Purpose: To evaluate 1-year survival and success rates of 6-mm short implants placed in mandibular molar sites with two different abutments (dome/ball) retaining existing removable partial dentures (RPDs).

Materials and Methods: In 19 patients, 38 implants of 6-mm length were placed bilaterally. After 4 months, each participant received the dome abutment, which 2 months later was exchanged with the ball abutment. Clinical data were recorded at abutment connection (4 months postsurgery) and at 6 and 12 months postsurgery, including probing depth, bleeding on probing, presence of plaque, and standardized radiographs. Implant success was assessed using the following criteria: presence of pain, mobility, radiographic bone loss, probing depth, and the presence of exudate. For descriptive analyses, mean and SD values were calculated. Paired sample t tests and linear regressions with a significance level of $\alpha < .05$ were applied to analyze the evolution of peri-implant parameters and the influence of implant placement depth.

Results: The overall mean marginal bone level alteration (DMBL) was $1.05 \pm 0.69$ mm. A statistically significant marginal bone loss over time was observed at the mesial and distal aspects of all implants ($P < .05$). The implant survival rate was 100%. No implants showed pain, exudate, mobility, or probing depth $> 7$ mm. Three implants were classified as having satisfactory survival due to a DMBL $> 2$ mm (resulting success rate: 92.1%). No influence of implant placement depth was found.

Conclusion: These short-term results suggest that short implants can be used in mandibular molar sites for additional posterior support of free-end RPDs. However, in individual cases, DMBL $> 2$ mm may occur. Int J Prosthodont 2022 February 22. doi: 10.11607/ijp.7827

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The decrease of complete edentulism in industrialized countries is an exemplary indicator of the success of preventive measures in dentistry. In 1992, 73% of partially edentulous people in the USA were missing posterior teeth. The absence of molars and premolars in particular is associated with a reduction in chewing function. Although there are different treatment options, including tooth- and implant-supported fixed partial dentures (FPDs), removable partial dentures (RPD) are still commonly used, especially for the rehabilitation of multiple or extended tooth gaps. RPDs may be easier to clean and more affordable but often demonstrate less stability and retention compared to FPDs. In clasp-retained free-end RPDs (Kennedy Class I or II), the distal ends even tend to move in lateral directions, resulting in rotational movements. Moreover, patients with free-end RPDs encounter various other problems, such as occlusal disharmony and pain of the soft tissue underneath the denture base and connector owing to displacement of the RPD distal extension. Furthermore, it was stated that the vertical and horizontal alveolar bone resorption, especially in the mandible, under RPDs is increased due to the pressure over the mylohyoid ridge, which consequently leads to a change of the occlusal plane. In 25% to 50% of the cases treated with RPDs, patients require new dentures after 5 to 10 years.

To overcome these clinical challenges, it was suggested to convert a conventional free-end RPD to an implant-assisted RPD (IARPD) by placing additional implants in posterior sites. This option is expected to enhance retention, stability, and comfort and to decrease pressure on the soft tissue, reducing the atrophy of the alveolar bone. However, there is no clear evidence on which type of abutment is best suited for such situations. Soft loading protocols with nonretentive abutments seem to be advantageous over retentive abutments with regard to postoperative sensitivity, especially in the early phases after implant surgery. One option would therefore be to use a healing abutment first and adjust the prosthesis accordingly, but then an increased rate of loosening of the healing abutments must be expected. Furthermore, patients seem to prefer retentive over nonretentive abutments.

Implant placement in posterior mandibular sites, especially when the mandible is severely resorbed, can be challenging due to the resulting proximity to the alveolar nerve. Therefore, the use of short implants to avoid the technically demanding and expensive vertical bone augmentations required in such cases has become the focus of clinical research in recent years. The demand for short implants increased from 0.8% of all implants in 2005 to 8.7% in 2012. Although there are different definitions of "short implant," nowadays implants with a length ≤ 6 mm are called short. A systematic review comparing ≤ 6 mm vs longer implants for fixed restorations in partially edentulous patients showed similar implant survival rates in the two groups, but higher variability for the short implants. Systematic reviews on the performance of short implants in RPDs are not available, but high implant and prosthetic survival rates in the short term could be demonstrated. However, another systematic review showed that the majority of failures observed in implants with a length of 6 mm occurred early (76%). In another study, 71% of the failed short implants (5 to 8 mm) were early failures. These results suggest that observing clinical and radiologic parameters of short implants is relevant, especially during the first year following implant placement.

