The Radiographic Bone Loss Pattern Adjacent to Immediately Placed, Immediately Loaded Implants

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Purpose: *The purpose of this study was to evaluate radiographic bone levels adjacent to implants placed in fresh extraction sockets (ESs) and immediately loaded with a fixed full-arch provisional restoration compared to bone levels adjacent to implants placed in native bone (NB) under the same restorative conditions.* ***Materials and Methods:*** *Patients with a hopeless maxillary and/or mandibular dentition had their remaining teeth extracted and 6 to 8 implants placed and restored within 72 hours. Radiographs were obtained at time 0, 3 to 6 months, and annually for 5 years. The radiographs were digitized, and the bone level changes were measured using a computer-assisted method.* ***Results:*** *A total of 139 implants, 42 ES and 97 NB, placed in 17 patients were evaluated. The overall results indicated that for all implants (ES + NB), 0.60 ± 0.71 mm of bone was lost after 6 months; 1.17 ± 0.59 mm of bone was lost after 18 months; 0.87 ± 0.76 mm bone was lost after 36 months; and 1.35 ± 0.42 mm of bone was lost after 60 months. When stratifying for NB versus ES implants, it was found that for NB implants, 0.75 ± 0.21 mm of bone was lost after 6 months; 1.31 ± 0.91 mm of bone was lost after 12 months; 1.07 ± 0.21 mm of bone was lost after 36 months; and 1.45 ± 0.49 mm of bone was lost after 54 months. For ES implants, 0.14 ± 0.33 mm of bone was lost after 6 months; 1.02 ± 0.27 mm of bone was lost after 12 months; 0.86 ± 0.42 mm of bone was lost after 36 months; and 1.30 ± 0.48 mm of bone was lost after 54 months.* ***Conclusion:*** *The combination of ES and NB implants can be immediately loaded with a fixed full-arch prosthesis and remain stable for greater than 5 years. The bone loss adjacent to these implants is similar to that seen surrounding those placed and restored using traditional protocols.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:187–194

Key words: *bone loss, dental implants, extraction sockets, immediate loading, immediate placement, radiographic analysis, radiographic bone levels*

The evolution of osseointegration has occurred quickly based upon the documentation of long-term studies.[1] If the process of osseointegration is completed successfully, it will result in an implant adequately anchored to bone and able to withstand functional loading. For success to be clinically and experimentally meaningful, criteria developed by Albrektsson and coworkers must be met.[2] These criteria specify that the average vertical bone loss should be no more than 1.5 mm for the first year of function and 0.2 mm thereafter. These criteria were based on implants placed in native bone and allowed to heal for 3 to 6 months before restoration; however, these standards of success remain in place. In long-term studies by Adell and associates,[3] Quirynen and colleagues,[4] and Lindquist and coworkers,[5] not only did the high success rates remain stable but so did the level of crestal bone.

The immediate implant (placed into the socket at the time of tooth extraction) offers several advantages: a shorter healing time, reduced resorption of the alveolar process, and fewer surgical visits.[6,7] Multiple investigations demonstrate success rates greater than 90% for implants placed into fresh extraction sockets in partially edentulous arches.[8–11] The success of immediate implants has been well documented histologically.[12,13]

Human studies have confirmed that nonsubmerged implants follow the same pattern of bone loss as those submerged. The greatest amount of

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bone loss occurs in the first year (0.5 to 1.6 mm), and very little occurs in the subsequent years (< 0.2 mm/y).[14,15] Studies concerned with the bone loss surrounding implants placed in extraction sockets have focused on the fill of defects rather than the loss of crestal height over time.[16] Schwartz-Arad and associates compared the cervical bone resorption adjacent to 124 immediate and 202 delayed implants placed in jaws requiring the removal of all remaining teeth.[17] After an average of 3.5 years in function, the immediate implants had less cervical bone loss than the implants placed in native bone, 0.61 ± 1.18 mm compared to 0.89 ± 1.24 mm, respectively.

