CHAPTER 4

REMOVABLE PARTIAL DENTURES IN THE MANDIBLE;

FUNCTIONAL, CLINICAL AND RADIOGRAPHICAL PARAMETERS IN RELATION TO IMPLANT POSITION

This chapter is an edited version of the manuscript:
Jensen C, Speksnijder CM, Raghoebar GM, Kerdijk W, Meijer HJA, Cune MS. Implant-supported mandibular removable partial dentures; functional, clinical and radiographical parameters in relation to implant position. (Accepted for publication)

Abstract

Background. Patients with a Kennedy class I situation often encounter problems with their Removable Partial Denture (RPD).

Objectives. To assess the functional benefits of implant support to Removable Partial Dentures (RPD) in patients with a bilateral free-ending situation in the mandible, to assess clinical and radiographical performance of the implants and to determine the most favourable implant position with respect to these aspects: premolar (PM) or molar (M) region.

Materials and methods. Thirty subjects received 2 PM and 2 M Implants. A new RPD was made. Implant support was provided 3 months later. Two PM implants supported the RPD. After 3 months the 2 M implants were used or vice versa. Masticatory performance was determined by assessing the Mixing Ability Index (MAI) at the end of each stage of treatment. Clinical and radiographic parameters regarding implants and abutment teeth were assessed. Non-parametric statistical analysis for related samples and post-hoc comparisons were performed.

Results. Masticatory performance differed significantly between the stages of treatment ($p<0.001$). MAI-scores did not change significantly after a new RPD was provided, but improved with implant support. The implant position had no significant effect on MAI when functioning with an ISRPD.

No implants were lost, mechanical complications to the implants or RPD were not observed and clinical and radiographical parameters for both implants and teeth during the relatively short observation period were favourable. Higher scores for bleeding on probing were seen for molar implants.

Conclusions. In patients with a bilateral free-ending situation in the mandible who perceive functional problems with their conventional RPD yet would like to continue wearing one, implant support significantly improves masticatory function. No marked difference was seen between molar and premolar implant support. No major problems in relation to the clinical function of the implants, the abutment teeth and the RPD itself were observed.

Introduction

Loss of posterior teeth reduces masticatory performance[1-4], the degree of which relates to the number of remaining occlusal units.[5] They compensate their masticatory impairment by increasing the number of chewing cycles before swallowing, so chewing their food takes them longer than others with a full dentition.[6]

In patients with bilateral mandibular posteriorly unbounded saddles, providing a Removable Partial Denture (RPD) is one of the means available to restore function and aesthetics. However, data regarding the effect on masticatory performance are contradictory. Some report improved masticatory performance, particularly in patients with more serious functional problems.[7-10] Others don't see improvement when providing an RPD or differences between subjects with or without an RPD in shortened dental arches.[11] In clinical practice mandibular distal extension RPD's enjoy a poor reputation among both dentists and patients. Patients' appreciation is unpredictable and complaints include food retention underneath the saddle and pain, resulting from a lack of stability and retention of the RPD. Patients discontinue wearing them or insist on replacement by a new one at a high rate.[12-17]

The main problem with bilateral mandibular distal extension RPD's is of biomechanical origin. Occlusal forces move the saddles into a tissue-ward direction because distal support is lacking, compromising the anterior abutment teeth as well through potentially destructive rotational forces. As a corollary, long term use of an RPD is associated with poor adaptation of retainers, occlusal disharmony, pain, periodontal problems and ongoing resorption.[18-20]

In fully edentulous subjects there is overwhelming evidence that implant support to mandibular dentures effectively improves various oral functions, among which is masticatory performance.[21-23] Since denture complaints from partly edentulous patients resemble those of fully edentulous patients, providing implant support to RPD's may be to the functional and psychological benefit of partly edentulous patients too. It presumably improves stability, retention and chewing ability, patient comfort in general, and even nutrient intake.[19,20,24-30] The use of unaesthetic clasps can often be avoided with implant support.[31]

