Split-Mouth Comparison of Splinted and Nonsplinted Prostheses on Short Implants: 3-Year Results

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Purpose: *To compare splinted and individual restorations supported by short implants featuring an internal connection utilizing a split-mouth design.* ***Materials and Methods:*** *Splinted and nonsplinted implant crowns were prospectively compared in 18 patients. After verifying the need for at least two consecutive implants bilaterally, computed tomography scans were made, virtual planning was done, and qualifying patients were enrolled. Implants were placed using a two-stage surgical approach. After 3 to 5 months, patients were randomly restored with splinted prostheses on their left or right side. Nonsplinted restorations were made for contralateral sides. Radiographs were taken at prostheses seating and yearly exams. Radiographic bone levels were analyzed and compared (SAS 9.4) to determine differences between splinted and nonsplinted implants. Complications such as screw loosening, screw breakage, or porcelain fracture were assessed at recalls.* ***Results:*** *Eighteen patients (9 men and 9 women) with an age range from 49 to 76 years (mean = 56 years), received ≥ 4 implants in symmetrical posterior locations. Implants (n = 82) ranged in length from 6 to 11 mm with 70 implants ≤ 9 mm and 38 implants = 6 mm. At the time of this report, 3-year examinations and bone level comparisons were completed on 15 patients. One patient was lost to follow-up, one deviated from study protocol by smoking, and one was splinted on both sides due to repeated screw breakage. Screw loosening occurred in five patients on their nonsplinted side. These were 6-mm implants except for one patient. Porcelain chipping occurred for one patient on the splinted side. One 6-mm-length nonsplinted implant was lost after loading; this implant was successfully replaced after grafting. This patient had a total of six implants placed; ongoing bone level measurements included two pairs of implants only. For all implants combined, there was no significant difference (P > .05) at 1, 2, or 3 years for mean bone change around splinted and nonsplinted implants. However, length was identified as a significant factor (P = .0039). Further analysis revealed statistically significant differences between splinted and nonsplinted for 6-mm-length implants at 24 (P = .0061) and 36 (P = .0144) months. A gain in mean bone level of 0.41 and 0.37 mm was observed for nonsplinted implants at 24 and 36 months compared with baseline. Bone levels for the splinted 6-mm implants were not statistically different from baseline measurements (P > .05).* ***Conclusion:*** *Results of this prospective 3-year study of splinted ipsilateral and nonsplinted contralateral implants in 15 patients show: (1) peri-implant bone levels around splinted and nonsplinted implants were not statistically different for implants greater than 6 mm in length; (2) nonsplinted 6-mm implants revealed a gain in bone at 24 and 36 months compared with baseline; (3) all screw loosening only occurred on the nonsplinted side for 5 of 15 patients; and (4) implant loss after loading occurred for one 6-mm nonsplinted implant.* Int J Oral Maxillofac Implants 2016;31:1135–1141. doi: 10.11607/jomi.4565

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Considerations for deciding to splint or not to splint adjacent implants include implant length, occlusion, hygiene, abutment connection design, and difficulty achieving a passively fitting framework. Load sharing by splinting restorations is frequently planned when implant length, occlusion, or potential for screw loosening are considered to be less than optimum. When these factors are considered to be favorable, individual restorations may be preferred for ease of hygiene and framework passivity. However, current literature has minimal clinical evidence to help clinicians make this decision.

Historically, a high frequency of screw loosening was one reason to splint adjacent externally hexed implants.[1,2] Load sharing was another reason to splint.[3,4] In vitro studies showed more even stress patterns for splinted implants featuring an external hex.[3,4]

Implant length has also been considered to be a key factor in the decision to splint. Earlier clinical studies reported a decrease in the clinical success of implants shorter than 10 mm.[5–9] These clinical findings provided support for splinting short implants.

One clinical study concluded that multiple nonsplinted implants ≥ 10 mm can be successfully used.[10] This was based on no significant difference in bone level changes between splinted and nonsplinted implants. Implants ranged between 10 and 13 mm in length and featured an external hex connection. All restorations were cement retained, and no patients received both splinted and nonsplinted prostheses.

Much of the rationale for splinting has been based on evidence for externally hexed implants. Internal connections have shown increased joint stability.[11] This may be the reason to reevaluate splinting recommendations.