During the last decade, immediate loading has challenged the protocols of delayed loading. Jaffin and associates outlined the benefits of this treatment, which include elimination of the need for a removable partial denture, which may cause micromotion of the implants, and extraction of diseased, hopeless teeth.[18] Many practitioners have used immediately loaded implants as a temporary support for the provisional prosthesis but have not relied on their long-term survival.[19–21] Other studies have successfully demonstrated immediate loading in both mature bone and fresh sockets.[18,22]

Few studies have dealt with full-arch maxillary restorations on immediately loaded implants. In 2004, Jaffin and coworkers evaluated the predictability of immediate loading in the maxilla.[23] Of the 236 implants loaded, 16 failed. Equal success of both immediate and nonimmediately placed implants was observed.

Testori and associates[24] measured bone loss around immediately loaded implants. The majority of bone loss occurred in the first 2 months and declined thereafter. The results were well within Albrektsson's criteria for success. In addition, Testori and coworkers histologically evaluated immediately loaded implants at 2 and 4 months of function. Bone-implant contact and crestal loss were not significantly different from submerged nonloaded implants. It can be concluded that immediately loaded implants in the anterior mandible can osseointegrate and support prostheses with no greater bone loss than that demonstrated with conventionally loaded implants.

With the demand for immediate placement and immediate loading of full-arch fixed restorations, it is essential to establish the predictability of this treatment. The purpose of this study was to evaluate the radiographic bone level changes adjacent to implants placed in fresh extraction sockets and immediately loaded compared to implants placed in native bone in the same arch under the same restorative conditions followed up for 60 months.

MATERIALS AND METHODS

This study involved 17 patients ages 57 to 82 (9 women and 8 men) who presented to a private practice setting for implant treatment of a failing dentition. The patients expressed strong reservations concerning wearing a removable prosthesis or were advised of the possibility of immediately loading their implants. The following criteria, previously described by Jaffin and associates,[18,23] were used to select the patients:

- Adequate bone volume for the placement of a minimum of four 10-mm-long screw-type implants in the mandible and 6 in the maxilla
- Bone density readings greater than 350 Hounsfield units as measured by interactive computerized tomogram (CT), if CT was deemed necessary
- Adequate anterior/posterior relation possible
- Evaluation of opposing dentition such that edge-to-edge occlusion could be avoided
- Ability of the patient to cope with failure

The patients in this study were in good health. Patients with diabetes were not excluded if their condition was well controlled. Although smoking was discouraged, neither smokers nor bruxers were excluded.

Once the patients had a thorough understanding of the procedure and alternative treatment options, they were referred to the restorative dentist for a complete presurgical consultation. The evaluation included a waxup to final tooth position and determination of proper vertical dimension. Metal-reinforced, heat-cured provisional fixed partial dentures as well as surgical templates were fabricated. In some maxillary cases, an opaque marker was painted on the template for use during the CT scan. The patient was then referred to the radiologist for CT study. The scans were evaluated on a computer utilizing the interactive CT program Simplant (Materialise, Columbia, MD). In certain cases, a CT scan was not deemed necessary if adequate bone volume of good density was apparent on a complete-mouth set of parallel periapical radiographs. The radiographs and waxups were analyzed to determine whether parallelism of the implants could be achieved. If parallel implants could be achieved, the abutments were connected at the time of surgery. The interim restoration, which was fabricated by the restorative dentist, was also seated on the day of surgery.

In other cases, analysis of the CT scan revealed that parallelism could not be accomplished. In these cases, the implants were indexed, and impressions were made at the time of surgery. The impressions were sent to a prosthetic laboratory that selected the

appropriate abutments, indexed them, and fabricated the interim restoration. Within 3 days, the abutments and the restoration were placed. The patient then returned to the restorative dentist's office for refinement of the prosthesis, occlusal adjustment, and cementation.