Implant-supported RPD (ISRPD) treatment is relatively cheap and easy to perform. A Kennedy class I or II situation is basically transformed into a class III situation, with a more favourable transfer of forces from the mucosa toward the implant(s) and abutment teeth. With the cuspid or first bicuspid as most distal tooth, the position of the implant in the edentulous zone is more or less optional and at the discretion of the prosthodontist or surgeon. Little evidence is available with respect to functional and clinical outcomes on which to base the decision. Theoretical models indicate that a more posterior position, i.e. at the position of the first or second molar, reduces the

pressure to soft tissues and alveolar bone the most, whereas an implant positioned directly distal to the remaining dentition reduces the stress on the abutment teeth.[32]

The aim of this study was to assess the functional benefits of implant support to removable partial dentures in patients with a full upper denture and a bilateral free-ending situation in the mandible, to assess the clinical and radiographical performance of the implants and abutment teeth, and to determine the most favourable implant position with respect to these aspects: premolar (PM) or molar (M) region.

Materials and methods

Study setup and patient population

The study was set up as a within-subject comparison randomized clinical trial for which permission from the medical ethical committee of the University Medical Center of Groningen was granted (METc 2011.194). Thirty subjects with a full upper denture and complaints regarding their bilateral free-ending mandibular RPD were included fulfilling the following criteria:

- ≥ 18 years of age;
- the saddle area reaches until the first mandibular premolar or cuspid, both left and right;
- the bone volume distal from the most posterior abutment teeth allows the placement of implants with a minimum length of 8 mm and minimum diameter of 3.3 mm;
- the patient is capable of understanding and giving informed consent.

Potential subjects with medical and general contraindications for the surgical procedures, those with a history of local radiotherapy to the head and neck region, those who experienced implant loss in the past, subjects who are incapable of performing basal oral hygiene measures and those with decreased masticatory function due to physical disability or with active, uncontrolled periodontal pathology of the remaining dentition were excluded from participation.

One of the authors (CJ) was involved during the inclusion of the subjects, coordination of the trial and performed all measurements but did not provide surgical or prosthodontic care.

Surgical and prosthetic procedures

All subjects gave informed consent and received 2 implants on either side of the mandible (Straumann RN, Straumann, Switzerland) that were provided with cover screws and submerged. Two implants were placed in the premolar region (PM implant support) and two were placed in the molar region (M implant support). A surgical guide was used to achieve the right position and inclination. After 3 months, all implants were

exposed in a second-stage surgery and low healing abutments were inserted.

A new RPD was made according to standard prosthetic procedures. The design involved a lingual plate and a clasp on either side. The housing of the Locator® abutment (Zest Anchors, Inc., Escondido, California, USA) was already incorporated in the RPD, but not the Teflon matrix so it provided neither retention nor support to the RPD. Three months later and following a randomization scheme, either the PM or M implants were provided with a Locator® abutment. The remaining implants were left unloaded for future investigation. After 3 months, the other pair of implants was loaded. Consequently, 2 groups can be distinguished (PM -> M support and M -> PM support). Figure 1a-d represent a typical clinical case. A clear timeline of the trial and moments of data collection is depicted in Figure 2.

