Clinical Evaluation of Marginal Bone Level Change of Multiple Adjacent Implants Restored with Splinted and Nonsplinted Restorations: A 5-year Prospective Study

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Purpose: *The success of single-tooth implant restorations has resulted in an increased use of nonsplinted implants to replace adjacent missing teeth; however, this may result in excessive force transmission to the implant and bone, causing bone loss. The purpose of this prospective study was to compare the marginal bone level change of adjacent splinted implants and of nonsplinted implants functionally loaded with cemented restorations up to 5 years in maxillae.* ***Material and Methods:*** *Between 2002 and 2004, all patients who received three consecutive adjacent implants in a private office and a university implant dentistry department were included in this study. All implants were placed in posterior maxillae. Maxillary left implants were restored with splinted cemented restorations, and maxillary right implants were restored with nonsplinted cemented restorations. Marginal bone resorption was measured with intraoral radiographs annually for 5 years. The data were analyzed statistically with the Mann-Whitney* U *test and the two-sample Kolmogorov-Smirnov test to identify differences between splinted and nonsplinted implant restorations.* ***Results:*** *One hundred thirty-two implants were placed in 44 patients. Two subjects (6 implants in total) did not complete the study. Three implants failed at stage-two surgery. Of the remaining 123 implants, 63 were restored with splinted cemented restorations and 60 were restored with nonsplinted cemented restorations. The mean marginal bone level changes at the 5-year recall were −0.7 ± 0.2 mm for splinted restorations and −0.8 ± 0.2 mm) for nonsplinted restorations.* ***Conclusions:*** *Peri-implant marginal bone loss around nonsplinted implants in the present study was statistically equivalent to that observed in splinted implants. Multiple nonsplinted implants can be successfully included in many clinical situations in an effort to optimize esthetics and circumvent the problem of nonpassively fitting frameworks.* INT J ORAL MAXILLOFAC IMPLANTS 2010;25:1189−1194

Key words: *bone level changes, dental implants, implant crowns, implant-supported prostheses, splinting*

Marginal bone loss around implants of various systems has been described during the first year of loading and in subsequent years.[1–5] This peri-implant bone loss has been attributed to numerous factors, such as surgical trauma,[6] peri-implantitis,[7,8] occlusal overload,[9–12] biologic width formation,[13,14] implant macroscopic and microscopic characteristics at the neck region in contact with bone,[2,15–17] the implant-abutment interface design,[18–20] and the position of the microgap.[14,21] Prevention of horizontal and vertical marginal peri-implant bone resorption following loading is fundamental in maintaining stable gingival levels and profiles around implant-supported restorations.[22]

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The management of occlusal forces upon the restoration influences the long-term success of an implant-supported prosthesis.[9–12] Some authors report that splinting implants helps to distribute functional loads and therefore reduces marginal bone loss. This has been studied using finite element analysis[23] and photoelastic modeling.[24] However, it has been shown for the single-tooth implant restoration that marginal bone levels can be optimally maintained, even though these restorations are subjected to higher forces with differing vectors.[25–29] This has also resulted in an increased use of nonsplinted implants to replace adjacent missing teeth, in an effort to optimize esthetics and circumvent the problem of nonpassively fitting frameworks.[30,31]

The purpose of this prospective clinical study was to compare the marginal bone loss around adjacent splinted implants with that around adjacent nonsplinted implants functionally loaded with cemented restorations up to 5 years in maxillae.

MATERIAL AND METHODS

All consecutive patients who received three adjacent implants in a private office setting and in the Implantology Department at the University of Padua, Italy, between January 2002 and December 2004 were included in this study. Patients included in the study had no systemic contraindications for oral surgery procedures, had multiple edentulous sites in only one side of the posterior maxilla (premolar and molar areas), and had adequate bone width precluding the need for bone augmentation. All implant restorations occluded with natural teeth, and the second molars were always missing. This study was approved by the Clinical Medical Ethical Committee of the Italian Dental Association. The consent of patients was obtained prior to implant placement.

The age of the patients ranged from 37 to 58 years (mean age, 51 years). All implants were 4 mm wide and featured an external hexagon (Biomet 3i). Implants were surgically placed by the same clinician with the use of surgical guides. Maxillary left implants were restored with splinted cemented restorations, and maxillary right implants were restored with nonsplinted cemented restorations. All implants were placed at the bone crest level and radiographs were obtained to demonstrate the bone level at the time of implant placement. At second-stage surgery, 4 months after placement of the implants, matching-diameter titanium healing caps (THA54, Biomet 3i) were connected to implants. Radiographs were obtained.