On the day of surgery, the mucoperiosteal tissues of the maxilla and/or mandible were infiltrated with a local anesthesia (lidocaine or Mepivacaine; Novocol Pharmaceuticals, Cambridge, ON, Canada) and the teeth were extracted atraumatically. The mouth was prepared with 0.12% chlorhexidine rinse (Peridex solution, Zila Pharmaceuticals, Phoeniz, AZ) for 2 minutes, and the patient was surgically draped for implant placement. Straumann (Basel, Switzerland) titanium plasma-sprayed (TPS) or sandblasted large-grit acid-etched (SLA) implants were placed using a standard surgical protocol. First, using the surgical template, the anterior sites were drilled; care was taken to place the right and left implants parallel to one another. The posterior sites were then prepared with the template in place to ensure that these were also parallel. At least 8 mm of the implant had to be engaged in the bone, even when an extraction site was selected. Apical preparation, or widening of the socket, was necessary in some cases to ensure that at least 8 mm of each implant was engaged in bone. All osteotomies were tapped. Types 1 and 2 bone were tapped to the depth of the socket.[1] Type 3 bone was tapped to within 5 mm of the apex. If the abutments were placed immediately, the interim restoration was seated the day of surgery.

For cases in which the laboratory selected the abutments and fabricated the provisional restoration, an occlusal registration was carried out prior to tooth extraction. All implants were examined, and any bone that covered the implant shoulder was removed. Impression and positioning copings were hand-tightened, and an impression was obtained. Using a clear template of the tooth position and the articulated mounted casts, abutments were selected and indexed with an acrylic jig. The provisional restoration was then fabricated on the master casts. Within 3 days, the cover screws were removed, and the abutments were hand-tightened into place. The provisional prosthesis was seated, and the patient was sent back to the restorative dentist for adjustments. At 12 weeks the provisional restorations were removed. The abutments were torqued to 35 Ncm, and fabrication of the definitive restoration commenced.[18,23]

Standard parallel periapical radiographs of the implants were obtained at the time of surgery (baseline), between 1 and 3 months, at final prosthesis delivery (3 to 6 months), and annually for up to 6 years. The radiographs were exposed at 90 kilovolts (peak) or kV(p), 12 μA, and 0.5 second. They were developed in an automatic developer. The radiographs were digitalized and downloaded to Implant Analysis Toolkit software.[15] This standardized the images at 675 dpi, with a resulting average size of 940 × 620 pixels at 8 bits per plane and 256 scales of gray. The image analysis algorithm calculated the ratio between selected points. The results were displayed in a dialog box. The obtained data were saved in a text or tab-delimited file for importation into a database for further statistical analysis.

For all implants, the change in bone height over time was measured by first marking the radiographic landmarks (implant shoulder and apical tip). The distance between these 2 points was a known distance. The height of alveolar bone on the mesial and distal implant surface was marked last. The image analysis algorithm calculated the ratio between the selected points. This measurement was converted, or standardized, to determine magnification in the image processing system (Fig 1a).

For comparison, implants were divided into 2 groups: those placed in native bone (NB) and those placed in fresh extraction sockets (ESs). The ES implants were further divided into ES implants with an adjacent vertical defect and ES implants without an adjacent vertical defect. If a vertical defect was not present, the change in the marginal bone was measured as already described (Fig 1b).

If a mesial or distal vertical defect was present adjacent to the ES implant, the change in the depth of the defect was measured. The change in defect depth could have occurred because of either a loss of crestal bone height or a gain in bone from the defect base. Both scenarios were accounted for by marking the implant shoulder and apical tip and defining this as a known distance. The base of the defect was marked last, and the image analysis algorithm calculated the ratio between the selected points. This procedure was repeated with the coronal crest of the defect as the third reference. The change in defect depth between 2 time points and the direction in which the change in bone level had occurred was determined (Fig 1c; Table 1).