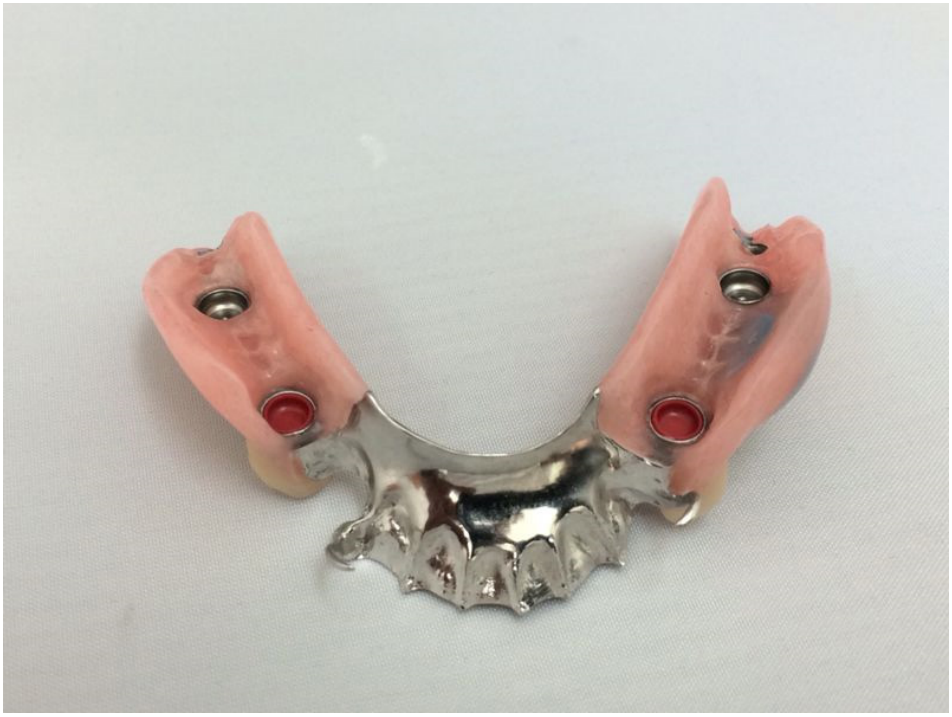

Figure 1a. Implant-supported bilaterally free-ending mandibular partial denture with red nylon matrices incorporated to engage with 2 locator abutments at the position of a premolar (premolar-implant support). Molar implant not active, housing without a matrix.

Figure 1b Occlusal view of cast model. Locator abutments at the premolar implants, low healing abutments in the molar implants (premolar support).

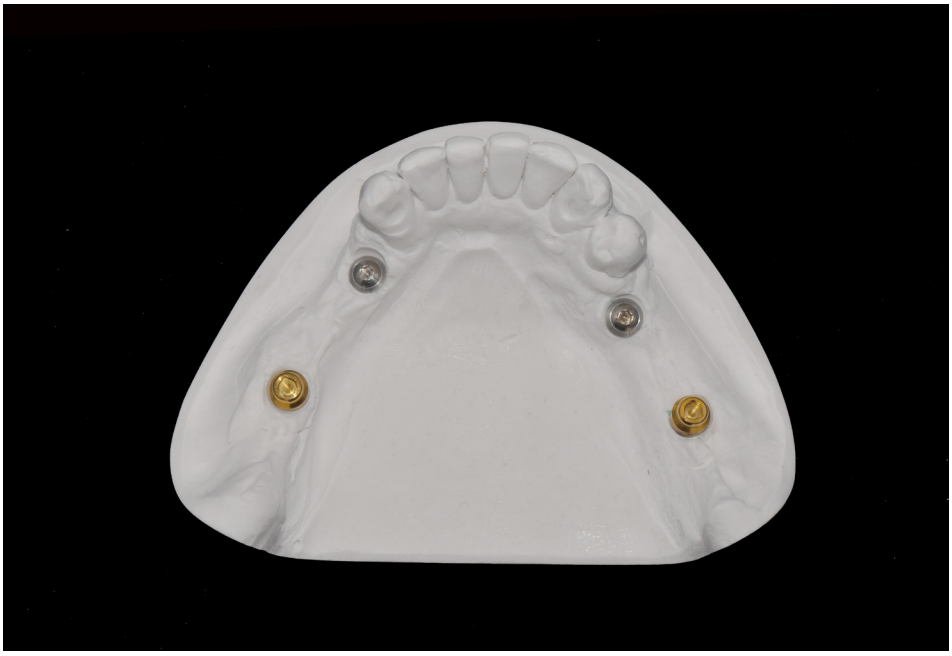

Figure 1c. Vice versa. Molar implants active after placement of locator abutments, premolar implants with low healing abutments (molar support).

Figure 1d. The housings are laser welded to the metal base of the removable partial denture. Matrix in situ at the position of the premolar implant.

Masticatory performance

Masticatory performance was studied by means of a mixing ability test and constituted the primary outcome measure of the study.[33-35] The test and method of analysis are described in detail by others and is described here in brief. The test measures how well a subject is able to mix a wax tablet by chewing on it for a total number of fifteen chewing strokes. The tablet (Figure 3a,b) consists of two, 3-mm layers of red and blue wax and has a diameter of 20 mm. The wax is a soft material that forms a compact bolus during chewing.

