Restoring a single tooth or several missing teeth using implant-supported restorations is a well-documented treatment option with high predictability and survival rates. Implant-supported restorations are the preferred treatment option for patients and restorative dentists compared to other options, such as removable partial restorations or fixed partial restorations (FPRs) supported by adjacent teeth. The more esthetic appearance and convenient function of fixed implant-supported restorations are important factors when considering patient preference. The survival rates of a single implant supporting a single crown or splinted implants supporting an FPR are more than 95% to 97% and 92% to 94%, respectively, after 5- and 10-year follow-ups.

The increased need for dental implants and implant-supported restorations in the United States has been reported. In a survey conducted by the European Association for Osseointegration (EAO) in 2019, 69% of European specialists agreed that there will be an increase in demand for dental implant treatments in the future.

The purpose of this study was to compare marginal bone loss (MBL) and clinical complications between surviving implants (SIs) and recently placed implants (RIs) splinted together to support a fixed partial restoration (FPR). This retrospective study employed the medical records of patients treated with implant-supported FPRs in the Maccabi-Dent Dental Clinic. Patients were included if they were over the age of 18 years, were treated with RIs adjacent to existing SIs that had previously supported FPRs for more than 1 year, and the RIs and SIs were splinted to support new FPRs. Patients who did not receive annual follow-up or whose records had nondiagnostic radiographs or lacked sufficient restorative data were excluded. MBL was assessed at the last available radiograph and compared to one taken 1 year after loading the splinted RIs and SIs together. Clinical complication data were gathered from patient records.

The medical records of 1,907 patients treated with a total of 7,306 implants were examined. Data from 187 implants were extracted from 46 patient records that met the inclusion criteria, with 96 RIs and 91 SIs supporting 56 FPRs. Mean follow-up was 39 ± 17.5 months. During the follow-up, two implants failed. The overall survival rate was 98.94% (98.96% in RIs and 98.91% in SIs), and the mean MBL in all implants was 0.41 ± 0.58 mm (0.4 ± 0.53 mm in RIs and 0.42 ± 0.45 mm in SIs). Peri-implantitis was reported in eight (4.3%) implants (four RIs and four SIs), screw loosening was reported in nine (4.8%) implants (three RIs and six SIs), ceramic chipping was reported in three (5.3%) restorations supported by four RIs and six SIs, and decementation was reported in one (1.8%) restoration supported by one RI and one SI. There was no statistically significant difference in survival rate, MBL, peri-implantitis, or screw loosening between RIs and SIs.

Splinting RIs and SIs for new prosthetic restoration support is a reasonable treatment choice with a high implant survival rate, low incidence of complications, and acceptable MBL.

**Keywords:** implant complications, implant survival, marginal bone loss, old implants, splinted implant
cases where SIs are in the vicinity of or between RIs, the options available to the restorative dentist are restoring the RIs separately or splinting the implants.15

SIs are implants that were performed as part of previous treatment the patient received to restore failed teeth. They were loaded with a fixed implant-supported restoration. RIs are implant placements that were performed at a later point in the patient due to the failure of additional teeth adjacent to the previously placed and loaded SIs. As the SI and RI placements were performed by different specialists at different times, the brand of the SIs could be different from the RIs.

Studies have compared marginal bone loss (MBL), prosthetic complications, and implant survival in splinted and unsplinted implant-supported restorations. Vigolo et al16 demonstrated a statistically significant difference of 0.1 mm in MBL after 5- and 10-year follow-ups in favor of splinted implants. Some studies reported no statistically significant difference in MBL between splinted and unsplinted implants.17–22 However, they did report a statistically significant increase in implant failure in unsplinted implants.17,19,22 Other studies reported an increase in prosthetic complications in unsplinted implants, including screw loosening, restoration chipping, restoration fracture, and decementation.16,18–21,23 Currently, the decision to splint implants is a clinical decision influenced by parameters such as oral hygiene, occlusion, implant length, and the passive fit of the restoration framework.16,18,21

Long-term complications of fixed implant-supported restorations, such as ceramic chipping and framework fracture, as well as the positioning of RIs adjacent to SIs, may lead to replacement of the restoration.17,19,23,10,24 Restoring SIs is challenging and requires careful assessment of the implants and the supporting bone. SIs should meet the criteria defining their successful or satisfactory survival status, demonstrating no clinical signs of pain, mobility, exudates, or MBL of 2 to 4 mm.25

The aim of the present study was to compare MBL and clinical complications between splinted SIs and RIs. The null hypothesis was that there will be no difference in MBL or clinical complications between SIs and RIs.