The aim of this study was to analyze the short-term survival and success rates of short implants placed in the posterior mandible in Kennedy Class I patients, transforming the the intraoral situation into Kennedy Class III. Secondary outcomes were the frequency of plaque, bleeding on probing (BOP), and probing depth (PD) at the implant sites. Furthermore, marginal bone level alterations (DMBL) at implant sites and the influence of implant depth on DMBL were analyzed. The research hypothesis associated with the aims of the study was: Short implants in mandibular molar sites for additional strategic support of free-end RPDs are a valid treatment option in atrophic alveolar ridges with regard to success and survival rates of implants after 1 year.

**MATERIALS AND METHODS**

**Study Design**
This study was designed as a prospective clinical cohort study without a control group and evaluated the clinical and radiographic outcomes of two types of abutments on short implants (6 mm) in the posterior mandible supporting mandibular IARPDs. Ethical approval was granted by the Bern Cantonal Ethics Committee (CEC; no: 223/13). This study met the standards of the Declaration of Helsinki and Good Clinical Practice (General Assembly of the World Medical Association, 2014). All participants gave their written informed consent. The study was registered in the German Clinical Trials Register (DRKS; no. DRKS00024147). The registration number was the same for the pilot and the present study.

**Materials**
All implants (SICinvent) had a length of 6 mm and a diameter of 4 or 4.5 mm and were made from grade IV titanium with an internal hexagonal implant-abutment connection. The implant neck is nonthreaded, and the first thread starts 1.5 mm below the implant platform, providing a variable intrabony implant depth of 4.5 to 6 mm. The overall implant surface, including the non-threaded neck, is zirconium oxide (ZrO₂) blasted and acid etched, resulting in a surface roughness of 1 µm.
Since the short implant has been specifically designed for use in vertically reduced bone volume, the osteotomy is completed with a reamer of the same length as the final implant length to avoid overpreparation of the implant site.

Two different abutments were used: dome and ball abutments. Dome abutments are comparable to tooth-supported copings and mainly serve as support for the prosthesis with no retentive function, allowing for initial soft loading of the implants without vertical force during removal of the IARP. The available heights were either 2.0 or 4.0 mm, measured from the implant shoulder to the gingival margin.

As retentive denture support, ball abutments with the corresponding matrices were used. The available abutment heights (transgingival portion) were either 2.0 or 4.0 mm, and the diameter of the patrices was 2.25 mm. The corresponding matrices (SICinvent) consisted of a gold-platinum alloy and were screwed onto a titanium housing (SICinvent). The retention force of the matrix could be adjusted with a screwdriver. Figure 1 demonstrates the two different applied abutment types.

**Patient Selection**

Between 2013 and 2018, partially edentulous patients with existing Kennedy Class I RPDs were recruited at the School of Dental Medicine, University of Bern. The existing RPDs were attached to natural teeth, implants, or a combination of both and replaced at least the second premolars and first molars. After evaluation of eligibility for participation, the patients were provided bilaterally with two short implants of 6-mm length in the edentulous molar sites. Eligibility was assessed based on a set of inclusion and exclusion criteria. The main inclusion criteria included good general health, minimum age of 18 years, sufficient width (at least 7 mm) and vertical bone height (at least 6 m) of the alveolar ridge, sufficient mandibular partial or hybrid denture, and stable antagonist natural/artificial dentition (at least to the first molar). The minimum vertical bone height was based on a minimum safe distance of 1.5 mm from the implant apex to the alveolar nerve, providing an intrabony implant portion of at least 4.5 mm. The exclusion criteria included the need for vertical bone augmentation and mental (eg, alcohol, drugs, dental anxiety), systemic (eg, pregnancy, diabetes mellitus, radiation, medication), and local (eg, insufficient bone quantity, poor oral hygiene) factors. A detailed overview of the eligibility criteria is given in the pilot study.23

**Admission and Preoperative Preparations**

All eligible participants signed the informed consent form prior to inclusion in the study. Subsequently, personal data were recorded, and the patients were evaluated clinically. For each patient, an orthopantomogram (OPT) and single-tooth radiographs of the remaining teeth were taken, and the anatomical situation in the desired implant sites analyzed. If the bone quantity was judged to be questionable for implant placement during clinical examination, a CBCT scan was obtained instead of OPT. An alginate impression of the mandible was then taken to fabricate a radiographic splint for standardized radiograph recording. This acrylic splint was supported...
on the remaining anterior dentition and was recessed in the area of the planned implant positions.

