Single-tooth implants have become one of the most highly used techniques to replace a missing single tooth. Immediate implant placement with immediate temporization accelerates the treatment period. After maxillary anterior tooth extraction, alveolar resorption and bone remodeling begins and may last for more than 1 year. The buccal bone plate in the maxilla resorbs more rapidly than the palatal bone due to its low thickness and reduced blood irrigation coming from the periodontal tissues after tooth loss. Immediate implant placement and temporization have been suggested to support soft and hard tissues and to decrease alveolar bone resorption. Wöhrle described the immediate implant placement protocol in association with immediate temporization in the maxillary esthetic zone. His results were very appreciated by patients while gingival tissue and bone were maintained. In general, immediate implantation and temporization protocols have revealed good outcomes and patient gratification in both extraction sockets and healed ridges.

Several factors influence marginal bone loss (MBL), such as local factors, implant surgery, and prosthetic restoration. The multiple manipulations of the abutment, disconnecting and reconnecting, provoke an alteration and inflammation of the epithelial cuff, thus influencing the stability of the hard tissues. Micromovements and gaps at the implant connection level also promote marginal bone reduction due to the contamination with buccal fluids considered to be a major factor of chronic inflammation and MBL. The decrease of the MBL in the immediate loading protocol might be related to the use of the definitive abutments during implant placement for both conventionally and immediately placed implants. However, only few long-term studies addressing the marginal bone levels and the peri-implant gingiva position in immediate implantation protocols have been published so far.

The objective of this study was to measure and compare marginal bone around immediately loaded implants by using the definitive abutments and supported by provisional crowns placed either in healed or in extraction sockets. In this study, 42 implants were placed in 36 patients needing single tooth replacement. Implants were inserted either in healed ridges (group 1) or in extraction sockets (group 2) and loaded immediately with prefabricated abutments. Two implants were lost during the healing period from group 2. The bone level around the implant shoulder was calculated mesially and distally on each implant using intraoral radiographs after crown cementation and 1, 3, 5, and 10 years following loading. Results: On the 10-year follow-up report, 36 implants were available for the clinical and radiologic evaluation. Besides the two implants lost during the osseointegration period, no implant loss was documented over the 5- to 10-year observation period. The average bone loss after implant and crown cementation was 0.266 ± 0.176 mm for 1 year, 0.194 ± 0.172 mm for 5 years, and 0.198 ± 0.165 mm for 10 years in healed ridges and 0.267 ± 0.161 mm for 1 year, 0.213 ± 0.185 mm for 5 years, and 0.287 ± 0.194 mm for 10 years in extraction sockets. Three crowns (in group 1) and one crown (in group 2) were replaced for esthetic reasons. Conclusion: The outcome of this study revealed that in both groups, the responses of marginal bone were similar. Immediate placement of the definitive prefabricated abutment in an immediate loading protocol appears to conserve marginal bone around the implant neck. Int J Oral Maxillofac. Implants 2021;36:1016–1023. doi: 10.11607/jomi.8772

**Keywords:** extraction socket, healed socket, immediate loading, marginal bone level, maxilla, single-tooth implant
ridges or fresh extraction sockets during a 10-year follow-up period.

MATERIALS AND METHODS

The original sample comprised 36 patients (15 females and 21 males; mean age of 31 years). Forty-two implants (Astra Tech TX implant system, Dentsply Implants) were placed in the anterior part of the maxilla by the same experimented surgeon. Twenty implants were inserted in healed sockets (group 1) and 22 in extraction sockets (group 2). This study followed the Helsinki agreement for research on humans.40

Data regarding patient selection, implant placement, and immediate loading were described in the author’s previous article.30

Briefly, following reflection of a mucoperiosteal flap, 42 dental implants were inserted in healed ridges 2 to 3 mm below the cementoenamel junction of the adjacent tooth. In the immediate implantation group, implants were stabilized on the palatal bone. Gaps between the buccal wall and implants were packed with the patient’s bone chips or bone substitute.