The statistical significance of the collected data was determined by examining the distribution of outcome variables. A mean adjacent implant-bone change (± SD) was calculated for each time point, utilizing the implant as the unit of measure. The amount (mm) of bone change from baseline was calculated for each time point. Comparison of the group mean change in bone level between the ES and NB groups was accomplished using the Bonferroni/Dunn test. Specific differences were analyzed using the Student *t* test. Two examiners evaluated the NB and ES implants, and

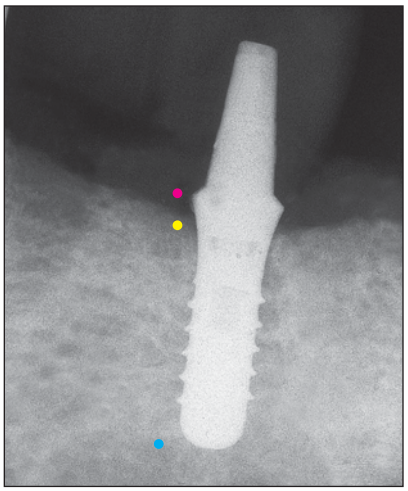

Fig 1a To facilitate measurement, the radiographs of implants in NB were marked as shown. Red dot = implant shoulder, yellow dot = crest of bone; blue dot = implant apex.

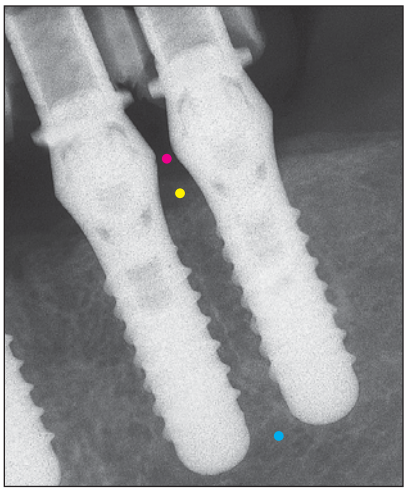

Fig 1b To facilitate measurement, the radiographs of implants in ES without a vertical defect were marked as shown. Red dot = implant shoulder, yellow dot = crest of bone; blue dot = implant apex.

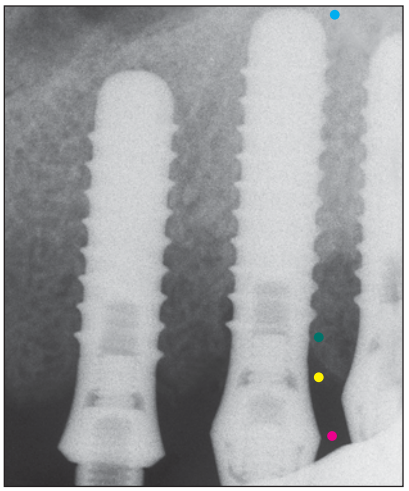

Fig 1c To facilitate measurement, the radiographs of implants in ES with vertical defects were marked as shown. Red dot = implant shoulder, yellow dot = crest of bone; blue dot = implant apex; green dot = base of defect.

Table 1 Radiographic Measurements

Implant group	Measurements made
All implants	Change in the most coronal bone-implant contact over time
ES implants with a vertical defect	• Initial depth of the adjacent defect • Change in the level of the base of the defect over time • Change in the level of the crest of the defect over time
ES implants without a vertical defect	Change in the most coronal bone-implant contact over time

Measurements were made mesially and distally, and the results were averaged. ES = extraction socket.

interexaminer reliability was assessed using an intraclass correlation coefficient as reported by Crohin.[15]

To determine the average change in bone level for this data set, the implants were placed into groups determined by time points: 0 to 6 months; 6 to 12 months; 12 to 36 months; and 36 to 54 months after placement. Mesial and distal bone changes were averaged to create a single value for each implant. These results were then averaged to create a single value representing the change in bone level within each time range. This process was repeated to create a single average value for the ES and NB groups.