**Surgical Procedures**

The implant surgery was performed following the manufacturer’s specific surgical protocol. The existing dentures served as a template for determination of the implant position. After applying terminal infiltration anesthesia (Ultracain D-S Forte, 4.0 mL, Sanofi-Aventis) buccally and lingually, the mucoperiosteal flaps were elevated and the osteotomy was performed. The implants were placed in the area of the first or second molars, and the diameter (4.0 mm or 4.5 mm) was chosen according to the crest width. All implants were placed at the bone level relative to the buccal bone crest whenever possible, and cover screws were mounted, allowing for a submerged healing period of 3 months. If the vertical bone height was not sufficient to place the implant 6 mm deep while maintaining a safe distance from the alveolar nerve, the implant was placed in a position where at least all threads were covered by bone (minimum depth 4.5 mm). The same criteria applied to the mesial side of the implant, which was left in a supracrestal position of up to 1.5 mm in the case of an alveolar ridge, ascending posterior to the implant position. The denture base was relieved and relined with a soft relining material (Reline Soft, GC) in the implant region.

**Prosthetic Procedures and Follow-up**

After a healing period of 3 months, the implants were exposed during second-stage surgery, and healing abutments were mounted. After an additional month of soft tissue healing, the existing dentures were modified to perform a polyether open-tray implant impression using the existing denture as an impression tray. In the dental lab, a master cast used for all subsequent denture transformations during the study was fabricated. After indirect relining of the dentures by a dental technician, the dome abutments were screwed on all implants using a torque wrench with an insertion torque of 20 Ncm as recommended by the manufacturer, and the modified dentures were delivered. All participants were invited for clinical follow-ups at 4 and 8 weeks after abutment connection. At the 8-week follow-up (6 months after implant placement), the dome abutments were exchanged for ball abutments using the same clinical and laboratory procedures as described above. When the denture framework interfered with the additional space requirements for incorporation of the matrix and the housing, the framework was reduced by the dental technician, resulting in matrices and housings surrounded by denture resin only. The abutment height was selected according to the height of the dome abutments. Afterward, standardized radiographs were recorded. Figure 2 shows both abutment types intraorally, as well as the bottom side of the corresponding IARPDs. After wearing the second abutment for a total of 8 weeks, a further clinical follow-up was performed. All study participants were asked about their preferred abutment, and, if necessary, the dome abutments were remounted and the prostheses modified accordingly. One year after implant surgery, all participants were invited for a...
Enkling et al

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Enrollment

Participants included (n = 19)

3-month follow-up:
Second-stage surgery

Implants uncovered (n = 19)

4-month follow-up:
Abutment 1

Clinical data recorded, dome abutments mounted (n = 19)

6-month follow-up:
Abutment 2

Clinical data recorded, dome abutments mounted, standardized radiographs (n = 19)

8-month follow-up:
Final decision

Ball abutment (n = 18)
Dome abutment (n = 1)

12-month follow-up

Clinical data recorded, standardized radiographs (n = 19)

1-year analysis

Clinical/radiologic recording, standardized radiographs (n = 19/16)

Fig 3  Chronological sequence of clinical and follow-up procedures during the course of the study. The data of three participants were excluded from radiologic evaluation because the baseline radiograph was not recorded with their individual radiographic splint. This resulted in data from 19 participants in terms of clinical data and 16 participants in terms of radiologic outcomes.

Details of the Clinical Evaluation

Each implant was evaluated clinically 4, 5, 6, 7, 8, and 12 months after implant placement. The clinical examinations comprised the evaluation of biologic and/or technical complications. Furthermore, the presence of plaque, BOP, and PD at the mesial, distal, buccal, and lingual aspects were recorded at the 4, 6, and 12-month follow-ups. The width of the keratinized mucosa (KM) at the buccal and lingual aspects was recorded at the 4-month follow-up. All parameters were recorded manually by a single operator using a millimeter-scaled probe.

