (MP) and the anterior region (MBF), as can be seen in Figure 1. The ES estimations for the before-after changes (12-month–baseline) were for MP: ES = 0.804 (20 cycles) and ES = 1.284 (50 cycles); and for MBF: ES = 1.210 (anterior) and ES = 1.507 (posterior). In all cases, the magnitude of change was considered as having a large effect ($d > 0.80$). On the other hand, no significant differences were observed among the 3-, 6- and 12-month periods, suggesting that the improvements achieved in the initial stage of overdenture use were maintained throughout the 1-year follow-up period.

Table 1 shows the MP and MBF values in the pre-treatment (baseline) and post-treatment (3-, 6- and 12-month values) stages, which were compared according to subgroups of the independent variables. The mean VOH values (20 and 50 chewing cycles) and mean maximum bite force (anterior and posterior) were considered for analysis. Patients treated using the flapless surgical protocol showed better MP values at the 3-month post-treatment ($p = .019$), and higher MBF values were observed for less resorbed ridges (Classes 3 and 4) at baseline ($p = .016$). No other significant differences were observed for age, gender and loading protocols.

Multiple LMM regression models in Table 2 show that the likelihood of improved MP was associated with lower age groups ($B = -0.028$; $p = .031$), less resorbed ridges ($B = -0.039$; $p = .038$), higher number of chewing cycles ($B = -0.267$; $p < .001$) and time following treatment ($p < .001$). Flapless surgery had a positive effect at the 3-month follow-up ($B = -0.084$; $p = .004$). A positive effect on MBF was observed for male patients ($B = 6.74$; $p = .036$), less resorbed ridges ($B = 17.7$; $p < .001$); in the posterior region ($B = 59.1$; $p < .001$), and at all post-treatment stages compared to baseline ($p < .001$).

Finally, a LMM estimate was calculated for the fixed-effect of MBF (predictor) on MP (outcome). A correlation matrix which

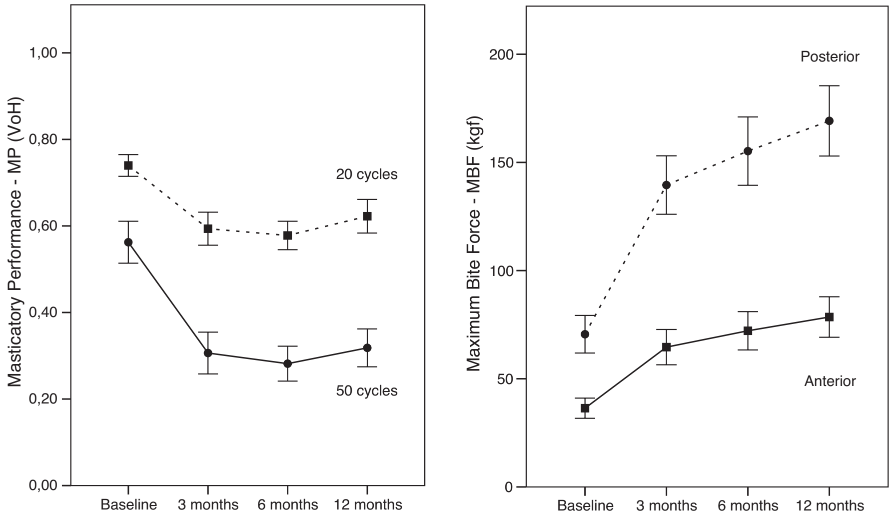

FIGURE 1 Changes in masticatory performance and maximum bite force according to the study time points. Data are expressed as mean and 95% confidence interval.

TABLE 1 Mean masticatory performance (MP) and mean maximum bite force (MBF) according to the treatment stage and clinical and demographic variables.