RESULTS

A total of 17 patients received 139 implants, 42 of which were placed in ES. Fifty-four implants were placed in 8 maxillae and 85 in 11 mandibles. The pattern of bone change was similar for the 2 arches.

When all implants were considered, there was a bone level decrease of 0.60 ± 0.71 mm (mean ± SD) during the first 6 months after placement. When comparing implants placed in NB versus implants placed in extraction sockets, it was found that the level of bone surrounding the NB implants decreased by 0.75 ± 0.21 mm after 6 months, while the bone level surrounding the ES implants decreased by 0.14 ± 0.33 mm after 6 months. The difference between the ES and NB groups was statistically significant ($P < .05$; Fig 2).

Eighteen months after placement, bone level had decreased 1.17 ± 0.59 mm for the entire sample. After stratifying the implants into 2 groups, NB versus ES, it was found that bone level surrounding the NB implants had decreased by 1.31 ± 0.91 mm after 12 months, while the bone level surrounding the ES implants had decreased by 1.02 ± 0.27 mm after 12 months (Table 2; Fig 2).

This trend of similar bone level changes in all implants continued over the next 60 months after placement. By 36 months after placement, the bone level had decreased by 0.87 ± 0.76 mm from baseline; by 60 months after placement, it had decreased a total of 1.35 ± 0.41 mm from baseline. The level of bone surrounding the NB implants had decreased by 1.07 ± 0.21 mm from baseline at 36 months and by 1.45 ± 0.49 mm after 54 months. The bone level surrounding the ES implants had decreased by 0.86 ± 0.42 mm from baseline after 36 months and by 1.30 ± 0.48 mm after 54 months (Fig 2; Table 2).

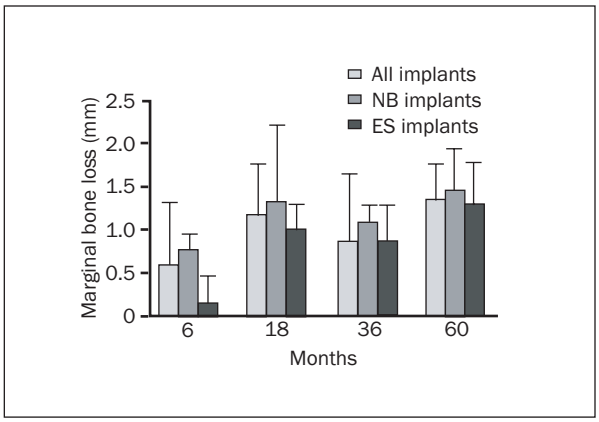

Fig 2 Bone loss over 60 months for all groups.

There is often a residual vertical defect adjacent to an implant placed in an extraction socket (32 of the 42 ES implants). To determine the bone fill at the defect base and/or the bone loss at the defect crest, the implant radiographs were marked on the Implant Analysis Tool Kit as described (Fig 1). Each ES implant was individually followed over time. The 3-month, 4- to 7-month, and 1-year radiographs of the ES implants were compared to the implant's initial radiograph to determine any bone changes and the direction, crestal or basal, from which these changes occurred.

Where there was a defect adjacent to an implant, bone was lost from the crest of the defect and gained from the base of the defect. The average depth of a defect adjacent to an implant placed in an extraction socket was found to be 1.71 ± 1.37 mm. Three months after placement, there was a loss of bone level from the defect crest of 0.36 ± 0.23 mm and a gain in bone level from the defect base of 0.61 ± 0.62 mm. After 1 year this trend continued: There was a loss of bone level from the defect crest of 0.73 ± 0.56 mm and a gain from the defect base of 0.65 ± 1.31 mm (Figs 3 and 4).