Standardized radiographs were obtained at implant placement and after 6 and 12 months (Fig 4). The radiographs were taken using individual radiographic splints. Two investigators not involved in the clinical procedures evaluated the radiographs independently (T.T. and A.M.). Calibration was performed by identifying the position of the first bone-to-implant contact (BIC) in 20 randomly selected radiographs together with the senior author (S.A-A.). The MBL was assessed at the mesial and distal aspects of the implants by measuring the distance between the implant shoulder and the first visible BIC along the implant axis at two different time points. If the measurements of the investigators differed more than 0.2 mm, the investigators discussed the position of the BIC and repeated their measurements independently. Based on the individual determination of MBL in the pilot study (individual MBL values n = 140), the mean interinvestigator variability was 0 ± 0.08 mm. The limit of agreement between the two investigators ranged from –0.15 to 0.16 mm. Analyses were performed using ImageJ2 software (National Institutes of Health). All individual measurements were averaged and subsequently rounded to tenths of millimeters. For calculating the MBL alterations (DMBL), follow-up MBL values were subtracted from their respective postsurgical MBL values. Although this would result in negative values for bone loss over time, positive values are used in this manuscript to describe bone loss for better readability.
Evaluation of Implant Success, Survival, and Failure

An implant that was no longer present at one of the follow-up appointments was considered a loss. Accordingly, all implants present, regardless of their condition, were considered surviving. Implant success was assessed with the criteria defined by the International Congress of Oral Implantologists (ICOI), considering the presence of pain, exudate, and mobility, as well as PD and MBL changes. Implants that showed no pain, no mobility, no radiographic bone loss ≥ 2 mm, and no exudate history were considered successful. If the radiographic bone loss was between 2 and 3 mm, but the other criteria were unchanged, the implants were considered as satisfactory survival. Implants showing sensitivity on function, radiographic bone loss > 3 mm, PD > 7 mm, or exudate history were considered as compromised survival.

Statistical Analysis

The sample size calculation based on implant success (primary outcome) assuming a 1-year success rate of 90% using short implants and margin of error set at 19% resulted in 38 implants (estimation of probabilities by BiAS for Windows 11.10 [epsilon-Verlag], two-sided 95% CI). For descriptive analyses, mean and SD values were calculated. Furthermore, the relative frequency of BOP and plaque-positive implant sites were calculated. The evolution of MBL and the clinical parameters (BOP, plaque-positive implant sites, and PD) were evaluated with a paired samples t test. Furthermore, the influence of the implant placement depth was analyzed using linear regression and adjusted for the MBL at baseline. The α was P < .05 for all analyses.

RESULTS

Study Sample

A total of 19 participants (12 men [63%] and 7 women [47%]) with 38 implants placed bilaterally in the mandibular region of the first molars was included. The sample size was based on a previous study with a similar design, including 35 implants in 20 patients. Six of the patients included in the present analyses were part of the pilot study conducted for stratification of the abutment sequence. In the pilot study, 6 patients received the dome abutments first, followed by the ball abutments, and in 6 participants, the abutment sequence was the other way around. Consequently, only the data of the 6 participants with the dome-ball abutment sequence was included here to report on a uniform study sample (n = 19) with this specific abutment sequence. The implant diameters were either 4.0 mm (n = 29) or 4.5 mm (n = 9). The abutment height was either 2 mm (n = 11) or 4 mm (n = 27). At the time of surgery (baseline), the age of the patients ranged from 53 to 80 years (median: 68). The included subjects had been wearing an RPD for a period ranging from 9 months to 49 years, with a median of 72 months (interquartile range [IQR]: 32 to 160). Six patients reported a smoking habit, with pack years ranging from 13 to 25. Bone augmentation procedures were not performed in any of the participants.

Implant Survival and Success

No implants were lost during the 1-year follow-up period. Hence, the implant survival rate during the first year was 100%. No implants showed any signs of pain, mobility, or exudate. However, three implants in three subjects demonstrated a DMBL of > 2 mm at the mesial and/or distal aspect, resulting in an implant success rate of 92.1%. In one participant, the DMBL was 2.4 mm at the mesial aspect of the left implant. Another participant demonstrated a DMBL of 2.1 mm at each aspect of the right implant. In another participant, the DMBL was 2.7

Fig 4 Standardized radiographs at (a) implant placement, (b) the 6-month follow-up (before changing the abutment), and (c) the 12-month follow-up using the radiologic splint for standardized radiograph recording. The mesial implant position was supracrestal due to the ascending posterior alveolar ridge.
mm at the mesial and 3 mm at the distal aspect of the left implant. Based on the success criteria established by the ICOI, those three implants were rated as satisfactory survivals.