A recent clinical study reported a high 2-year success rate for 6-mm-length implants featuring internal connections.[12] However, all of the implants in this study were splinted.

There are no published studies comparing splinted and nonsplinted short implants in the same patient population.

An in vitro study compared splinted and nonsplinted 6-mm-length implants with internal connections.[13] For these very short implants, stress distributions were significantly different under oblique loading conditions where splinting was favored. Although splinting was preferred for 6-mm implants, the authors recommended clinical evaluation.

This prospective study aimed to compare splinted and nonsplinted short implants in the same patient population.

MATERIALS AND METHODS

This 5-year prospective clinical study comparing splinted and nonsplinted implant crowns was approved by The Ohio State University institutional review board for 20 patients based on the following inclusion and exclusion criteria.

Patients were required to meet the following inclusion criteria: *(1)* at least two missing teeth in the same locations bilaterally, *(2)* similar available bone on both sides to accommodate use of the same implant sizes, *(3)* bone height between 7 and 12 mm, *(4)* at least 18 years of age, *(5)* willing to participate for the duration of the study including 5-year follow-up postrestoration, *(6)* willing to provide informed consent, *(7)* general good health, *(8)* without dental pathologies, *(9)* ample bone to fully accommodate the implants without impinging on vital structures, *(10)* extractions done at least 3 months prior to implant placement, *(11)* restored following 2 to 3 months healing time for the mandibular arch and 4 to 5 months healing time for the maxillary arch, and *(12)* restored with opposing occlusion.

Patients were excluded from the study if any of the following applied: *(1)* untreated caries and/or periodontal disease of residual dentition; *(2)* edentulism in the area of implant placement of less than 2 months; *(3)* current need for presurgical bone or soft tissue augmentation in the planned implant area; *(4)* presurgical bone or soft tissue augmentation, within 5 months, in the planned implant area; *(5)* systemic or local disease or condition that would compromise postoperative healing and/or osseointegration; *(6)* systemic corticosteroids or any other medication that would compromise postoperative healing and/or osseointegration; *(7)* current alcohol or drug abuse; *(8)* unable or unwilling to return for follow-up visits for a period of 5 years; *(9)* current use of smoking tobacco; *(10)* current use of bisphosphonates; or *(11)* pregnancy or nursing at the time of enrollment.

Screening and Planning Protocol

Diagnostic impressions were made with irreversible hydrocolloid (Kromopan 100, Lascod) and poured in Type III stone (Quickstone, Whip Mix) for study candidates. Barium teeth (Ivoclar Vivadent) were diagnostically arranged using type II regular base plate wax (Tru wax, Dentsply Trubyte) for visibility on cone beam computed tomography (CBCT) scans. Scan appliances were subsequently processed with clear polymethylmethacrylate acrylic resin (Ortho-Jet, Lang Dental Manufacturing Company).

Scan guides were clinically evaluated and adjusted as necessary to achieve stable fit. CBCT scans (i-CAT, Imaging Sciences International) were taken with the scan appliances seated. FacilitatePro software (DENTSPLY Implants) was used to plan for implant sizes and positions. Virtual implant placement was planned for optimal surgical location and ideal prosthetics by the surgery and prosthodontic team. After plans were made and eligibility confirmed, patients had surgical consults and were informed whether they qualified for inclusion in the study. Patients officially enrolled in the study by paying the determined fee and signing the consent forms. Following enrollment, computer-aided design/computer-assisted manufacturing (CAD/CAM) surgical guides (Materialise Dental) were designed and ordered.