Prefabricated abutments, TiDesign or ZirDesign (Astra Tech TX implant system, Dentsply Implants), were used as definitive abutments for temporization and stabilized with a torque controller at 10 Ncm. Provisional crowns were customized in the mouth and cemented with temporary cement. Occlusion was adjusted in maximum intercuspal position with contacts in centric relation only.

Eight weeks following surgery, the definitive ceramic crowns were cemented.

Standardized intraoral radiographs were taken with the long-cone paralleling technique, with the central ray of the x-ray beam directed at a right angle to the alveolar bone (XCP holder Rinn, Dentsply Sirona). The receptor holder/bite block was individualized by using the resin record.

The films were manipulated manually according to temperature/time rules (the film should be rinsed for 10 to 15 seconds in a bath of fresh, running water, and the temperature of the water must be as close as possible to the temperature of the developer and fixer), digitalized using a Kodak Eos camera with a Macro lens (focal length: 100 mm, ratio 1/1), and saved in high-resolution JPEG format. Marginal bone levels were measured using the software (Dbswin, Durr Dental). For calibration and determination of the magnification of the radiologic images, the well-defined diameter and length of each implant were used.

Regular follow-up was based on clinical and radiologic assessments performed immediately after cementation of the definitive crown and yearly until the 10th year.

Clinical and Radiologic Examination

At the 10-year recall visit, the clinical elements recorded were as follows: oral hygiene status, presence of pain, implant or crown mobility, peri-implantitis, and mucositis. Radiologic measurements were acquired using the long-cone paralleling technique with individualized x-ray holder. Marginal bone levels were measured using the software with only 0.1 mm mesially and distally (Dbswin, Durr Dental). For calibration and determination of the exact magnification of the images, the well-defined diameter and length of each implant were used (Fig 1). Two oral and maxillofacial radiologists performed all measurements, which were recorded in millimeters.

In a previous study, MBL was evaluated at implant placement (T1), 8 weeks at fixation of the crown (T2), 1 year (T3), 3 years (T4), and 5 years (T5). The 10-year period measurements (T6) were calculated and compared with the previous measurements (T5) for each clinical case.

Statistical Analysis

Interexaminer correlation analysis was performed to calibrate the accuracy of the measuring process. To compare the 10-year MBL at the mesial and distal sites, the same statistical analysis of the previous study was used (the linear mixed model and the paired Student t test). A value of $P < .05$ was considered statistically significant.

RESULTS

Of the 42 implants formerly enrolled, 2 implants were lost in group 2 through the healing period and were
At the 5-year follow-up, no implant failures were observed; only minor prosthetic complications were registered: cracked porcelain of four crowns after 1 year and two crowns were changed for esthetic purposes. At the 10-year follow-up, 36 of 40 implants were well osseointegrated, and only 30 of 36 patients were still available for clinical and radiologic evaluation, where no crown or abutment loosening was reported. Four patients with four implants dropped out due to change of address abroad, but when the authors called them, they said that their implants are still in function.

Interexaminer correlation analysis discovered a non-significant error margin ($P < .11$).

Excluding the two lost implants, all implants were still in function, and no implant loss was documented, demonstrating a 95.23% cumulative survival rate of 90.4%. Complications observed were as follows: one case of mucositis in group 2; no crown or abutment loosening was reported. Two cases showed a decrease in the buccal bone size in group 2 (Fig 2).

The mean MBL changes from baseline to the 10-year follow-up and the radiologic findings are reported in Table 1.

Statistical analysis showed an average MBL at 10 years of $0.260 \pm 0.275$ mm in the fresh extraction group and $0.110 \pm 0.155$ mm in the healed socket group. The linear mixed model analysis showed that time had a major influence on the average MBL on the mesial site but not on the distal site (Table 2).

Paired $t$ test results demonstrated statistically significant differences between mesial and distal sites at T1 for all implants but remained stable afterward (Table 3).