### Radiologic Outcomes

For analysis of the radiologic outcomes, only the data of 16 out of the 19 participants were included. Baseline radiographs of 3 participants were not recorded using the individual radiographic splints; therefore, the baseline MBL data of those participants were not considered reliable enough to calculate DMBL. However, in those 3 participants, the bone loss did not appear to be even close to the 2-mm limit that would have moved the implants from the success category to the satisfactory survival category. After 1 year, the overall DMBL across all implants was 1.05 ± 0.69 mm. Table 1 reports the mean MBL and DMBL separately for both implant sites at the mesial and distal implant aspects at implant placement and the 6- and 12-month follow-ups, as well as for the respective intervals. Statistically significant DMBL was found in most implant sites at every time interval, indicating continuous bone level alterations over time. The change was not significant only at the distal aspect of the implants in the left molar site between 6 and 12 months (0.23 ± 0.43 mm; \( P = .55 \)). Generally, the DMBL was higher in the initial 6 months. No influence of the placement depth on DMBL could be observed at any of the evaluated implant sites (Table 2).

### Clinical Outcomes

KM was present in both implant sites at the buccal as well as the lingual aspects. The mean width of the KM around the implants was 2.9 ± 1.6 mm and 3.2 ± 1.6 mm at the left and right implant sites, respectively. An overview of the presence of plaque and BOP-positive sites is given in Table 3. At the right implant site, the presence of plaque increased significantly between 4 and

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**Table 1** Marginal Bone Level\(^a\) (mm) at the Mesial and Distal Implant Aspects

<table>
<thead>
<tr>
<th>Implant site</th>
<th>Follow-up, mo</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum to maximum</th>
<th>( \Delta \text{MBL (95% CI)} )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left mesial</td>
<td>BL</td>
<td>0.19</td>
<td>0.71</td>
<td>–0.69 to 1.55</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>6</td>
<td>1.13</td>
<td>0.78</td>
<td>–0.20 to 2.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>1.32</td>
<td>0.89</td>
<td>–0.16 to 3.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>6 vs BL</td>
<td>0.94</td>
<td>0.65</td>
<td>0.22 to 2.61</td>
<td>0.94 (0.60 to 1.29)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs BL</td>
<td>1.12</td>
<td>0.67</td>
<td>0.40 to 2.72</td>
<td>1.12 (0.77 to 1.48)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs 6</td>
<td>0.18</td>
<td>0.20</td>
<td>–0.01 to 0.76</td>
<td>0.18 (0.08 to 0.29)</td>
<td>.002</td>
</tr>
<tr>
<td>Right mesial</td>
<td>BL</td>
<td>–0.03</td>
<td>0.80</td>
<td>–1.33 to 1.58</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>6</td>
<td>0.89</td>
<td>1.04</td>
<td>–1.06 to 2.62</td>
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<tr>
<td></td>
<td>12</td>
<td>0.98</td>
<td>1.05</td>
<td>–1.02 to 2.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>6 vs BL</td>
<td>0.92</td>
<td>0.67</td>
<td>–0.09 to 1.85</td>
<td>0.92 (0.56 to 1.27)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs BL</td>
<td>1.01</td>
<td>0.70</td>
<td>–0.10 to 2.12</td>
<td>1.01 (0.63 to 1.38)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs 6</td>
<td>0.09</td>
<td>0.12</td>
<td>–0.05 to 0.38</td>
<td>0.09 (0.02 to 0.16)</td>
<td>.011</td>
</tr>
<tr>
<td>Left distal</td>
<td>BL</td>
<td>–0.15</td>
<td>0.75</td>
<td>–1.35 to 1.17</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>6</td>
<td>0.66</td>
<td>0.66</td>
<td>–0.41 to 2.05</td>
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<td></td>
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<tr>
<td></td>
<td>12</td>
<td>0.89</td>
<td>0.72</td>
<td>–0.33 to 2.36</td>
<td></td>
<td></td>
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<tr>
<td>Difference</td>
<td>6 vs BL</td>
<td>0.81</td>
<td>0.62</td>
<td>0.09 to 2.22</td>
<td>0.81 (0.48 to 1.14)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs BL</td>
<td>1.03</td>
<td>0.75</td>
<td>–0.33 to 3.05</td>
<td>1.03 (0.63 to 1.43)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs 6</td>
<td>0.23</td>
<td>0.43</td>
<td>–0.90 to 1.00</td>
<td>0.23 (–0.01 to 0.46)</td>
<td>.055</td>
</tr>
<tr>
<td>Right distal</td>
<td>BL</td>
<td>–0.23</td>
<td>0.67</td>
<td>–1.21 to 1.22</td>
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<td></td>
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<tr>
<td></td>
<td>6</td>
<td>0.62</td>
<td>0.70</td>
<td>–0.45 to 1.81</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>12</td>
<td>0.74</td>
<td>0.74</td>
<td>–0.12 to 2.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>6 vs BL</td>
<td>0.85</td>
<td>0.51</td>
<td>0.16 to 1.77</td>
<td>0.85 (0.58 to 1.12)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs BL</td>
<td>0.97</td>
<td>0.57</td>
<td>0.17 to 2.05</td>
<td>0.97 (0.66 to 1.27)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>12 vs 6</td>
<td>0.12</td>
<td>0.11</td>
<td>–0.03 to 0.33</td>
<td>0.12 (0.06 to 0.17)</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

