Purpose: To evaluate marginal bone level changes over 3 years around platform-shifting implants with internal conical connections, and to identify the factors relating to bone level changes. Materials and Methods: Systemically healthy patients who lost one tooth or two consecutive teeth were enrolled in the study. The subjects received one or two implants with platform-shifting and internal conical connections in healed bone in a submerged manner. Digital standardized periapical radiographs were obtained at the time of implant placement, at prosthesis delivery, at 1 year, and at 3 years after the definitive restorations. Marginal bone level changes were measured at the mesial and distal aspects of each implant. Spearman correlation coefficients were calculated to examine the correlation between marginal bone level changes and clinical factors (age, vertical mucosal thickness, implant length and diameter, insertion torque value, and vertical implant position). Results: Twenty-five patients with 30 implants (8 men and 17 women, mean age: 61.24 ± 13.18 years) were followed up to 3 years after the definitive restorations. The implant survival rate was 100%, and no remarkable complications were found. Mean peri-implant marginal bone level changes were –0.41 ± 0.61 mm (from placement to prosthesis delivery: C1); –0.08 ± 0.54 mm (from prosthesis delivery to 1 year: C2); –0.04 ± 0.95 mm (from prosthesis delivery to 3 years: C3); and 0.04 ± 0.60 mm (from 1 year to 3 years: C4), respectively. Statistically significant differences in bone level changes were observed between C1 and C3, and C1 and C4. Significant correlations of marginal bone level changes with implant diameter in C1 and with vertical implant position in C2 and C3 were observed. Conclusion: Within the limitations of this study, platform-shifting implants with internal conical connections appeared to prevent marginal bone resorption, especially after delivery of definitive prostheses, although marginal bone resorption attributed to the reestablishment of biologic width following subcrestal placement might be unavoidable. Int J Oral Maxillofac Implants 2021;36:574–580. doi: 10.11607/jomi.8425

Keywords: internal conical connection, marginal bone level, platform-shifting, radiographic evaluation
microleakage and peri-implant marginal bone resorption due to its mechanical stability.\textsuperscript{11–13} The well-known platform-shifting (also known as platform-switching) concept has also been introduced and generally used recently.\textsuperscript{12,14,15} This concept is based on the allocation of more space for soft tissue and the inward reposition of the implant-abutment connection to decrease the effect of microgap on surrounding bone. Several systematic reviews and meta-analyses clearly indicated the positive effects of the platform-shifting concept on peri-implant bone preservation.\textsuperscript{16–19} Although recent studies investigating the effect of platform-shifting implants with internal conical connections (Morse taper connection) on peri-implant bone level have been published and shown favorable outcomes,\textsuperscript{12,20–25} the correlation between marginal bone level changes and various factors, such as patient-related, surgical, or prosthetic factors, in this type of implant remains uncertain.

The primary aim of this prospective study was to evaluate radiographic marginal bone level changes around platform-shifting implants with internal conical connections after 3 years of function. Furthermore, this study also examined the correlation between peri-implant bone level changes and patient-related and implant treatment–related factors.

\section*{MATERIALS AND METHODS}

This single-center prospective study was conducted at the Department of Prosthodontics and Regenerative Dentistry and Implant Center at Kyushu University Hospital after institutional ethics committee approval.

\subsection*{Patient Selection}

Thirty adult male or female patients (\(\geq 20\) years of age) who were systemically healthy with good oral hygiene (O’Leary’s Plaque Control Record < 25% at screening), lost one tooth or two adjacent teeth to be replaced with dental implants, and had sufficient bone volume (buccolingual alveolar width \(\geq 6\) mm and apicocoronal height \(\geq 10\) mm at the implant shoulder position) in the prospective implant sites (completely healed after teeth extraction) were eligible for this study. Patients who had systemic diseases precluding surgical intervention, who had signs or symptoms of temporomandibular disorders or bruxism, or who experienced bone augmentation with bone substitute at extraction sockets were excluded. Smokers who smoked more than 10 cigarettes per day or light smokers (< 10 cigarettes per day) who could not abstain from smoking 2 weeks before and after implant-related surgery were also excluded. All of the enrolled patients who met the inclusion criteria gave informed consent.