At the 10-year follow-up, 36 implants were still in function from 30 cases and were available for evaluation, where no implant loss was recorded over the 10-year evaluation period.

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**Table 1** MBL Measurements in Millimeters (Mean ± SD) Related to Time Periods

<table>
<thead>
<tr>
<th>T</th>
<th>Mesial</th>
<th>Distal</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>T2</td>
<td>0.065 ± 0.143</td>
<td>0.213 ± 0.270</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>0.208 ± 0.247</td>
<td>0.217 ± 0.252</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>0.260 ± 0.275</td>
<td>0.315 ± 0.325</td>
</tr>
<tr>
<td>Healed</td>
<td>T2</td>
<td>0.169 ± 0.221</td>
<td>0.319 ± 0.246</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>0.125 ± 0.175</td>
<td>0.263 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>0.110 ± 0.155</td>
<td>0.285 ± 0.24</td>
</tr>
</tbody>
</table>

$T2 =$ crown cementation; $T3 =$ 1-year follow-up; $T4 =$ 3-year follow-up; $T5 =$ 5-year follow-up; $T6 =$ 10-year follow-up.

**Table 2** Linear Mixed Model Results

<table>
<thead>
<tr>
<th></th>
<th>Average $P$</th>
<th>Mesial</th>
<th>Distal</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2 (crown cementation)</td>
<td>.527</td>
<td>.085</td>
<td>.88</td>
</tr>
<tr>
<td>T3 (1 y)</td>
<td>.007</td>
<td>.014</td>
<td>.172</td>
</tr>
<tr>
<td>T4 (3 y)</td>
<td>.034</td>
<td>.145</td>
<td>.077</td>
</tr>
<tr>
<td>T5 (5 y)</td>
<td>.079</td>
<td>.183</td>
<td>.097</td>
</tr>
<tr>
<td>T6 (10 y)</td>
<td>.045</td>
<td>.140</td>
<td>.165</td>
</tr>
</tbody>
</table>

**Table 3** Mesial and Distal MBL Calculations at Variable Time Periods Using the Paired $t$ test

<table>
<thead>
<tr>
<th>T2</th>
<th>Mean ± SD</th>
<th>$P$</th>
<th>T5</th>
<th>Mean ± SD</th>
<th>$P$</th>
<th>T6</th>
<th>Mean ± SD</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate temporization</td>
<td>0.148 ± 0.28</td>
<td>.019</td>
<td>0.08 ± 0.34</td>
<td>.933</td>
<td>0.055 ± 0.36</td>
<td>.975</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healed-temporization</td>
<td>0.150 ± 0.32</td>
<td>.081</td>
<td>0.138 ± 0.20</td>
<td>.092</td>
<td>0.175 ± 0.25</td>
<td>.085</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

For cumulative success rate, the findings of the present study showed a 95.23% cumulative survival rate of switched-platform implants and 90.47% cumulative survival on the prosthetic level. Hence, the present results were well aligned with previously stated data in the literature.

Gotfredsen\(^1\) observed, in a 10-year prospective study, a 100% cumulative survival rate at the implant level and 90% at the prosthetic level. Moreover, in a 10-year follow-up of immediate implantation, Covani et al\(^{41}\) observed a cumulative success rate of 91.8%. Further, Vigolo et al\(^{42}\) described a cumulative implant success rate of 93.7% over a 10-year period. The 10-year survival rate of switched-platform implants, placed and immediately loaded with single crowns in the anterior region, resulted in a success rate of 93.7% over a 10-year period. The 10-year survival rate of switched-platform implants, placed and immediately loaded with single crowns in the anterior part of the maxilla, was 97.1%.\(^{43}\) In the same context, Donati et al\(^{44}\) stated a cumulative survival rate of 90.9% at the implant level in a 12-year follow-up period.

Recently, Raes et al\(^{45}\) observed, after 8 years of immediately loaded single implants, a cumulative survival rate of 93.8% for implants sited in extraction sockets and 100% for implants placed in healed ridges.