MATERIALS AND METHODS

This retrospective study examined computerized medical records of patients treated with implant-supported fixed prosthetic restorations at Maccabi-Dent Dental Clinic, Assuta Medical Center, Tel-Aviv, between 2015 and 2018. The research was approved by the Tel Aviv University Ethics Committee and Assuta Medical Center Helsinki Committee (0083-19-ASMC).

Patients were included if they were over the age of 18 years and treated with one or more RIs splinted to one or more adjacent SIs to support a new FPR. The SIs also needed to have previously supported an FPR for at least 1 year prior to the placement of the RIs, meet the criteria defining them as successful or satisfactory survival status,25 and be deemed restorable by specialists in periodontology and prosthodontics, while the RIs had to have been performed by specialists in periodontology. The patients completed their treatment plan that included a new prosthetic FPR supported by the SI and RI implants. The medical records presented annual follow-up visits, annual hygienist treatments, legible radiographs, and sufficiently recorded data regarding implant type, length, width, date of implant placement, and type of prosthesis. Medical records were excluded when there were incomplete surgical or restorative data, nondiagnostic radiographs, no record of annual follow-up visits or annual hygienist therapy, or when the records presented systemic conditions known to affect bone metabolism, such as unbalanced diabetes mellitus, neoplasm, radiation therapy, or chemotherapy.

The gathered data included patient sex and age; implant number, position, type, length, width, date of placement, and date of loading; abutment and prosthesis type; restoration retention type (cemented or screw-retained); type of opposing dentition; patient systemic condition and medications; bruxism; documentation of clinical complications; and radiographs.

The first year after implant loading is characterized by higher bone loss than the following years.26,27 To prevent bias, MBL was measured by comparing the latest available periapical radiograph of the implants to the one performed 1 year after implant loading, assessing modifications of the distance from a radiographic landmark (the implant-abutment connection) to the coronal point of marginal bone in contact with the implant. Evaluation of the mesial and distal surfaces was performed. Changes were calculated according to the known distance between the implant-abutment connection and the first thread of the implants, as specified by implant manufacturers (Fig 1). The radiographic assessment was performed using an image processing program (ImageJ, National Institutes of Health).28 When bone loss of > 1 mm was identified, the radiograph was evaluated again by a different researcher. Data were gathered using Microsoft Excel 2016 (version 16.0, Microsoft Corporation).

Statistical Analysis

Study variables were summarized for analytical purposes. A mixed-model analysis was used. The dependent variables were the mean mesial, distal, and total bone loss measurements, as well as the clinical complications of implant loss, peri-implantitis, screw loosening, restoration fracture, and decementation. Chi-square test was performed for the categorical dependent variables, and
A t test was performed for the quantitative variables. Two-way analysis of variance (ANOVA) was performed to test extraneous variables that were not evenly distributed among the SI and RI groups. Statistical significance was inferred at the nominal level of Type I error of α = .05. All analyses were performed using the statistical software SPSS Statistics 27 (IBM).

RESULTS

The medical records of 1,907 patients treated with a total of 7,306 implants between 2015 and 2018 were assessed, and the records of 97 patients with 414 implants reported splinting SIs to RIs. Of these, 27 records with 104 implants had insufficient follow-up radiographs, 16 records with 75 implants lacked sufficient prosthetic data and follow-up time, and 8 records with 48 implants had patient systemic medical conditions that fit the exclusion criteria, and so were not included. The medical records of the remaining 46 patients (25 men, 21 women, mean age 60.11 ± 9.76 years) with 187 implants met the inclusion criteria, including 96 RIs splinted to 91 SIs. The implants supported 56 porcelain-fused-to-metal (PFM) FPRs. The mean follow-up was 39.2 ± 17.5 months. Follow-up was initiated 12 months after the SIs and RIs were splinted and loaded. No sinus augmentation or bone augmentation procedures were performed prior to or during RI positioning. No immediate loading of the RIs and SIs with a provisional prosthesis was performed.

Implant types included in the study were MIS Lance Plus, MIS Seven (MIS Implants Technologies), Alpha Bio Spiral, Alpha Bio Dual Fit (Alpha Bio Tec), NobelReplace (Nobel BioCare), Straumann Standard Plus (Straumann), Zimmer Biomet Spline, Zimmer Biomet Tapered Screw Vent (Zimmer Biomet), and AB Dental One Piece (AB Dental) (Table 1).