The change in marginal bone adjacent to ES implants without a vertical defect also was followed over time. The bone loss was 0.17 ± 0.11 mm after 0 to 3 months, 0.57 ± 0.32 mm after 3 to 6 months, and 0.81 ± 0.05 mm after 6 to 12 months (Table 2; Fig 5). This bone loss was not significantly less ($P > .05$) than that demonstrated by the NB implants over the same 6- to 12-month time period (Figs 6 and 7).

Table 2 Bone Change (Gain or Loss) from Baseline over 60 mo

Time/group	Bone change (loss or gain in mm)	SD
Bone loss for all implants		
0 to 6 mo	0.600	0.714
6 to 18 mo	1.173	0.589
18 to 36 mo	0.870	0.763
36 to 60 mo	1.350	0.410
Bone loss for ES implants		
0 to 6 mo	0.138	0.327
6 to 12 mo	1.019	0.270
12 to 36 mo	0.865	0.418
36 to 54 mo	1.303	0.479
Bone loss for NB implants		
0 to 6 mo	0.751	0.210
6 to 12 mo	1.314	0.907
12 to 36 mo	0.700	0.214
36 to 54 mo	1.452	0.489
Bone loss from the crest of the vertical defect		
0 to 3 mo	0.361	0.227
3 to 6 mo	0.287	0.983
6 to 12 mo	0.727	0.556
12 to 24 mo	0.264	0.320
Bone gain from the base of the vertical defect		
0 to 3 mo	0.606	0.617
3 to 6 mo	0.261	0.678
6 to 12 mo	0.654	1.314
12 to 24 mo	1.140	1.091
Marginal bone loss of ES implants without vertical defect		
0 to 3 mo	0.165	0.108
3 to 6 mo	0.569	0.323
6 to 12 mo	0.814	0.005
12 to 24 mo	0.825	1.095

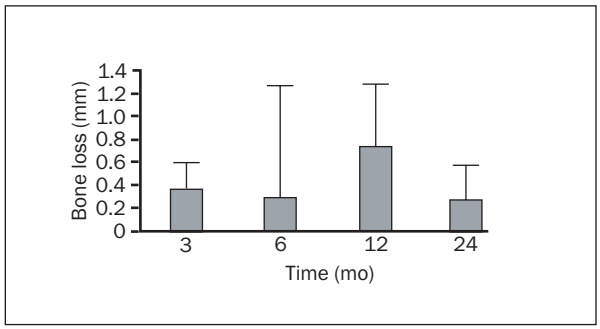

Fig 3 Bone loss from crest of the vertical defect over time.

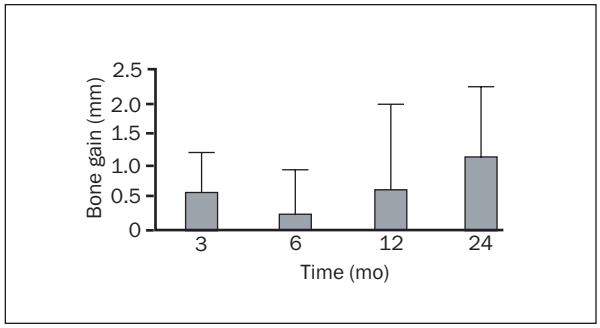

Fig 4 Bone gain from base of the vertical defect over time.

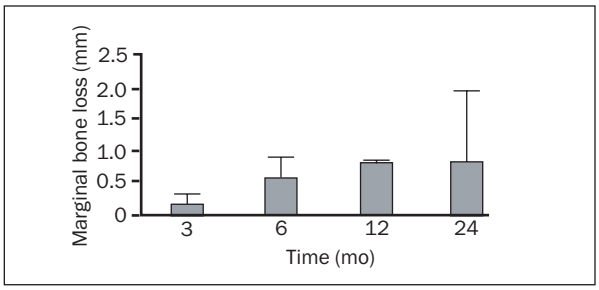

Fig 5 Marginal bone loss around ES implants with no vertical defects.