The definitive impressions were made 3 weeks after stage-two surgery. Impression trays that were 2 mm thick were fabricated (Palatray LC resin, Heraeus Kulzer) in accordance with the manufacturer's instructions. The impression trays had openings to allow access for the coping screws and had been previously coated with tray adhesive (Dental-Medizin, 3M ESPE). Prior to each impression procedure, square impression copings (pick-up type, IIC12, Biomet 3i) were secured to both groups of implants. An elastomeric impression material (Impregum Penta, 3M ESPE) was machine-mixed (Pentamix, 3M ESPE), and a standard impression technique was used for all impressions.[32,33] Implant replicas (ILA20, Biomet 3i) were connected to the impression copings.[32,33] The impressions were poured with Type IV stone (New Fujirock, GC Corp). All laboratory procedures were performed by the same technician and all prostheses were provided by the same prosthodontist.

For all implants, gold abutments (SGUCA1C, Biomet 3i) were screwed to implant replicas using waxing posts, and wax (Green Inlay Casting Wax, Kerr Dental Laboratory Products) was added directly to the gold cylinders following standard waxing procedures. The waxed cylinders were then invested in a carbon-free phosphate-bonded investment (Ceramicor, Cendres & Métaux SA) and cast in a noble alloy (Esteticor Plus, Cendres & Métaux SA; composition: Au 45.0%, Pd 38.9%, Ag 5.0%, In 8.6%). The custom abutments were screwed to implants clinically using Gold-Tite screws (Biomet 3i) and torqued to 32 Ncm (Torque Driver CATDO, Biomet 3i).

Conventional metal-ceramic fixed partial restorations for the patients who received multiple splinted restorations and conventional metal-ceramic single crowns for the patients who received multiple nonsplinted restorations were fabricated. The occlusal surfaces in both groups were ceramic. All custom abutments were prepared by the technician with a chamfer preparation line, and all metal-ceramic restorations, splinted and nonsplinted, had a 0.4-mm-thick circumferential metal margin. For esthetic reasons, all margins were placed 1 mm subgingival on buccal surfaces and at the gingival level on other surfaces. The restorations were handled carefully in the dental laboratory to prevent further contamination of the abutment surfaces.[34] The occlusal surfaces of all the restorations were designed to avoid premature occlusal contacts during lateral and protrusive movements. A canine-protected articulation was the occlusal scheme for all patients. Radiographs were obtained during all prosthetic phases (impression phase, abutment try-in, final try-in). All definitive restorations, splinted and nonsplinted, were cemented with provisional cement (Temp Bond NE, Kerr Italia).

The follow-up protocol included patient assessments every 3 months during the first year and every 6 months in subsequent years. Implants were classified as surviving based on the absence of mobility; the absence of painful symptoms, discomfort, altered sensation, paresthesia, or infection attributable to the implants; the absence of peri-implant radiolucency during radiographic evaluation; and the absence of progressive marginal bone loss (mean vertical bone loss had to be < 0.2 mm annually following the first year of function).[35–37]

Radiographs were made at each follow-up appointment (Figs 1 and 2). During the 5 years following prosthetic rehabilitation, disconnection and reconnection of the abutments was avoided to prevent bone loss as described in previous animal studies.[38] During the 5-year clinical observation period, periapical radiographs were taken at each follow-up appointment for each implant using an individual stent and the long-cone technique (Fig 3). This technique was designed to control imaging geometry by consistently placing the films at a standard distance from the x-ray cone, parallel to the long axis of the implant and perpendicular to the central ray, and it

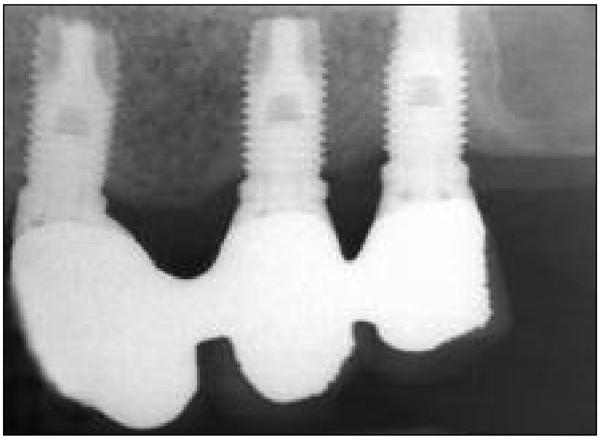

Fig 1a Radiograph showing three definitive splinted restorations in the maxillary left quadrant at the time of abutment and prosthesis placement.