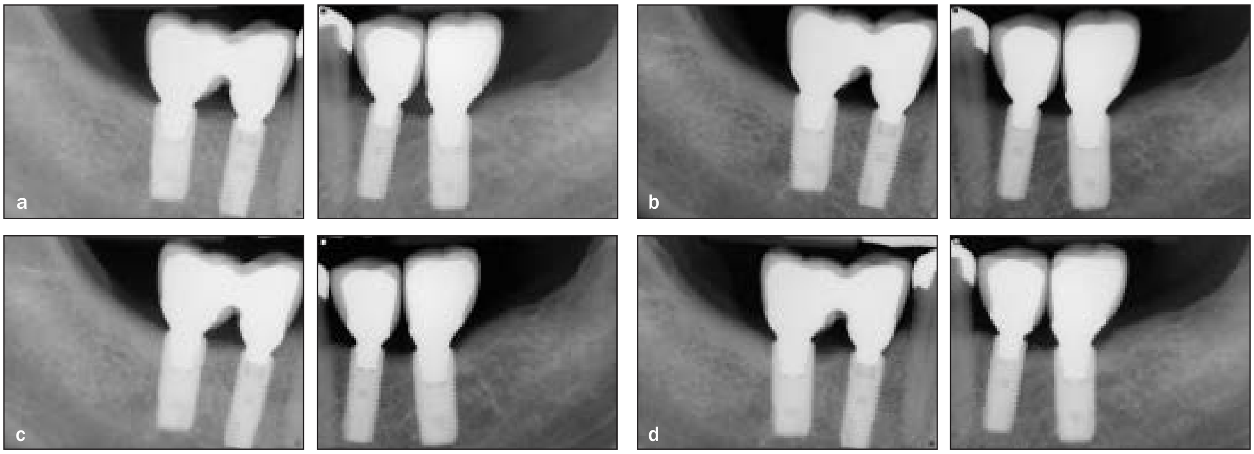

Fig 1 Radiographs taken at *(a)* prostheses seating appointment (baseline), *(b)* 1-, *(c)* 2-, and *(d)* 3-year recalls.

Surgical Protocol

Qualifying patients received four to eight study implants (OsseoSpeed, DENTSPLY Implants). Patients with asymmetrical edentulous areas received additional nonstudy implants. All implants were placed by the same surgeon in symmetrical locations using CAD/CAM surgical guides and a two-stage surgical protocol. CAD/CAM guides could not be fully used for five patients due to limited interocclusal distance. In these situations, guides were used to communicate pilot drill position only. For two other patients, CAD/CAM guides fractured prior to completion of surgery. Osteotomies were prepared using the drill sequence recommended by the guide protocol with external irrigation. Healing abutments were seated after implant placement, and panoramic films were taken. Mandibular and maxillary implants were scheduled for uncovery and restorations following 3 or 5 months, respectively.

Prosthetic Protocol

Following 3 or 5 months, definitive impressions were made using polyvinylsiloxane (Reprosil, Dentsply) after confirming complete seating of impression posts (DENTSPLY Implants) with radiographs. Implant replicas (DENTSPLY Implants) were connected to the impression posts. Impressions were poured with type IV stone (Kerr Supra Stone). Patients were randomly restored with splinted prostheses on their left or right side. Nonsplinted restorations were made for contralateral sides. For consistency, the same abutment type (Cast Design, DENTSPLY Implants) was used for all restorations. Occlusal surfaces were the same bilaterally for all patients. Screw retention was achieved for all patients except one who received cement-retained crowns. All laboratory procedures were performed by the same commercial laboratory, and all prostheses were provided by two prosthodontists. Complications such as screw loosening, screw breakage, porcelain fracture, or implant failure were assessed at annual examinations and compared for different implant dimensions. Patient preference for splinted or nonsplinted crowns was also recorded.

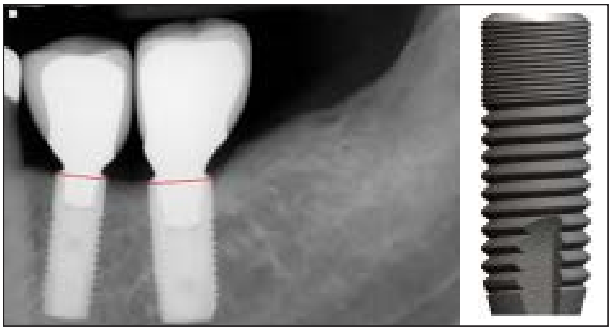

Fig 2 Reference point for bone level measurements at base of machined implant bevel.

Radiographic Protocol

Radiographs were taken at prostheses insertion and yearly examinations (Fig 1). Radiographs for 1, 2, and 3 years were analyzed and compared for bone level changes by a calibrated radiologist using the bottom of the machined bevel as a reference point (Fig 2). Radiographs taken at the time of prosthesis insertion were used as the baseline. All measurements were corrected for magnification based on the diameter of the implant used.