After being chewed, the wax is flattened between foil to a thickness of 2.0 mm to avoid shadows in the image by the oblique illumination of the scanner's lamp. The flattened wax is then photographed using a high-quality scanner (Epson® V750, Long Beach, CA, USA). The images of the wax are analysed and processed using a commercially available program for image analysis (Adobe Photoshop CS3, San Jose,

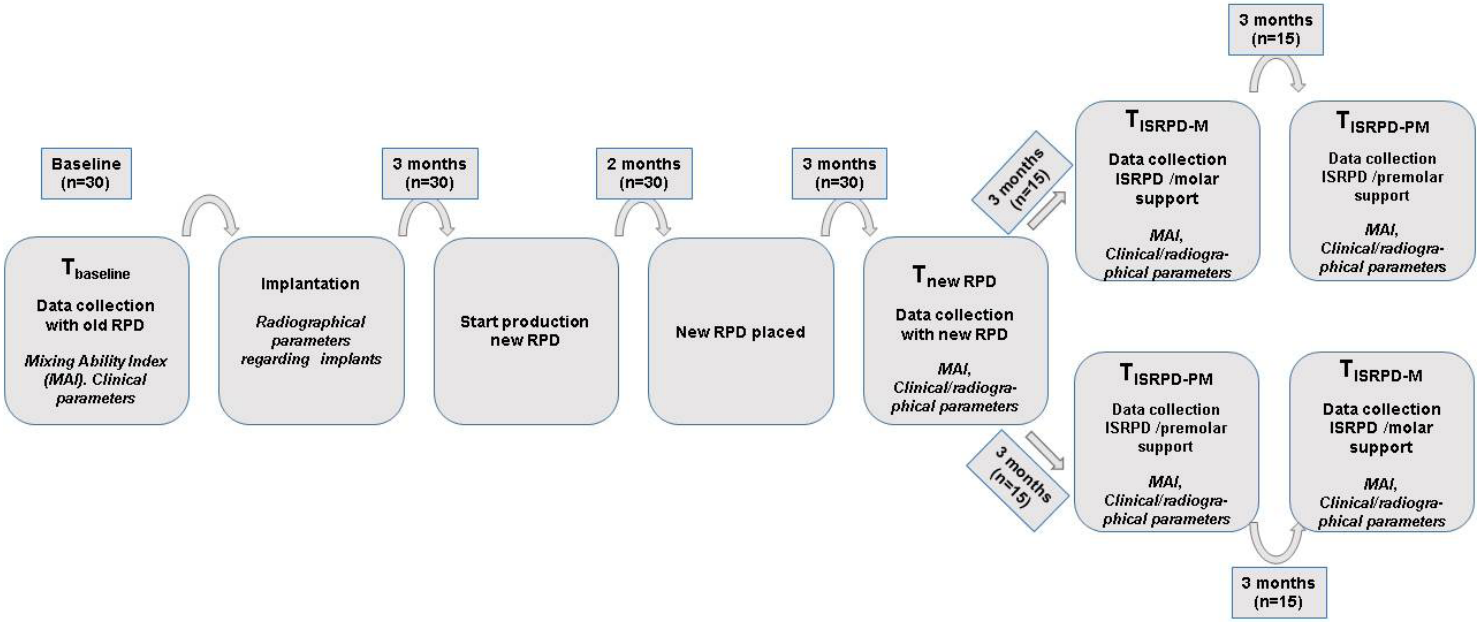

Figure 2. Time line.

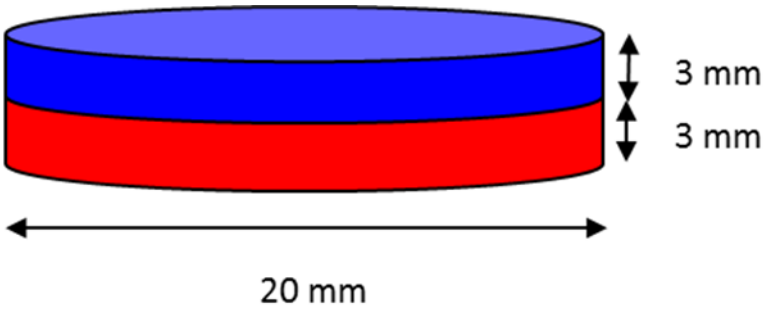

Figure 3a. Pristine wax tablet for the mixing ability test.