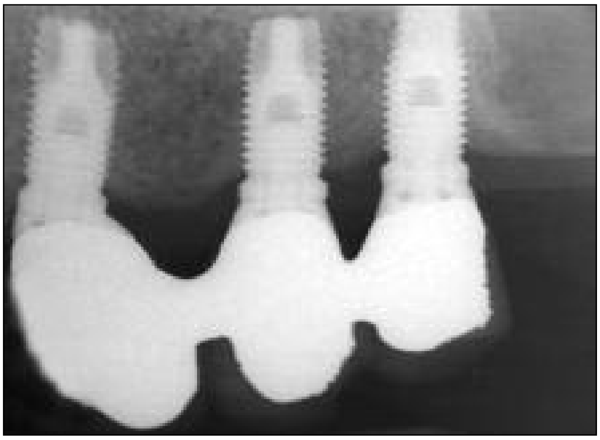

Fig 1b Same patient at 5 years after abutment and prosthesis placement.

Fig 2a Radiograph showing three nonsplinted definitive single-tooth restorations in the maxillary right quadrant at the time of abutment and prosthesis placement.

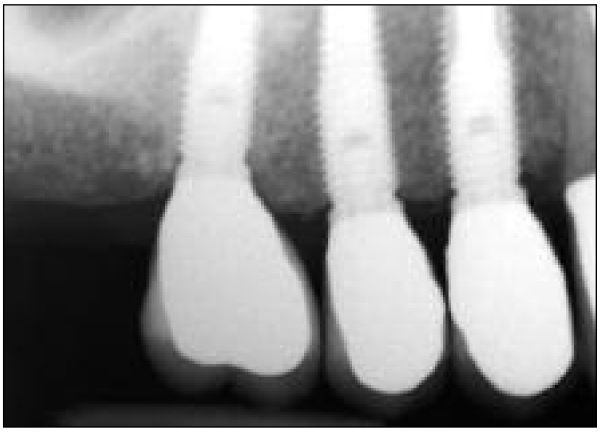

Fig 2b Same patient 5 years after abutment and prosthesis placement.

allowed standardization of consecutive radiographs, as suggested by previous studies.[39–44] The radiographic films were evaluated using a 6× magnifying lens, which permitted the measurement of marginal bone levels to an accuracy of ± 0.1 mm. The initial measurement of the marginal bone level, made with the same standardized intraoral radiographic method, was performed at the time of abutment and prosthetic restoration insertion; this measurement was used as baseline. The apical end of the smooth collar of the implants was considered the coronal reference point. All radiographic measurements were performed by the same operator. Intraoperator variability was assessed using 10 repeated measurements of the bone levels for one selected implant in each group at 1 year after abutment and prosthetic restoration insertion. The number and length of implants used and the quality of the bone[45] at the implant sites are summarized in Tables 1 and 2.

Fig 3 An individual acrylic resin stent (Duralay, Reliance Dental) was used with the long-cone technique to control imaging geometry by consistently placing the films at a standard distance from the x-ray cone, as suggested by previous studies.[39–44]

Table 1 Lengths of Implants Used

Group/length (mm)	Code	No. of implants
Maxillary left implants (splinted)		
10	OSS 410	26
11.5	OSS 411	23
13	OSS 413	14
Maxillary right implants (nonsplinted)		
10	OSS 410	24
11.5	OSS 411	19
13	OSS 413	17

Table 2 Bone Quality at Implant Sites as Determined at Placement Surgery[44]

Groups/bone quality	No. of implants
Maxillary left implants (splinted)	
Type 1	19
Type 2	17
Type 3	17
Type 4	10
Maxillary right implants (nonsplinted)	
Type 1	20
Type 2	15
Type 3	15
Type 4	10

The Mann-Whitney *U* test and the two-sample Kolmogorov-Smirnov test were used to determine whether there was a statistically significant difference in the change in peri-implant marginal bone level between the implants restored with splinted restorations and the implants restored with nonsplinted restorations.

RESULTS

One hundred thirty-two implants were placed in 44 patients (23 women and 21 men). Two subjects (who had received six implants altogether) did not complete the study. All other patients returned to the office for recall appointments. All implants under investigation have been accounted for.

Three implants in one patient had failed by the time of stage-two surgery, before the definitive prosthetic rehabilitation was completed; this male patient was restored with a removable partial denture. Of the remaining 123 implants, 63 maxillary left implants were restored with splinted cemented restorations and 60 maxillary right implants were restored with nonsplinted cemented restorations. All 123 implants survived. No patient reported any prosthetic complications. With respect to intraoperator variability, the standard deviations of the 10 repeated measurements were 0.1 mm for the selected implants of both groups. These small standard deviations indicate acceptable reliability of the measurement method.