\subsection*{Implant and Clinical Procedure}

The GC Aadva standard implant system (GC Corporation) was adopted in this study. This implant system is characterized by platform shifting with internal conical connection. The implants (Ti–6Al–4V alloy) had sandblasted and acid-etched surfaces (Sa value: 2.0 to 2.3 \(\mu\)m).\textsuperscript{26} The detailed schematic diagram of the implant-abutment connection is shown in Fig 1. The implant variations were as follows: (1) diameter—narrow (3.3 mm), regular (4.0 mm), and wide (5.0 mm); and (2) length—8, 10, 12, and 14 mm.

All patients were treated with two-stage implant surgery according to the manufacturer’s instructions in healed sites. Prophylactic antibiotic therapy was administered before surgery. Under local anesthesia, a full-thickness flap was reflected, and the sites were prepared under abundant irrigation of cold saline solution. Implants were placed without any tissue grafting. All implants were aimed to be placed basically at bone crestal level. However, vertical implant position was reassessed with a digital periapical radiograph. The distance between the implant and peri-implant bone level was measured, and a plus measurement value means subcrestal placement. The final insertion torque value was measured during placement. If the insertion torque exceeded 50 Ncm, the site was reprepared and placed again (including just removal and reinsertion). After a submerged healing period of 3 months in the mandible and 6 months in the maxilla, stage-two surgery was performed. Healing abutments were connected to the implants in all cases. The heights of healing abutments (3.0, 4.5, and 6.0 mm) were selected according to the thickness of mucosa. After soft tissue healing, all implants were initially restored with the screw-retained provisional restorations fabricated with acrylic resin to confirm occlusal function. Final impressions were taken following the appreciation of the relationship between form and function of provisional restorations. The cemented or screw-retained definitive restorations selected by prosthodontists were fabricated.

\subsection*{Radiographic Peri-implant Marginal Bone Evaluation}

Mesial and distal peri-implant marginal bone level was evaluated with standardized periapical radiographs.
Digital periapical radiographs using customized holders oriented at the natural dentition by occlusal fixation for each patient were obtained at the time of implant placement, at prosthesis delivery, at 1 year, and at 3 years after the definitive restorations (Fig 2). Marginal bone level was defined as the distance from the mesial or distal first visible bone contact to the implant shoulder (CITA Clinical Finder, FUJIFILM). Changes of mesial and distal marginal bone level (mm) were also calculated and defined as follows:

- C1: Bone level changes from placement to prosthesis delivery
- C2: From prosthesis delivery to 1 year
- C3: From prosthesis delivery to 3 years
- C4: From 1 year to 3 years

**Data Analysis**
Mean values and SDs of marginal bone level changes were calculated based on peri-implant marginal bone level. To compare marginal bone level changes between two different time periods statistically, the Friedman test with post hoc pairwise comparisons was used. The Spearman rank correlation coefficients were calculated to investigate the relationships between marginal bone level changes and some factors. The factors correlated with bone level change were classified into the following categories:

1. Patient-related factors: Age and vertical mucosal thickness
2. Implant-related factors: Implant length and diameter
3. Surgical factors: Insertion torque value and vertical implant position judged by radiographic measurements (subcrestal placement was described as a plus measurement value)

All statistical comparisons were conducted at the .05 level of significance.

Fig 2 Radiographic images for marginal bone level measurement through the follow-up period: (a) immediately after implant placement, (b) at the time of prosthesis delivery, (c) 1-year follow-up, and (d) 3-year follow-up.
RESULTS

Between January 2014 and March 2015, 31 patients were assessed for their eligibility, and a total of 30 patients were enrolled as planned in the present study. Although all implants were placed and restored successfully, five patients were defined as dropouts due to pregnancy (one patient) and the failure of follow-up as necessary (four patients). Consequently, 25 patients (8 men and 17 women, mean age: 61.2 ± 13.2 years) with 30 implants completed the prospective 3-year follow-up after the delivery of definitive prostheses and were considered for analyses. All implants and prostheses (19 screw-retained and 6 cement-retained) were stable without any complications, which correspond to overall success and survival rates of 100%, including implants and prostheses. The distributions of implants and implant sites are described in Tables 1 and 2, respectively.

Mesial and distal peri-implant marginal bone levels were measured per implant, meaning marginal bone levels from 60 sites (30 implants) were recorded at each time point. The mean values of marginal bone level changes were as follows—C1 (from placement to prosthesis delivery): –0.41 ± 0.61 mm; C2 (from prosthesis delivery to 1 year): –0.08 ± 0.54 mm; C3 (from prosthesis delivery to 3 years): –0.04 ± 0.95 mm; and C4 (from 1 year to 3 years): 0.04 ± 0.60 mm (Fig 3). The mean value of C1 showed slightly more bone resorption, and statistical differences were detected compared with C3 and C4.