	MP				MBF			
		Follow-up				Follow-up		
	Baseline	3-month	6-month	12-month	Baseline	3-month	6-month	12-month
Sex								
Male	0.66 (0.19)	0.47 (0.23)	0.42 (0.22)	0.46 (0.22)	55.6 (34.9)	106.7 (65.9)	117.8 (65.7)	127.6 (72.7)
Female	0.65 (0.14)	0.44 (0.23)	0.44 (0.22)	0.48 (0.24)	52.3 (34.5)	99.4 (56.8)	111.4 (70.2)	121.9 (71.5)
p-value[a]	.869	.550	.605	.679	.578	.488	.587	.679
Age groups								
50% younger	0.65 (0.19)	0.42 (0.22)	0.43 (0.21)	0.45 (0.24)	54.0 (35.5)	102.5 (59.2)	112.3 (66.5)	122.8 (71.7)
50% older	0.65 (0.18)	0.48 (0.24)	0.43 (0.22)	0.49 (0.22)	53.0 (33.8)	101.7 (61.5)	115.0 (70.7)	124.9 (72.8)
p-value	.932	.113	.986	.286	.868	.943	.815	.861
Surgical protocol								
Flapless	0.64 (0.18)	0.49 (0.22)	0.41 (0.22)	0.48 (0.23)	53.1 (32.1)	103.4 (56.2)	116.4 (61.0)	122.9 (64.2)
Flapped	0.66 (0.19)	0.40 (0.22)	0.45 (0.22)	0.46 (0.23)	53.9 (37.0)	100.9 (64.0)	111.1 (75.2)	124.8 (78.0)
p-value	.609	.019[a]	.320	.556	.882	.803	.643	.881
Loading protocol								
Immediate	0.63 (0.20)	0.46 (0.23)	0.43 (0.22)	0.47 (0.23)	57.0 (33.9)	101.8 (60.8)	110.4 (64.7)	120.1 (62.0)
Delayed	0.67 (0.17)	0.44 (0.24)	0.43 (0.21)	0.47 (0.23)	50.3 (35.0)	102.3 (60.0)	116.8 (72.2)	127.5 (80.1)
p-value	.255	.700	.937	.886	.240	.959	.577	.542
Ridge form								
3 and 4	0.64 (0.19)	0.44 (0.23)	0.42 (0.21)	0.46 (0.23)	56.3 (35.1)	104.2 (61.4)	116.6 (70.9)	126.9 (74.0)
5 and 6	0.70 (0.18)	0.51 (0.22)	0.48 (0.24)	0.51 0.23)	37.2 (26.3)	89.1 (51.5)	95.7 (48.7)	103.3 (49.9)
p-value	.216	.203	.246	.453	.016[a]	.301	.206	.192

Note: Data are expressed as means (and standard deviations).
[a]Independent *t*-test;

accounted for the dependency of the repeated time points, number of chewing cycles and bite region resulted in a correlation coefficient of −0.811, showing that higher bite force was positively associated with lower VoH values that is, better MP.

4 | DISCUSSION

The results of this study showed that the provision of mandibular overdentures supported by four titanium–zirconium mini implants

TABLE 2 Linear mixed-effects model estimates for the effects of independent variables on repeated measures of masticatory performance (MP) and maximum bite force (MBF).

MP				MBF			
Independent variables	**Subgroups**	***B* (SE)**	***p***	**Independent variables**	**Subgroups**	***B* (SE)**	***p***
Intercept		0.794 (0.022)	<.001	Intercept		14.3 (4.6)	.002
Age	Younger	−0.028 (0.013)	.031	Sex	Male	6.74 (3.20)	.036
	Older	Ref.			Female	Ref.	
Ridge form	3–4	−0.039 (0.019)	.038	Ridge form	3–4	17.7 (4.38)	<.001
	5–6	Ref.			5–6	Ref.	
Chewing cycles	50	−0.267 (0.019)	<.001	Region	Posterior	59.1 (3.69)	<.001
	20	Ref.			Anterior	Ref.	
Time points	12-month	−0.128 (0.026)	<.001	Time points	12-month	53.9 (4.61)	<.001
	6-month	−0.164 (0.024)	<.001		6-month	45.6 (4.39)	<.001
	3-month	−0.121 (0.025)	<.001		3-month	36.8 (4.06)	<.001
	Baseline	Ref.			Baseline	Ref.	
Surgery at 3-month follow-up	Flapless	−0.084 (0.029)	.004				
	Flapped	Ref.					

Note: Data are expressed as regression coefficients (*B*) and their standard errors (SE).

result in positive functional outcomes, that is, increased MP and MBF. Therefore, this study provides additional evidence on the clinical performance of this mini implant system and complements the findings from previous publications on this same patient cohort concerning favourable short-term surgical outcomes[20] and satisfactory 1-year implant survival and peri-implant outcomes.[28]

Previous evidence showed that implant-retained overdentures improve MP, bite force and patient satisfaction, while having no effect on nutritional state, compared to pre-treatment condition with conventional dentures.[4] Similar effects were found for a hybrid prosthesis that also significantly improved the quality of life for edentulous patients compared with conventional removable complete dentures.[31] Although the survival rate of mini implants may not be as high as that of standard implants,[32,33] overdentures retained by four mini implants are comparable to overdentures with two standard implants concerning the quality of life impacts and patient satisfaction,[32,34] and marginal bone loss.[33] Therefore, although there is sound evidence favouring the use of 2-implant overdenture with standard implant-diameter treatment, using mini implants may also be considered a suitable option for cases with limited bone width.

This study provides additional evidence for a novel mini-implant system used to retain mandibular overdentures, in relation to these parameters, specifically showing that patient's functional parameters, measured in terms of MP and MBF, are markedly improve post-treatment. Moreover, longitudinal studies that assessed chewing function in denture wearers have suggested that this is a continuous learning process, as a result of better patient adaptation to the dentures. Therefore, MP tends to improve with the continuous use of newly inserted dentures during the post-treatment adaptation period.[35] The same effect is observed in the transition from conventional to implat-retained dentures. A study comparing the effect of a single-implant mandibular overdenture showed that the MP increased over time independently from the implant loading protocol at the '4-month follow-up compared to the baseline data without implant.[36] Another study suggests that functional rehabilitation in terms of MP and muscle activity does not occur immediately after implant rehabilitation with mandibular overdentures, but requires a significant time for functional improvement, which may occur after a 3-month adaptation period.[37] These studies corroborate our results that showed significant functional improvement at 3-month follow-up after rehabilitation with mandibular overdentures retained by mini-implants, and this benefit is maintained throughout the 1-year follow-up period.