In a retrospective study with a 14- to 20-year follow-up, cumulative survival rates of 96.1% were observed for implants and 80.4% for crowns.\(^{46}\)

According to Albrektsson and Zarb\(^{48}\) and Roos et al,\(^{49}\) the tolerated MBL was 1.5 mm during the first year of loading and < 0.2 mm bone loss annually, that is, a maximum of 3.5 mm of MBL after 10 years of loading.

In the present report, the bone loss after 1 year was 0.267 ± 0.161 mm for the immediate implantation group and 0.266 ± 0.176 mm for the healed ridge group. At 5 years, it was 0.213 ± 0.185 mm and 0.194 ± 0.172 mm, respectively. At 10 years, the average MBL was 0.287 ± 0.194 mm and 0.198 ± 0.165 mm, respectively. No meaningful difference in MBL was observed in the two groups.

Data analysis showed that commonly, MBL occurred at T1, after which the rate of MBL maintained a value of approximately 0.01 to 0.02 mm/year. Remarkably, in certain cases, bone was recovered at T5 but remained stable at T6.

In this study, MBL figures obtained showed lower values compared with those of other studies with the same follow-up periods, which may be related to the placement of the definitive abutments during the surgical step.\(^{1,41–47,50,51}\)

In a previous study of MBL evaluation, Jemt\(^{50}\) compared deep or regular placement of implant necks in healed ridges with a delayed protocol. His results were 1.34 mm (SD: 0.57) and 1.67 mm (SD: 0.57) in the first group and 1.49 mm (SD: 0.58) and 1.56 mm (SD: 0.71) in the second group at 5 and 10 years, respectively.

Overall, the average MBL around single implants from implant placement to the 1-, 5-, and 18-year follow-ups was 0.5 mm (SD: 1.14), 0.5 mm (SD: 1.01), and 0.3 mm (SD: 0.92), respectively. Implants showed MBL of 0.1 to 0.6 mm (7%), 0.7 to 1.2 mm (10%), and > 2.4 mm (2%) between the 5- and 18-year periods of implants placed in healed sites without immediate loading.\(^{51}\)

Gotfredsen\(^1\) evaluated the 10-year results of single implants placed in the maxilla and fixed in healed ridges of 20 patients, where mean MBL was 0.75 mm, and 15% (3 subjects) presented between 1 and 1.4 mm and 5% (1 subject) lost > 2 mm of bone.

The mean MBL at 10 years in healed ridges, with cemented and screw-retained crowns, was 1.1 ± 0.2 mm for both types of restorations.\(^{42}\)

In 2012, Vigolo et al\(^{42}\) reported that the MBL from the implant neck to the crestal bone, for implants placed in healed ridges with immediate temporization, from baseline to 10 years was 1.0 ± 0.22 mm. In the mesial part, MBL varied from 3.57 ± 1.1 mm at baseline to 3.77 ± 0.7 mm at 10 years. In the distal part, MBL was 3.49 ± 0.8 mm at baseline to 3.73 ± 0.7 mm at 10 years. However, in their study, implant placement was used as the baseline for radiologic calculation and not the definitive crown cementation, whereas in the present study and in other investigations, the baseline of radiologic measurements was at the time of definitive crown fixation.

Donati et al\(^{44}\) observed an MBL of 0.53 mm (SD: 1.26) among the 5- to 12-year follow-up group and 0.67 mm (SD: 2.20) at 12 years around implants placed on healed ridges.

Winitisky et al\(^{46}\) detected a mean MBL of 0.2 mm at the first year of loading and a constant MBL of 0.01 mm yearly in a report of 14 to 20 years of follow-up. Raes et al\(^{45}\) detected bone loss in the immediate implantation group at 1.01 ± 1.73 mm after 1 year and 0.98 ± 1.71 mm after 8 years.