\( \text{BL} = \text{baseline.} \)

\(^a\)Negative values indicate subcrestal implant positions.

\(^b\)\( P \) values from paired sample \( t \) tests (\( n = 16 \) participants).
6 months \((P = .034)\) and decreased afterward \((P = .025)\). At the right implant site, the number of BOP-positive sites decreased significantly between 6 and 12 months \((P = .046)\). No statistically significant changes in the presence of plaque or BOP-positive sites at the left implant were observed. Mean PD ranged from 2.21 ± 1.05 mm (left implant site at 6 months) to 2.79 ± 1.31 mm (right implant site at 6 months). No significant changes of PD at any of the two implant sites over time were observed. No major biologic complications occurred during the 1-year follow-up. However, three matrices had to be repolymerized to the dentures due to loosening, and another three dentures had to be relined due to occlusal misfit after the initial relining impression. One participant chose the dome abutment as a final option, and the denture was modified accordingly. All other participants stayed with the ball abutments (Fig 5).

### DISCUSSION

Based on the 1-year data of the present study, demonstrating 100% implant survival and 92.1% implant success, a short implant may be recommended as a strategic implant, confirming the research hypothesis. No patient reported pain on function, and no mobility of implants could be detected in any patient during the 12-month observation period. Comparing the current results to other studies on short implants, similar success and survival rates have been reported. Studies have reported that short implants may have similar outcomes compared to longer implants. Fewer surgical complications were reported when using short implants instead of standard implants with bone augmentation, and no difference was found in survival rates. Hence, it may be stated that the use of 6-mm short implants is...
a viable alternative to longer implants, especially when bone augmentation procedures can be avoided.\textsuperscript{18,29}

In the present study, plaque was more frequently present in both implant sites after 6 months than after 4 months, although a statistically significant difference could only be demonstrated for the right implant site. A possible explanation for the higher values after 6 months may be the loose fit of the IARPD supported by the nonretentive dome abutment. This would also explain the fact that the highest number of BOP-positive implants was found at the 6-month follow-up, since the presence of plaque leads to peri-implant mucosa inflammation over time.\textsuperscript{30} Furthermore, improvements in peri-implant mucosa health over time have been described in the literature.\textsuperscript{31}

It could be shown that the presence of KM with a width of $\geq 2$ mm is positively associated with peri-implant health.\textsuperscript{32} Biologic complications, such as higher plaque accumulation, gingival inflammation, mucosal recession, and loss of attachment, were correlated with a reduced amount of KM around implants.\textsuperscript{24,33}

Considering those results, a certain width of the KM seems important to maintain healthy and stable peri-implant conditions.\textsuperscript{34} In the present study, KM was present at the buccal and lingual aspects of all implants. The mean thickness was $>2$ mm in both implant sites, which might have contributed to the stability of the peri-implant mucosa. Although there were maximum PD values of 6 mm in single-implant sites, no significant changes of the mean PD over time could be shown, confirming the stable peri-implant mucosal conditions. Measuring the PD longitudinally helps to monitor the implant and its peri-implant tissue health over time. Studies have shown that PD greater than 5 to 6 mm around implants has a higher incidence of anaerobic bacterial colonization and is more likely to cause infection of the implant.\textsuperscript{35}