The results of the Spearman correlation tests are shown in Table 3. There was a weak, but nominally significant, correlation between C1 (from placement to prosthesis delivery) marginal bone level changes and diameter (ρ = 0.29, \( \text{P} < .05 \)), implying that subcrestal implant placement was correlated with marginal bone resorption. No significant correlations were detected in C4 (from 1 year to 3 years; Table 3).

Table 1 Implant Distribution

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length 8 mm</th>
<th>10 mm</th>
<th>12 mm</th>
<th>14 mm</th>
<th>Total</th>
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<tr>
<td>3.3 mm</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4.0 mm</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>–</td>
<td>10</td>
</tr>
<tr>
<td>5.0 mm</td>
<td>3</td>
<td>9</td>
<td>5</td>
<td>–</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>16</td>
<td>8</td>
<td>1</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 2 Implant Site Distribution

<table>
<thead>
<tr>
<th>Tooth number</th>
<th>No. of implants in the maxilla</th>
<th>Right</th>
<th>Left</th>
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<tr>
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<tr>
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<td>21</td>
<td>21</td>
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<td>22</td>
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<td>26</td>
<td>26</td>
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<tr>
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<td>1</td>
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<td>–</td>
<td>34</td>
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<td>–</td>
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</tr>
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<tr>
<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
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</table>

Table 3 Spearman Correlation Values Between Marginal Bone Change and Related Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>–0.047</td>
<td>0.022</td>
<td>0.0043</td>
<td>0.031</td>
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<tr>
<td>VMT</td>
<td>0.042</td>
<td>–0.12</td>
<td>0.043</td>
<td>0.031</td>
</tr>
<tr>
<td>Length</td>
<td>0.045</td>
<td>0.011</td>
<td>0.031</td>
<td>0.031</td>
</tr>
<tr>
<td>Diameter</td>
<td>0.29</td>
<td>–0.03</td>
<td>0.12</td>
<td>0.031</td>
</tr>
<tr>
<td>ITV</td>
<td>–0.072</td>
<td>–0.10</td>
<td>0.051</td>
<td>0.031</td>
</tr>
<tr>
<td>VIP</td>
<td>–0.060</td>
<td>–0.45</td>
<td>–0.32</td>
<td>–0.32</td>
</tr>
</tbody>
</table>

MBLC = marginal bone change; \( \rho \) = Spearman correlation coefficient; VMT = vertical mucosal thickness; ITV = insertion torque value; VIP = vertical implant position.
C1 = from implant placement to prosthesis delivery; C2 = from prosthesis delivery to 1 year; C3 = from prosthesis delivery to 3 years; C4 = from 1 year to 3 years.
\( *\)P < .05, statistically significant.
DISCUSSION

The support by stable marginal bone around implants is one of the prerequisites for the prognosis of implant-supported prostheses. However, marginal bone level change caused by multiple biologic and mechanical factors might be observed causally after abutment connection and occlusal loading.\(^5\)\(^-\)\(^7\) It has also been reported that the implant-abutment junction with microgap might lead to increased bone resorption.\(^9\),\(^10\) To minimize the effect of microgap on marginal bone level, several attempts have been reported. Conical connection can provide rigid connection and reduce the effect of microgap and micromotion on peri-implant marginal bone.\(^11\),\(^12\) To assess the effect of the internal conical connection of the present implant system, the pullout value (removal value) of the fastened abutment with recommended torque (20 Ncm) was measured after removal of a screw in vitro. The mean value was 4.3 ± 0.46 kgf, meaning a rigid connection. It has also been suggested that the platform-shifting concept plays a critical role in shifting microgap away from peri-implant marginal bone.\(^12\),\(^14\),\(^15\) The present prospective study was conducted to evaluate the effect of platform-shifting implants with conical connections on peri-implant marginal bone level change and to analyze the influence of the factors associated with a sequence of implant treatment.