In this study, MBL for group 1 showed a mean value of 0.198 ± 0.165 mm at 10 years, while other studies revealed an increase of mean values up to 1.56 mm,\(^{50}\) 0.3 mm,\(^{51}\) 0.75 mm,\(^{1}\) 1.1 ± 0.2 mm,\(^{42}\) 1.0 ± 0.22 mm,\(^{43}\) 0.67 mm,\(^{44}\) 0.3 mm,\(^{46}\) and 0.49 ± 1.89 mm.\(^{45}\)

For the immediate implantation and temporization group, the present data showed an average MBL of 0.287 ± 0.194 mm, while Raes et al\(^{45}\) observed an average of 0.98 ± 1.71 mm at 8 years, which can be correlated to the creation of the biologic width.\(^{29}\)

The differences were obvious among healed sites (Fig 3) and extraction socket sites (Fig 4) and could be validated to the bone regeneration in the gaps during the healing period.\(^{52,53}\)

This study documented similarities in the interproximal MBL in both groups. The distal surfaces of the implant necks showed a lower MBL than the mesial surfaces. The
anatomical elements, such as interdental septum or incisive fissure, may explain these results. Stress distribution around the connection of implants could also play an important role in this issue.55,56 One of the reasons for a low MBL rate may be due to the immediate insertion of the prefabricated abutment during implant surgery. These outcomes are in agreement with other clinical reports on the manipulation of abutments and on marginal bone resorption.15,57,58 Berglundh et al23 observed marginal bone changes at abutment manipulation (connection/disconnection) and loading. It has been stated that the main amount of bone loss occurs after immediate abutment placement and that the bone level will remain stable after. These results are in harmony with the present findings and with other clinical studies.54,59,60

Peri-implantitis and mucositis are well stated in the literature.61,62 In the present study, only one case of mucositis was observed and treated successfully with local antiseptic and cleaning. No peri-implantitis was recorded because marginal bone level was stable over the years. The lower rate of soft tissue complications could be related to the strict oral hygiene regimen introduced in the present study and followed by the patients.

Technical complications are well documented in patients with cement single crowns on implants.63 In a prospective study over 12 years, El-Chaar64 reported five patients (13%) with complications, such as crown porcelain fracture or abutment screw loosening. Gøtfredsen,1 in his prospective study, documented two cases of re-cementation (10%), two cases of porcelain cracks (10%), and two cases of loosening of abutment screws (10%).

Brägger et al65 reported, in a long-term study, that two patients (3%) presented loosening of abutment screws and three patients (4%) showed porcelain fractures.

In the present study, only four crowns were replaced for porcelain fracture reasons in groups 1 and 2, offering a 10-year crown cumulative survival rate of 90.47%. The crowns changing for esthetic reasons was not considered as a technical failure. Complications included no crown or abutment loosening. Also, two cases in group 2 exhibited alteration of the buccal bone volume.

The immediate loading protocol is a credible and successful technique when the inclusion and exclusion criteria in the treatment plan are well established.

Fig 3  Standardized radiographs of implant inserted in extraction alveolar bone with immediate loading protocol at different time points: (a) initial; (b) implant surgery; (c) immediate loading; (d) 8 weeks after crown placement; (e) 1 year; (f) 3 years; (g) 5 years; (h) 10 years.
In the immediate implant placement, the depth of the neck is apically deeper than the implant placed in healed ridges. Placement of the definitive abutment during implant placement played an important role in protecting the blood clot, avoiding interruption of the early marginal bone healing, mineralization, and eventually bone loss. The remodeling of crestal bone around the implant-abutment connection is linked to healthy gingival margins. Loading is a biomechanical stimulation where several elements should be studied to sustain and protect the bone level and to support soft tissues.

CONCLUSIONS

An immediate loading protocol using the definitive abutment during implant placement seems to conserve marginal bone levels around implants and reduce the soft tissue collapse. This immediate loading is similar whether implants are inserted in healed or in new extraction sites and can be maintained over a period of 10 years.

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