During the follow-up time, two implants—one in the RI group and one in the SI group—were lost due to peri-implantitis and loss of stability. Both implants were in the same patient, supporting the same prosthetic restoration. The overall implant survival rate was 98.94% (RI = 98.96% and SI = 98.91%). No statistically significant difference was found in implant loss between SIs and RIs.

The mean MBL in all implants was 0.41 ± 0.58 mm. The mean MBL in the SI group and the RI group was 0.42 ± 0.56 mm and 0.4 ± 0.53 mm, respectively. No statistically significant difference was found in mean MBL between SIs and RIs. The mean MBL in distal MBL between SIs and RIs, 0.41 ± 0.56 mm and 0.4 ± 0.53 mm, respectively. No statistically significant difference was found in mean mesial MBL between SIs and RIs, 0.41 ± 0.56 mm and 0.4 ± 0.53 mm, respectively (Table 2).

### Table 1 Distribution of Implant Type in the SI and RI Groups

<table>
<thead>
<tr>
<th>Implant type</th>
<th>SI group</th>
<th>RI group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIS Lance Plus</td>
<td>19 (20.8)</td>
<td>88 (91.6)</td>
<td>107 (57.3)</td>
</tr>
<tr>
<td>MIS Seven</td>
<td>7 (7.6)</td>
<td>3 (3.1)</td>
<td>10 (5.3)</td>
</tr>
<tr>
<td>Alpha Bio Spiral Implant</td>
<td>29 (31.8)</td>
<td>4 (4.1)</td>
<td>33 (17.6)</td>
</tr>
<tr>
<td>Alpha Bio Dual Fit Implant</td>
<td>18 (20)</td>
<td>1 (1.2)</td>
<td>19 (10.2)</td>
</tr>
<tr>
<td>NobelReplace</td>
<td>8 (8.8)</td>
<td>0 (0)</td>
<td>8 (4.2)</td>
</tr>
<tr>
<td>Straumann Standard Plus</td>
<td>2 (2.2)</td>
<td>0 (0)</td>
<td>2 (1.1)</td>
</tr>
<tr>
<td>Zimmer Biomet Spline</td>
<td>2 (2.2)</td>
<td>0 (0)</td>
<td>2 (1.1)</td>
</tr>
<tr>
<td>Zimmer Biomet Tapered Screw Vent</td>
<td>4 (4.4)</td>
<td>0 (0)</td>
<td>4 (2.1)</td>
</tr>
<tr>
<td>AB Dental One Piece</td>
<td>2 (2.2)</td>
<td>0 (0)</td>
<td>2 (1.1)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>91 (100)</td>
<td>96 (100)</td>
<td>187 (100)</td>
</tr>
</tbody>
</table>

Data reported as n (%).
The RI-SI splint ratio amounted to 46 RIs splinted to 29 single SIs with mean MBL of 0.3 ± 0.21 mm and 0.34 ± 0.37 mm, respectively, and 49 RIs splinted to 61 multiple SIs, with mean MBL of 0.48 ± 0.52 mm and 0.46 ± 0.64 mm, respectively. There was no statistical difference in mean MBL between RIs and SIs, whether the RIs were splinted to a single SI or multiple SIs.

Peri-implantitis was reported in 8 (4.3%) implants, 4 (4.16%) RIs and 4 (4.4%) SIs. Screw loosening was reported in 9 (4.8%) implants, 3 (3.1%) RIs and 6 (6.5%) SIs. Prosthetic restoration ceramic chipping was reported in 3 (5.3%) restorations supported by 4 RIs and 6 SIs for a total of 10 (5.3%) of the 187 splinted implants. Decementation was reported in 1 (1.8%) prosthetic restoration supported by 1 (1.04%) RI and 1 (1.09%) SI, which was a total of 2 (1.07%) of the 187 splinted implants (Table 3). No statistically significant difference was found between RIs and SIs in peri-implantitis or screw loosening.

There was no statistically significant difference between the SI group and the RI group in age, gender, implant length, implant width, maxillary vs mandibular placement, straight vs angled vs T-base abutment, cemented vs screw-retained restoration, natural vs artificial opposing dentition, or tooth- vs implant-supported PFM; prevalence of bruxism was similar in both groups. There was no statistically significant difference in follow-up between the SI and RI groups.

There was a statistically significant difference between the SI and RI groups in the posterior and anterior implant positions ($P = .041$), where more RIs were positioned in the canine and incisor positions than SIs. After inclusion of the anterior/posterior position in a two-way ANOVA model, no statistically significant difference was found in average MBL for SIs and RIs in the anterior position. The MBL in the anterior position for SIs and RIs was 0.57 ± 0.31 mm and 0.55 ± 0.37 mm, respectively. MBL in the posterior position was 0.46 ± 0.1 mm and 0.49 ± 0.12 mm.