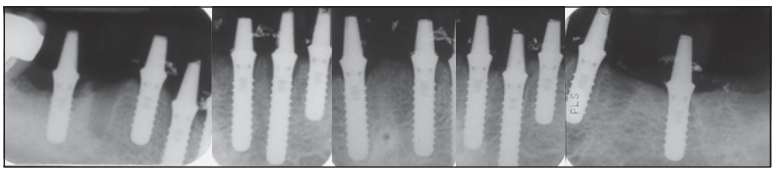

Fig 6 Radiographs obtained at implant placement for NB and ES implants with and without vertical defects.

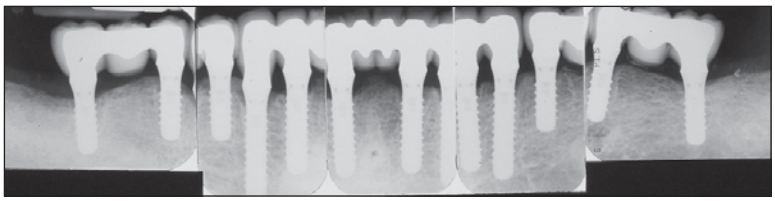

Fig 7 Radiographs of same patient at 60 months postinsertion and loading.

DISCUSSION

The traditional protocol, which required the implant to remain unloaded for an extended period to achieve osseointegration, was based on initial clinical observations rather than experimental data. Therefore, it was reasonable to question whether this restorative delay was essential for implant success.[1,25] However, the extended healing period was supported by studies of bone biology. Brånemark described the osseous changes taking place at the microscopic level that required 3 to 6 months of undisturbed healing.[26]

Szmukler-Moncler and associates reviewed the histologic literature to determine how much micromotion a healing implant could tolerate.[25] It was revealed that an implant could osseointegrate despite a range of motion of 50 μm to 150 μm. The design and surface of the implant as well as the type of restoration placed each played a key role in determining whether integration would occur.

The fact that different restorative designs produce varying degrees of movement at the bone-implant interface has been established. Glantz and coworkers evaluated the strain produced by various fixed mandibular prostheses.[27,28] The results indicated that while removable partial dentures produce direct and unpredictable loading on individual abutments, a rigid fixed restoration can decrease micromotion at the implant surface. This theory was validated by Randow and colleagues, who immediately loaded titanium implants with a rigid fixed suprastructure.[29] In their study, 27 patients were each treated with 5 to 6 implants placed between the mental foramina. The experimental group was restored within 20 days with a fixed appliance. The control-group implants remained unloaded for 4 months before second-stage surgery and abutment connection. After 18 months, all implants were stable. The radiographic comparison of marginal bone loss revealed 0.4 mm of bone loss in the experimental group and 0.8 mm of bone loss in the control group. The results for both groups were within the accepted criteria for success. These implants were followed for a total of 5 years with no failures, which suggested a "paradigm shift" for the treatment of the edentulous mandible. Ericsson and Nilner stated that due to the stability of the cross-arch rigid fixed suprastructure, the success of immediate/early loaded intraforaminal implants was equivalent to that of implants restored under traditional protocols.[30] The clinical aspects of the immediate implant restoration were summarized by Morton and associates.[31] The findings in this review were consistent with the guidelines set by Tarnow and coworkers.[21] Both studies produced a set of recommendations to achieve a proper occlusal scheme of the provisional prosthesis. The goal was to limit micromotion and thereby increase implant success. This begins with proper surgical placement of the implants and concludes with a rigid framework with a passive fit.

There has been pressure to limit the number of surgeries and decrease the total treatment time. Immediate loading should increase patient accep-

tance and satisfaction. However, it is important to continually revisit the guiding principles that make osseointegration possible. It is essential to further evaluate implant success, as defined by Albrektsson, toward these advanced treatment options.[1]

This investigation evaluated the bone level changes that take place when implants are immediately placed and immediately loaded with full-arch fixed prostheses. The treatment was to extract the remaining teeth in the arch, place at least 4 implants in the mandible or 6 implants in the maxilla, and place a fixed provisional prosthesis within 72 hours of the surgery.