A commonly used parameter for the assessment of implant success is the amount of MBL around implants.\textsuperscript{24,36} Monitoring the MBL might be even more crucial around short implants than standard-length implants.\textsuperscript{37} It has been observed that the DMBL is higher in the first year after implant placement than in subsequent years.\textsuperscript{38} Similar to the results of the present study, other studies have observed pronounced DMBL, especially in the first period after implant placement when the implants are not loaded.\textsuperscript{39,40} Factors influencing bone remodeling are surgical trauma, poor bone quality, prosthodontic procedures, implant neck design, patient habits, general health of the patients,
the presence of a microgap at the implant-abutment connection, and the implant surface itself.⁴¹,⁴²,⁴³–⁴⁴ Thus, as long as the initial marginal bone resorption does not exceed predefined thresholds (e.g., 2 mm within the first year), it should not be interpreted as a pathologic process.⁴¹ In the current study, the overall mean MBL was 1.05 ± 0.69 mm. As described above, this pronounced change during the first year was to be expected and was also confirmed by other studies on short and standard-length implants.⁴⁹,⁵⁰,⁵¹ Interestingly, the same MBL during the first year, around implants with a diameter of 4 mm and a length of 6 mm in the posterior mandible, has been described in another study on short implants.⁴⁹ Afterward, the DMBL remained constant. Looking at the results of the present study in more detail, this could also apply here, as bone resorption noticeably decelerated in the second half of the year.

In the current study, no influence of implant depth on DMBL could be observed when comparing supra- and subcrestal implant placement. This finding follows the results described in the literature.⁴⁶ Nevertheless, this result is remarkable because the existing literature consists of data from implants with a length > 6 mm. If this result can be confirmed in the longer term, the implant used in the present study could also be suitable for use in alveolar ridges that are severely reduced vertically. However, to confirm this hypothesis, long-term observations are mandatory. Despite the variable placement depth, the applied soft loading protocol and the frequent exchange of the abutments may have further affected the DMBL. A similar soft-loading approach with soft denture relining and subsequent implant loading is described for overdentures with one-piece implants demonstrating small DMBL.⁴⁷ The soft loading and consequently decreased stress on the implant at an early stage could be a factor that positively influences peri-implant bone stability. However, the effect of stress on peri-implant bone stability is still unclear.⁴⁸ The frequent abutment changes have been demonstrated as a factor negatively influencing peri-implant bone stability. Therefore, the results of the present study should be interpreted accordingly under the aspect that the abutments were exchanged several times.⁴⁹

The present findings should be interpreted with caution due to the limitations of the study, such as the low number of participants and the short follow-up time of 12 months. In particular, the lack of radiographic evaluation of three patients is a major limitation. However, it should not be forgotten that the radiographs without the radiographic splints and the other parameters of these patients were collected. Longer follow-ups are necessary to assess the long-term survival and success of the short implants. IARPD fractures may occur more frequently in the future due to the increased space requirements to integrate the matrix into an existing prosthesis, especially when the denture frameworks need to be reduced. Maybe the use of CAD/CAM denture bases can prevent fractures due to their improved mechanical properties.⁵⁰ There was no control group with longer implants to compare implants in terms of clinical and radiologic outcomes. It should also be noted that only mandibular RPD wearers were included in the present study. Therefore, the results cannot be directly transferred to the maxilla, since short implants show a higher annual bone loss in the maxilla than in the mandible.⁵¹

CONCLUSION

Based on the high implant success and survival rates, placing 6-mm short implants in the posterior mandible to support an existing bilateral free-end RPD can be recommended. Stable conditions of the peri-implant mucosa could be demonstrated. However, this conclusion is based on a 1-year follow-up only. In individual cases, DMBL exceeding 2 mm must be expected during the first year. The equal DMBL in sub- and supracrestally placed implants suggests that the specific implant can be used with an intrabony length of only 4.5 mm. Longer follow-up times are necessary to fully evaluate this treatment concept, especially with regard to the stability of marginal bone.

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REFERENCES

Enkling et al