The type of implant showed a statistically significant difference between the SI and RI groups in the posterior and anterior implant positions ($P = .041$), where more RIs were positioned in the canine and incisor positions than SIs. After inclusion of the anterior/posterior position in a two-way ANOVA model, no statistically significant difference was found in average MBL for SIs and RIs in the anterior position. The MBL in the anterior position for SIs and RIs was 0.57 ± 0.31 mm and 0.55 ± 0.37 mm, respectively. MBL in the posterior position was 0.46 ± 0.1 mm and 0.49 ± 0.12 mm.

The tissue type of implant showed a statistically significant difference between the SI and RI groups. There were more MIS Lance Plus implants in the RI group than in the SI group ($P < .01$). After inclusion of implant type in a two-way ANOVA model, no statistically significant difference was found in MBL comparing either MIS Lance Plus implants in the SI and RI groups or the other implants in the SI and RI groups. The MBL for MIS Lance Plus implants in the SI and RI groups was 0.49 ± 0.65 mm and 0.44 ± 0.57 mm, respectively. The MBL in the other implant group in the SI and RI groups was 0.43 ± 0.58 mm and 0.56 ± 0.6 mm, respectively.

There was no statistically significant difference when comparing the average MBL in SIs and RIs in every patient, and the mean MBL was 0.39 ± 0.34 mm and 0.36 ± 0.33 mm, respectively.

### Table 2: Mean (SD) Marginal Bone Loss for the SI and RI Groups

<table>
<thead>
<tr>
<th>Marginal bone loss (mm)</th>
<th>SI group</th>
<th>RI group</th>
<th>All implants</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.42 (0.45)</td>
<td>0.4 (0.53)</td>
<td>0.41 (0.49)</td>
<td>.75</td>
</tr>
<tr>
<td>Mesial</td>
<td>0.41 (0.56)</td>
<td>0.35 (0.59)</td>
<td>0.38 (0.58)</td>
<td>.47</td>
</tr>
<tr>
<td>Distal</td>
<td>0.44 (0.59)</td>
<td>0.46 (0.57)</td>
<td>0.45 (0.58)</td>
<td>.86</td>
</tr>
</tbody>
</table>

### Table 3: Implant- and Restoration-Level Complications in the SI and RI Groups

<table>
<thead>
<tr>
<th>Complications (implant level)</th>
<th>SI group</th>
<th>RI group</th>
<th>Total</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of implants</td>
<td>91 (100)</td>
<td>96 (100)</td>
<td>187 (100)</td>
<td></td>
</tr>
<tr>
<td>Implant loss</td>
<td>1 (1.1)</td>
<td>1 (1.04)</td>
<td>2 (1.06)</td>
<td>1.0</td>
</tr>
<tr>
<td>Peri-implantitis</td>
<td>4 (4.4)</td>
<td>4 (4.16)</td>
<td>8 (4.3)</td>
<td>1.0</td>
</tr>
<tr>
<td>Screw loosening</td>
<td>6 (6.5)</td>
<td>3 (3.1)</td>
<td>9 (4.8)</td>
<td>.32</td>
</tr>
<tr>
<td>Ceramic chipping</td>
<td>6 (6.5)</td>
<td>4 (4.16)</td>
<td>10 (5.3)</td>
<td>.52</td>
</tr>
<tr>
<td>Decementation</td>
<td>1 (1.09)</td>
<td>1 (1.04)</td>
<td>2 (1.07)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Complications (restoration level)</th>
<th>SI group</th>
<th>RI group</th>
<th>Total</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of restorations</td>
<td>56 (100)</td>
<td>1 (1.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restoration loss</td>
<td>1 (1.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramic chipping</td>
<td>3 (5.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decementation</td>
<td>1 (1.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are reported as n (%) unless otherwise noted.

The experience of the clinicians at the time of RI positioning was defined by the number of years that passed from the date they received their periodontology specialist certificate (information gathered from their employee file in Maccabi-Dent). The mean clinician experience was 11.89 ± 2.81 years. The implants were divided into three groups depending on the years of experience of the clinician: < 10, 10 to 13, and > 13. There was no statistically significant difference in mean MBL and complications with RIs compared to SIs in any of the groups or between the groups.