Standard parallel periapical radiographs of the implants were obtained at the time of surgery (baseline), between 1 and 3 months, at final prosthesis delivery (3 to 6 months), and annually for up to 6 years. After digital analysis, the results indicate that during the first 6 months after placement, implants placed in extraction sockets showed less marginal bone loss than implants placed in native bone. After 1 year of placement, no significant difference in bone loss was found between the 2 groups. At all other time points thereafter, ES and NB implants demonstrated similar changes in marginal bone levels.

The further stratification of ES implants into those with or without an adjacent vertical defect revealed a similar degree of marginal bone loss between NB implants and ES implants without a vertical defect. A trend suggestive of less bone loss adjacent to ES implants without an adjacent vertical defect was observed. The analysis of the vertical defects adjacent to ES implants revealed that the average defect depth was 1.71 mm. One year after placement, there was a loss of bone level from the defect crest and a gain in bone level from the defect base. The resulting change in marginal bone for the ES implants was comparable to the change in bone level adjacent to NB implants at 6 to 12 months after placement.

The results of this study indicate that immediately placed implants may have a protective effect against initial bone loss. One year after placement and at all subsequent time points, the marginal bone changes of the ES and the NB implants were similar. This was true regardless of the presence of a vertical defect adjacent to an ES implant.

The marginal bone level changes reported in this study are in agreement with those reported for immediately loaded implants and implants immediately placed in extraction socket.[16,17,24] The majority of these studies employed a computer-assisted method of comparing serial radiographs, using the implant as an internal reference.

The protective effect offered by the ES implants is in agreement with the studies of Kan and associates[32] and Andersen and colleagues.[33] The results showed minor losses in marginal bone levels adjacent to implants placed in extraction sockets and in some cases gains in marginal bone due to bone fill of the adjacent defects. The bone loss reported in this study is also within the range of the specifications set forth by Albrektsson and coworkers[2] to define implant success. These results give further support to the immediate placement and loading as a treatment option for full-arch edentulism. Cooper and colleagues treated 10 patients with this method.[34] Fifty-four implants, 34 of which were placed into extraction sockets, were used to support an acrylic resin fixed denture placed at the time of surgery. Although 100% of the implants were deemed successful through mobility tests and radiographic determination of osseointegration, no attempt to quantify bone level changes was made. The investigations of Chow and associates and Grunder also show outstanding results with the immediate placement and immediate load protocol.[35,36] Chow and coworkers reported a 98.3% survival rate of 123 implants in 27 patients followed between 3 and 30 months. Grunder reported on 5 mandibles and 5 maxillae. The mandibular survival rate was 97.3% after 2 years for 43 implants, of which 31 were placed in extraction sockets. The maxillary survival rate was 87.5% after 2 years for 48 implants, 35 of which were placed in extraction sockets. Of the 6 failures, 3 were originally placed in native bone and 3 were placed in extraction sockets.

The implant survival achieved in the studies described, combined with the marginal bone level data reported in this study, further supports the immediate placement, immediate load treatment option. This implies that with proper treatment planning and patient selection, the implants placed in such scenarios will not suffer any greater marginal bone loss than implants placed under traditional protocols. The analysis of the data obtained from ES implants gives support to the theory that immediate placement takes advantage of the residual cortical plates and osteogenic potential that may be lost if socket remodeling is allowed to take place.

CONCLUSION

The implants placed with the immediate placement, immediate load protocol showed success rates equivalent to those reported with traditional methods. During the first 6 months after placement, the bone loss adjacent to implants placed in fresh extraction sockets was less than that of implants placed in native bone. After the first year, native bone implants and extraction socket implants underwent similar rates of adjacent bone loss.

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