Radiographs obtained at 4 months (stage-two surgery) showed no significant differences between groups. The mean (± SD) marginal bone level at the last recall, 5 years after abutments and prosthetic restorations were placed, was –0.7 ± 0.2 mm for implants with splinted cemented restorations and –0.8 ± 0.2 mm for implants with nonsplinted cemented restorations. There was no significant difference between groups ($P < .05$).

DISCUSSION

This 5-year prospective clinical study presents the results from 132 implants placed in 44 patients during the years 2002 to 2004. Adjacent implants were restored with metal-ceramic splinted restorations or with metal-ceramic nonsplinted restorations. These implants were evaluated radiographically for 5 years following prosthodontic rehabilitation with respect to peri-implant marginal bone level changes. The bone levels around the nonsplinted implants were equivalent to those observed around splinted implants.

Three implants were found to have failed at stage-two surgery before the definitive prosthetic rehabilitation was completed. This male patient had suffered some systemic cardiac complications after implant placement, and his dentition was restored with a removable partial denture.

No patients reported any prosthetic complications. No loosening of the abutment screws was observed in either group. Accurate evaluation of the occlusal scheme and the provision of appropriate variations in the occlusal contacts, both static and dynamic, may explain the lack of prosthetic complications, such as porcelain fracture or loosening of provisionally cemented definitive splinted or nonsplinted metal-ceramic restorations. All patients had a Class I canine relationship, although it was unusual that the same occlusal scheme was present in so many consecutive cases. The canine-protected occlusion was maintained for all patients.

In this study, all patients who received three adjacent implants were included. Maxillary left implants were restored with splinted cemented restorations and maxillary right implants were not splinted. In these studied cases, the ideal inclusion criteria should have been implants with a direct occlusal load; however, this is difficult to find in partially edentulous patients because of the different axial displacements between teeth and implants. Bone remodeling is related to the amount of loading, and the published data have suggested that functional loading of implants does not result in marginal bone loss. Therefore, splinted implants are usually indicated in clinical situations where there is a risk of mechanical overloading to reduce the forces on implants and surrounding tissues.[9–12] This study may have been more interesting if functional loads had been applied and the distributions of occlusal loads could have been evaluated. This would include, for example, immediate function with low primary stability, nonaxial loading, small (short or narrow) implants, poor bone quality, etc.

The results of the present clinical study indicate that nonsplinted implants can be successfully included in implant treatment. Here, nonsplinted implants showed an overall survival rate comparable to that obtained with splinted implants.

One limitation of this study may be represented by the measurement technique used in the research protocol. Accurate and reliable measurement methods are required to evaluate bone levels proximal to oral implants.[40] All radiographs in this study were performed with a standardized film holder. This device was designed to control imaging geometry by consistently placing the films at a standard distance from the x-ray cone, parallel to the long axis of the implant and perpendicular to the central ray. The radiographic films were then evaluated using a 6× magnifying lens. However, in a previous study, the microscope-assisted measurement technique of standardized radiographs was compared to the computer-assisted measurement technique. The computer technique showed low intraoperator and interoperator variability, and operators found fewer "unreadable" sites compared to the microscope technique.[43]

An advantage of nonsplinted implants is in the elimination of large prostheses with large quantities of metal and ceramic; this may reduce the risk of veneer and framework fracture.[31] When nonsplinted single-tooth restorations on multiple adjacent implants are used, if one unit is compromised, only one unit, rather than the entire multiple-unit fixed partial denture, needs to be removed. However, it also should be noted that there is a cost benefit in placing three units on two implants, as well as a real benefit in splinting three units if one implant subsequently fails. There is, in effect, a ready made fixed partial denture with minimal need for modification, and no delay is required for healing and integration of a replacement implant.

From an esthetic standpoint, nonsplinted single-tooth restorations on adjacent implants have the potential to give the impression of being more individual (and thus natural looking) than is often obtainable in a splinted situation.[31] Patients also appreciate the ability to more easily floss between units, as compared to the task of threading floss under a fixed partial denture. It should be emphasized that in this study only external-hexagon implants were used; however, similar conclusions were reached in studies that used internal-connection implants.[31] Furthermore, both groups were restored with cemented definitive prostheses. Different results may be achieved using screw-retained restorations. In fact, the influence of the cementation space acting as a stress release compared to the passivity problems associated with screw-retained prostheses should be studied.[46–48]

It should also be noted that all implants were placed only in the posterior maxilla. Further studies should be carried out in the anterior maxilla and in the mandible.

CONCLUSIONS

Within the limitations of this investigation, the following conclusions can be drawn:

1. The peri-implant marginal bone level changes around the nonsplinted implants used in the present study were comparable to those observed around splinted implants.
2. Multiple nonsplinted implants can be successfully included in many clinical situations.

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