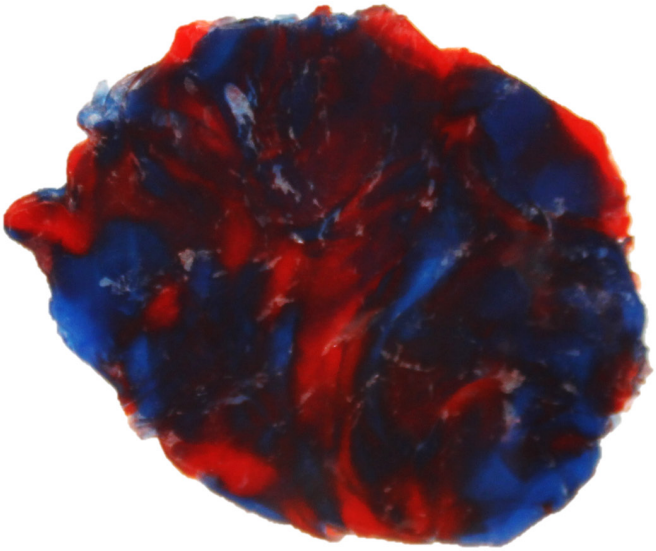

Figure 3b. Mixed tablet and flattened after 15 chewing strokes.

CA, USA). Intermediate colour intensities appear and the spreads of the intensities for red and blue decrease. A lower MAI score implies a better mixed tablet, hence better masticatory performance.

Clinical and radiographical parameters of the implants

Clinical and radiographical parameters included probing pocket depth (PPD), recession (REC) and bleeding on probing (BOP) and were assessed at 3 sites per implant (mesial, distal, buccal). A plastic periodontal probe with 0.25 N of calibrated probing force was used (Click-probe®, KerrHawe, Bioggio, Switzerland). PPD was measured in millimetres from the mucosal margin to the clinical pocket. REC was measured from the edge of the locator abutment to the mucosal margin in case of the implants. BOP was noted as no bleeding (score=0), small punctuated bleeding (score=1) or severe bleeding (score=2).

Marginal bone levels (MBL) were analysed on a digital panoramic radiograph (Oldelft, Orthoceph, OC100D, 85 KV) using the known implant length as a reference. The interface of the implant and the abutment was used as a reference line, from which all distances were measured using designated software (DicomWorks, Biomedical Engineering, University Medical Center Groningen, the Netherlands.[36] The error of the method used was reported 0.13 ± 0.01 mm for the assessment of the radiographic marginal bone height.[37,38] All radiographic assessments were performed by a single observer (CJ). Mean values per M or PM implant pair (left/right) were calculated for all variables. Depending on the group (PM -> M support or M -> PM support) the implant belonged to, data were obtained after 6 or 9 months following placement of the new RPD, hence 7.5 months on average.

Clinical and radiographical parameters abutment teeth

Clinical parameters were assessed at 6 sites for the most distal abutment teeth, both left and right and included PPD, BOP and REC. REC was measured in millimetres from the cemento-enamel junction to the marginal gingiva for the abutment teeth. PPD and BOP of teeth were assessed the same as those of the implants.

Maintenance

Mechanical complications regarding the (IS)RPD and locator abutments were noted during the course of the trial.

Sample size calculation and statistical analysis

The required sample size was calculated given X=0.05, power=0.80 and on the basis of the expected effect size for 2 dependent means (matched pairs).[39] The prospected outcome was based on a study on masticatory ability as reflected by the mixing index in edentulous subjects with and without implant support in the mandible after 15 chewing cycles (20.4 SD 2.3 versus 22.2 SD 3.4).[33] Twenty-two subjects would be required to have a 80 % chance of detecting, as significant at the 5 % level, an increase in the primary outcome measure from 20.4 in the control group to 22.2 in the experimental group, be it with the implants positioned anteriorly or posteriorly. Given the fact that

Table 1. Patient characteristics

Gender (male/female)	15/15
Mean Age (SD/range)	60.9 (1.2/43.8-71.0)
Group (PM*/M**)	15/15
Number of remaining natural teeth (5-6/7-8)	16/14

*PM = implants in premolar region first loaded
*M= implants in molar region first loaded

the expected effect in patients with some remaining natural teeth is presumably smaller than that in edentulous subjects and compensating for potential dropouts, the intended number of subjects to include in the study was determined at 30 patients.

Masticatory performance as expressed by the MAI with the old, the unsupported, the M implant-supported and the PM implant-supported RPD's will be compared with a Friedman test. In case of statistical significance ($X < 0.05$), post-hoc Wilcoxon signed rank tests will be performed with Bonferroni adjustment for multiple testing. Mann-Whitney U tests will be performed to detect any effects from treatment sequence (PM -> M support or PM -> M support).