The initial bone level change (from placement to prosthesis delivery), C1, was the main bone resorption (−0.41 ± 0.61 mm) through the follow-up period, although this bone resorption must be acceptable compared with previous studies.\(^12\)\(^-\)\(^25\) The initial bone resorption has been reported to be influenced by various factors, especially the reestablishment of biologic width or supracrestal tissue attachment\(^6\)\(^-\)\(^7\) and connection type after initial functional loading, up to 6 months.\(^8\) The present results also showed that statistically significant differences in marginal bone level changes were observed between C1 (from placement to prosthesis delivery) and C3 (from placement to 3 years), and C1 and C4 (from 1 year to 3 years). Previous studies indicated that some variables prior to definitive prosthesis delivery, such as surgical trauma including compression caused by implant insertion torque value,\(^27\),\(^28\) vertical and horizontal implant position,\(^29\)\(^-\)\(^36\) location of microgap,\(^9\),\(^10\) and vertical mucosal thickness or abutment height.\(^37\)\(^-\)\(^39\) In the C1 period (from placement to prosthesis delivery), the present analysis showed a weak correlation between bone level change and implant diameter, and it was statistically significant. Although it was suggested that a narrow implant was generally placed in a limited mesiodistal space, where more bone remodeling tended to be induced following implantation and the effect of a smaller horizontal mismatch of a platform-shifting narrow implant on bone resorption might be considered as previous studies showed,\(^40\),\(^41\) it must be hard to describe with a limited number of each diameter of implant and the smaller Spearman correlation coefficient. Further studies will be required to validate the effect of implant diameter on bone level change.

After the delivery of definitive prostheses, the mean values of C2 (from placement to 1 year) and C3 (from placement to 3 years) were −0.08 ± 0.54 mm and −0.04 ± 0.95 mm, respectively. Furthermore, C4 (from 1 year to 3 years) was 0.04 ± 0.60 mm, pointing to the increase of marginal bone level. Considering the criteria of implant success, which included < 0.2 mm/year bone resorption in the follow-up,\(^41\) platform-shifting implants with internal conical connections in the present study demonstrated satisfactory peri-implant marginal bone stability that was similar to previous studies.\(^12\)\(^-\)\(^25\) Peri-implant marginal bone level after loading has been potentially regulated by multiple factors.\(^12\),\(^23\),\(^24\) The present study demonstrated that subcrestal placement (43 out of 60 sites, total: 0.64 ± 0.79 mm subcrestally) was significantly correlated with marginal bone resorption after prosthesis delivery. Change of bone level around subcrestally placed implants has been investigated, and clinical suggestions are controversial.\(^29\)\(^-\)\(^33\),\(^42\),\(^43\) However, most studies generally reported that initial bone level change due to biologic width reestablishment and bone remodeling was influenced by subcrestal implant position, and further bone level was almost stable. A stronger correlation was observed in C2 (from prosthesis delivery to 1 year), and this bone resorption might be regarded as subsequent initial bone resorption due to biologic width reestablishment. However, the stability of peri-implant bone level was observed after 1 year. These results suggest that the platform-shifting concept and rigid conical connection contribute to the suppression of the effect of microgap or microleakage after main bone level change following implant restoration.

Although a limitation of the present study was the lack of a control group, the present study supports the positive effect of single- or 2-unit crowns supported by platform-shifting implants with internal conical connections on peri-implant marginal bone level preservation in addition to 3-year success and survival rates of 100%. To circumvent this limitation, some previous meta-analyses\(^15\)\(^-\)\(^19\) should be cited again. These articles concluded a positive effectiveness of platform-shifting implants on marginal bone level compared with platform-matched implants. In addition, a previous study by Pan et al\(^44\) evaluated the remodeling of the mesial and distal marginal bone level around platform-shifting and platform-matched dental implants over a 3-year period. This study also confirmed positive
results for using platform shifting from the viewpoint of marginal bone level change, although both platform shifting and platform matching showed bone gain. According to these studies, the positive effects of the platform-shifting system might be believed. The implants in this study also have an internal conical connection. These features might play a crucial role in minimizing the negative effects of microgap, micromotion, and microleakage. The results of the present study were favorable from the clinical point of view, even though initial bone resorption due to biologic width reestablishment and bone remodeling was unavoidable. Although the statistical analysis also suggested that bone resorption was correlated with subcrestal placement, it might be preferable to validate these implications in a longer-term study using a larger sample size.

CONCLUSIONS

Within the limitations of this prospective study, platform-shifting implants with internal conical connections have the potential to contribute to the preservation of peri-implant marginal bone level. Statistically, implant diameter and subcrestal placement showed significant correlations with change of peri-implant marginal bone level, while this study design is a clinically limited condition. Future studies with a larger number of subjects are needed to reassess the findings of this study.

ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

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