### DISCUSSION

The present study compared SIs and RIs during the time they were splinted and loaded, not the overall time SIs and RIs were performing separately in the oral cavity. Previous studies reported higher MBL the first year after loading newly placed implants compared to subsequent years, with 1 to 2 mm and 0.2 mm, respectively.25–27 This may be the result of bone remodeling during the first year.29 After the first year, the yearly rate of bone loss stabilizes and is comparable between

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different implant types. To prevent bias in MBL at the detriment of the RIs, follow-up was initiated 1 year after RI loading.

The mean MBL in all the splinted implants in this study was 0.41 ± 0.58 mm. Studies of newly placed splinted implants with comparable follow-up presented similar values of MBL. Eliasson et al reported MBL in splinted implants supporting fixed prosthetic restorations with mean MBL 1 year and 5 years after loading of 3.11 ± 0.57 mm and 3.53 ± 0.92 mm, respectively. The mean MBL was 0.42 mm during 4 years of follow-up. Yi et al reported MBL of 0.50 ± 0.77 mm after 3 years of loading in three splinted implants supporting FPR. Vigolo and Zaccaria compared MBL in splinted and unsplinted implants. They reported that MBL between the fifth and tenth years after splinted implants were loaded was 0.5 mm. Although there is a similarity in the results, splinted implants were inserted at the same time in previous studies. In the present study, new implants were splinted to existing implants that were already loaded for more than 1 year.

There was no statistically significant difference between SIs and RIs in implant survival, peri-implantitis, or screw loosening. Hsu et al compared the performance of CAD/CAM titanium abutments supporting splinted and single crowns and reported three implant failures and a 99% survival rate in splinted implants after 4 years of loading. De Santis et al reported a 98.7% survival rate in splinted implants supporting fixed prosthetic restorations after 4 years of loading, with two implant failures in the first year. In their study, guided bone augmentation was performed in all cases. Arvidson et al also reported a 98.7% implant survival rate in splinted implants supporting fixed prosthetic restorations after 4 years of loading. Two implant failures occurred after 3 and 6 months of loading, and another failure occurred after 4 years. Eliasson et al reported a 99.4% survival rate in splinted implants supporting fixed prosthetic restorations after 4 years of loading. The total implant survival rate in the present study was 98.94% after a minimum of 1 year of loading.

In the present study, implants were considered affected by peri-implantitis when there was documentation of a diagnosis by the periodontist performing the RI during the follow-up period. The prevalence of peri-implantitis at the implant level in this study was 4.3%. Previous studies with similar follow-up reported the prevalence of peri-implantitis in splinted implants to be between 3.2% and 6%. Ceramic chipping complications at the restoration level in this study were 5.3% and corresponded with previous reports on ceramic chipping complications of 5% to 7.6% in splinted implants with similar follow-up times. At the implant level, ceramic chipping occurred in 5.3% of the implants. Hsu et al reported ceramic chipping in 7% of splinted implants. Their results correlate with the results of the present study. In the present study, decementation occurred in one (1.8%) restoration, corresponding to previous reports of 1.5% to 3%.

In the present study, screw loosening complications occurred in 4.8% of the total splinted implants. Previous studies compared screw loosening complications in splinted and unsplinted implants with similar follow-up times and reported that screw loosening did not occur in splinted implants. Nevertheless, a systematic review by Pjetursson et al reported that the cumulative screw loosening complication rate at the 5-year follow-up in implant-supported fixed dental prostheses was 5.6% (3.7% to 8.3%) compared to 12.7% (5.7% to 27%) in implant-supported single crowns.

The results demonstrate that MBL and the prevalence of complications in SIs splinted to RIs are in accordance with those reported in the literature on newly placed splinted implants.

A few limitations were noted in this study. The small sample size was 46 patients with 187 implants, which excluded 43 patients with a total of 179 implants due to not appearing for regular follow-up appointments or lacking sufficient radiographs for MBL measurement. This exclusion might influence the results. There was a lack of homogeneity in implant type in the SI and RI groups. Although this topic was addressed, implant type had no statistically significant effect on MBL or complications in SIs and RIs.

CONCLUSIONS

There was no difference in MBL or complications between recently placed implants and previous surviving implants. Splinting recently inserted implants with previously performed implants for new FPR support is a reasonable treatment choice with a high implant survival rate, low incidence of complications, and acceptable MBL.

ACKNOWLEDGMENTS

The authors wish to thank Maccabi-Dent management—Dr Yaron Bernstein, Mr Doron Tomer, and Professor Jonathan Mann—for their support and assistance in advancing the research. Special thanks to Mr Eli Vizel, Administrative Manager of Maccabi-Dent Assuta, for providing the necessary facilities and assistance in data gathering for this project. The authors reported no conflicts of interest related to this study.
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