On the other hand, MP is negatively influenced by advanced age and reduced masticatory capability due to the progressive impairment on overall physical capacity, which is frequently accompanied by a decrease in body weight and muscle mass, leading to frailty and associated morbidity in older adults.[36,38] In this study, older patients demonstrated lower improvements in MP when considered together with other clinical factors such as the level of ridge resorption. Schimmel et al.[39] suggested that patients rehabilitated with dental implants may start improving biting or chewing immediately after the insertion of the implant-based dentures, but older subjects with clearly identified impairment in masticatory parameters may need to be trained to develop optimal function, and this process is age-dependent.

Patients with deficient objectively assessed MP/efficiency usually develop coping strategies for compensation, such as increasing the number of chewing cycles, swallowing unchewed food or even food avoidance.[40] Hence, objective tests are important to assess objective parameters, but may fall short of fully describing the patient's behaviour in terms of adequate nutrition or social interaction. Subjective assessment of the chewing function, that is, chewing ability might be beneficial to better understand these coping strategies; however, there is currently no widely accepted instrument available.[11]

Several devices and tests which aim to evaluate masticatory function have been previously used, including objective tests with direct analyses commonly found in studies testing the effect of implant intervention on chewing function. Comminution, mixing ability and gummy jelly (substance concentration) tests are commonly used.[11] Traditionally, comminution tests have been used with breakable test foods such as nuts or silicon cubes with a subsequent particle size analysis using a set of sieves with decreasing mesh sizes, indicating the spread of particles according to their size,[41] Both the comminution and mixing-ability tests correlated positively with the gummy jelly test that measures the glucose concentration obtained from a chewed specimen and can be considered acceptable alternatives that are less costly and less complex to perform.[41] A wax-mixing ability test also correlated significantly with the optocal comminution test. It was able to discriminate better between subjects with complete dentures and with implant retention than the comminution test.[42]

However, a different method based on the mixing-ability of a two-coloured gum was used in this present study. As the mixing ability tests depend less on the maximum available bite force and rather evaluate the ability to form and knead a bolus, it was suggested that they might be less suitable for research questions that indirectly assess the increase or decrease of bite force.[11] Nevertheless, previous studies in healthy volunteers reported that chewing function, measured by mixing ability tests, demonstrated that individuals with higher MBF tended to have better chewing function.[42,43] In this study, improvement in MP was positively associated with increased MBF, which suggest an overall improvement in oral function parameters as a result of the greater stability and better support provided by the mini implant retained overdentures. Finally, although the mixing-ability test using a two-coloured chewing gum is a quick and easy-to-perform method, there is still a need for well-designed validation studies focused on the understanding of specific colour-mixing characteristics, and standardisation of methods considering both the optoelectronic assessment tools, and the differences on properties of the test foods such as rheological characteristics and hardness.[11]

Concerning the method used to measure and assess changes in MBF, a sensitive electronic device is commonly used to measure bite force and to assist in the evaluation of treatment efficacy by comparing the bite force values before and after an intervention.[9] MBF in patients with mandibular implant-supported overdentures can be twice as high of patients with conventional dentures,[44] which may also have influence on greater satisfaction scores.[45] In this study it was demonstrated that lower MBF values were recorded in patients with severely resorbed ridges, which suggests that not only the implant support, but also the more favourable coverage of the denture bearing area has a positive effect on occlusal load distribution and bite force. However other studies have reported that patients with different ridge heights (low moderate, or high) had similar improvements in satisfaction with the dentures following treatment with either a mandibular conventional denture or implant overdenture.[46,47] Patients with advanced ridge resorption may benefit more from implant stabilisation than complete denture patients regarding improvements in MP.[48]

The findings of this study are in line with a large number of previous studies indicating that implant-retained overdentures positively affect a wide range of clinical outcomes, including functional outcomes. The benefits from implant interventions for edentulous patients have been assessed by objective tests based on standardised performance measures, such as MP and MBF. These are considered reliable surrogate endpoints which correlate with the patient's perceived ability to chew.[45] Nevertheless, although there is extensive evidence from observational and experimental studies indicating that performance measures can be reliable substitutes for clinically meaningful endpoints in clinical trials, the proper assessment of dental patient-reported outcome measures (d-PROMs) is essential to provide evidence of clinical benefits to patients after implant interventions.

5 | CONCLUSION

This study demonstrated that converting a complete mandibular denture into an overdenture retained by four titanium–zirconium mini implants markedly improved the MP and MBF for edentulous patients. The findings also suggest that improvements in chewing function and bite force are impacted by various clinical factors, as superior outcomes were observed for flapless surgeries and less resorbed edentulous ridges.

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CONFLICT OF INTEREST STATEMENT

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PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/joor.13722.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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