Clinical parameters were compared during the stage with PM and M implant support only. Here, the effect of treatment sequence as well as left-right differences were examined first. Statistical analyses were performed using standard statistical software (SPSS, version 23). The statistician (WK) was blinded with respect to the groups that were being evaluated.

Results

Patient and treatment characteristics are presented in table 1. No implants were lost, nor were mechanical complications related to the implants, locator abutments or RPD's noted during any of the stages of treatment. All patients have worn there RPD's during the whole course of the study.

Kolmogorov-Smirnov tests revealed that variables were indeed not normally distributed and therefore the anticipated non-parametric tests were used. No statistical significant effect of the sequence in which the implants were loaded was observed for any of the variables and for further analysis all data were grouped into either PM- or M-implant support.

Table 2. Masticatory performance (Mixing Ability Index) at different stages of treatment: old removable partial denture ($T_{baseline}$), new removable partial denture ($T_{new\ RPD}$), implant-supported removable partial denture with support at the molar position ($T_{ISRPD-M}$), implant-supported partial denture with support at the premolar position ($T_{ISRPD-PM}$). Mean values, standard deviations and range between brackets. Lower numbers indicate a better mixed tablet.

$T_{baseline}$	$T_{new\ RPD}$	$T_{ISRPD-M}$	$T_{ISRPD-PM}$	p-value
19.2 (2.2; 15.0 – 22.9)	20.2 (2.1; 16.5 – 25-1)	18.0 (1.4; 14.3 – 20.4)	17.9 (1.5; 15.7 – 21.3)	p < 0.001*

* Post-hoc tests: $T_{baseline} = T_{new\ RPD} > T_{ISRPD-M} = T_{ISRPD-PM}$

Table 3. Clinical and radiographical data regarding the M- and PM implants after 1 year of function. Data for the left and right implants were averaged. Mean values, standard deviation between brackets. Positive values denote an increase.

	M-Implant	PM-Implant	p-value
Probing pocket depth (mm)	1.69 (0.43)	1.76 (0.45)	ns
Recession (mm)	0	0	ns
Bleeding on probing	0.26 (0.29)	0.11 (0.11)	p=0.006
Marginal bone level (mm)	-1.10 (0.53)	-1.06 (0.59)	ns

Table 4. Clinical data regarding abutment teeth. Differences occurring during the period with molar ($T_{ISRPD-M}$) or premolar implant-support ($T_{ISRPD-PM}$). Data for the left and right teeth were averaged. Mean values, standard deviation between brackets. Positive values denote an increase during the interval.

	$T_{ISRPD-M}$	$T_{ISRPD-PM}$	p-value
Probing pocket depth (mm)	0.01 (0.35)	0.04 (0.32)	ns
Recession (mm)	0.01 (0.62)	0.37 (0.73)	ns
Bleeding on probing	0.10 (0.40)	0.00 (0.42)	ns

Masticatory performance

Masticatory performance as expressed by the MAI differed significantly between the stages of treatment ($X^2(3) = 31.68$, $p<0.001$). MAI-scores did not change significantly after a new RPD was provided, but improved with implant support, to a level that was statistical significantly higher than prior to treatment and after provision of a new, unsupported RPD. The implant position, M or PM, had no significant effect on masticatory performance (table 2).

Clinical and radiographical parameters implants

The implants functioned well as reflected by the parameters measured, with low probing depths and bleeding scores. A statistical significantly higher score for BOP was seen around the molar implants (Wilcoxon signed-ranks test, $Z=47.5$, $p=0.006$). No recession was seen during the observation period around any of the implants. Approximately 1 mm of marginal alveolar bone was lost on average 12 months after implant placement both around the M- and the PM-implants (table 3).

Clinical parameters abutment teeth

During the 3 month periods with M- and PM-support the periodontal health of the abutment teeth was stable. Values at the start and the end of an interval did not differ to a significant level (table 4).

Discussion

To investigate whether implant support to a Removable Partial Denture in patients with a mandibular bilateral free-ending situation improves masticatory function, a within subject comparison clinical trial was set up in which several clinical and radiographical outcome measures regarding implants and teeth were assessed as well. These variables were related to 2 different implant positions: the molar (M) or the premolar (PM) position. The studied population is rather homogenous. The cross-over study design employed has several advantages among which are the unchanged occlusion and vertical dimension and length of the borders of the RPD. Consequently, several sources of bias were avoided.

In this study masticatory performance was expressed as the Mixing Ability Index (MAI) which evaluates the ability to mix and knead a food bolus by mixing a paraffin wax tablet with a blue and red layer (see also the method section).[33] It has been shown that chewing on two-coloured paraffin wax is a reliable alternative for the often used comminution tests.[33,35,40] Comminution tests measure the degree of breakdown of a natural or artificial food by sieving the comminuted food.[1,21,41-46] However, subjects with a compromised oral function e.g. by wearing dentures are not always capable to fragment the test food, because their maximum bite force appeared to be lower than the force needed to break the test food particles.[21,45,47] For patients with compromised oral conditions, the MAI is a good alternative for food comminution tests: the test food is soft enough and forms a bolus that can be easily chewed on.[47] In previous studies the parameter 'masticatory performance' was operationalized in various ways with contradictory findings.[7-11] This makes the interpretation of those findings and comparison with the present one troublesome.

In in vitro studies dealing with Kennedy class I or II situations, it has been demonstrated that positions more to the posterior reduce the pressure on the alveolar ridge and hence the periosteum more favorably in comparison to situations where implants are positioned more to the anterior.[48-50] In situations with molar support the least amount of displacement of the mucosal tissues under load is seen.[18,32,51,52] The present data clearly demonstrate an improvement in masticatory performance when implant support was provided 3 months earlier. Three months functioning with a new denture is tentatively considered long enough for a patient to adapt. No noticeable differences with respect to the 2 implant positions tested was seen. Although not statistical significantly different, masticatory performance worsened after provision of a new, optimally made RPD without implant support. A similar trend was seen when a new denture was made for patients with lower denture complaints, despite the fact that they considered their new denture superior to their old one.[21,22] The results underscore the findings by others who reported an increase in bite force and mastication after

implant support to an RPD was provided, be it not to the level of that of a fixed implant-borne restoration.[26,28,53,54]

After fifteen chewing strokes the implant-supported RPD on the molar position and premolar position showed MAI colour spreads of the intensities for red and blue of 18.0 ± 1.4 and 17.9 ± 1.5 respectively. These results are comparable to outcomes of healthy persons of the same age with natural dentition (18.3 ± 2.0) and are much better than healthy persons of the same age with full dentures (22.2 ± 3.4) or full dentures with mandibular implant retention (20.4 ± 2.3).[33]

The observation period in the present study is relatively short to evaluate clinical performance. No implant loss was observed and clinical and radiographical data are representative for healthy and stable implant conditions, in line with the studies that follow a group of patients over a longer period of time.[55-57] No mechanical complications were observed, nor was maintenance required during the course of present study. Conventional mandibular free-ending RPD's are often not worn by patients. The ISRPD's in the present study were worn throughout the study.

Most clinical parameters (both concerning the implants and the teeth) revealed no difference when the implants at the molar or the premolar sites were loaded. Bleeding on probing around the implants was an exception, with a less favourable score being noted around molar (M) implants. During the observation period this has not lead to deeper probing depths or more marginal bone loss, but it remains to be seen what the long term effect may be.

No strong preference for implant position can be identified on the basis of the current data. A choice would have to be made on other grounds. This could be bone volume or risk to the alveolar nerve, ease of cleaning, or the choice for a strategic position for the future if a fixed restoration is desired. On the other hand, in a similar population as the one in the present study, others started seeing late implant failures (> 3 years) predominantly in short, implants at the second molar position.[57] They also observed a fairly large number of puncture fractures in the acrylic at the area of the matrix at posterior positions, which is not very likely to occur in the present population because of the metal framework used. The matrices were fused to the framework by laser welding. Studies comparing patients' preference regarding implant position have not been published to date.

In conclusion, in patients with a bilateral free-ending situation in the mandible who perceive functional problems with their conventional RPD yet would like to continue wearing one, implant support significantly improves masticatory function. No marked difference was seen between molar and premolar implant support. No major problems in relation to the clinical function of the implants, the abutment teeth and the RPD itself were observed.

Acknowledgments

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