Statistical Protocol

Data for splinted and nonsplinted implants were compared using SAS 9.4 (SAS), which was used for all statistical analyses. Group means and standard deviations were calculated. Splinted and nonsplinted prostheses were compared for all implant lengths using a mixed models repeated measures analysis of variance (ANOVA). A separate analysis was performed on the 6-mm

Table 1 Summary of Patient Demographics and Prosthetic Complications After Loading

Patient	Site of study implants[a]	Implant sizes	3-year recall status	Age (y)	Sex	Screw loosening	Porcelain chipping	Broken screws	Failure after loading
1	36, 35, 45, 46	4 × 6 mm for all	Active	69	F				
2	37, 36, 35, 45, 46, 47	4 × 6 mm for all	Active Data 37, 36, 46, 47	68	M	Nonsplinted			Nonsplinted
3	36, 35, 45, 46	4 × 6 mm for all	Active	67	F	Nonsplinted			
4	36, 35, 45, 46	4 × 11 mm for 35, 45 5 × 11 mm for 36, 46	Active	65	M				
5	37, 36, 46, 47	4 × 6 mm for 37, 47 4 × 8 mm for 36, 46	Active	66	F		Splinted		
6	36, 35, 45, 46	4 × 11 mm for all	Active	53	F				
7	36, 35, 34, 44, 45, 46	4 × 6 mm for all	Active	61	M				
8	36, 35, 45, 46	5 × 9 mm for 36, 46 4 × 11 mm for 35, 45	Active	56	M	Nonsplinted			
9	37, 36, 46, 47	4 × 6 mm for 37, 47 5 × 9 mm for 36,46	Active	59	F				
10	36, 35, 45, 46	3.5 × 9 mm for 35, 45 4 × 8 mm for 36, 46	Active	60	M				
11	36, 35, 45, 46	5 × 9 mm for 36, 46 4 × 11 mm for 35, 45	Active	65	M				
12	36, 35, 45, 46	4 × 6 mm for all	Active	76	F	Nonsplinted			
13	37, 36, 46, 47	4 × 6 mm for 37, 47 4 × 8 mm for 36, 46	Active	63	F				
14	37, 36, 46, 47	4 × 8 mm for 37, 47 5 × 9 mm for 36, 46	Active	72	M				
15	16, 15, 25, 26	4 × 6 mm for 15, 25 4 × 9 mm for 16, 26	Active	49	F	Nonsplinted			

[a]FDI tooth-numbering system.

implants with Dunnett's and Stepdown Bonferroni adjustments for multiple comparisons.

RESULTS

Eighteen patients (9 men and 9 women) with an age range from 49 to 76 years (mean = 56 years) received ≥ 4 implants in symmetrical posterior locations (Table 1). Implant lengths ranged from 6 to 11 mm and were classified as very short (6 mm), short (8 or 9 mm), or standard (11 mm). A total of 82 study implants were placed with 70 implants ≤ 9 mm and 38 implants = 6 mm. Only 12 implants were considered standard length.

Three patients received restorations made of gold alloy (Wilcast 50c, Wilkinson Dental Alloys). Restorations for all other patients were metal ceramic using low-fusing OMEGA 900 porcelain (Vident) and a high palladium alloy (Wilpal PF, Wilkinson Dental Alloys).

At the time of this report, 3-year exams and bone level comparisons had been completed on 15 of the 18 patients enrolled. One patient was lost to follow-up, one deviated from study protocol by smoking, and one was splinted on both sides due to repeated screw breakage and unwillingness to wear an occlusal guard (Fig 3). For this last patient, the broken prosthetic screws occurred 7 weeks and 13 weeks after receiving his prostheses. In an effort to improve the outcome for this patient, individual crowns were replaced with a splinted restoration. Subsequently, all recall radiographs show bone levels for two splinted sides and offered no comparison for splinted and nonsplinted prostheses. Approximately 1 year after receiving the splinted replacement prosthesis, this patient returned with two broken screws on the replacement side. Prosthetic screws were replaced with newer alloy screws (DENTSPLY Implants), and cusp angles were made shallower. No further prosthetic complications have been reported for this patient.

Table 2 shows the bone level data for 15 patients. All measurements were made from the base of the machined beveled implant surface and corrected for magnification based on known implant diameters. At baseline when prostheses were seated, mean bone

Fig 3 Broken screws occurred for one male patient on the nonsplinted side, twice. These 9-mm implants were subsequently splinted, and an occlusal guard was delivered. This exceptional patient did not wear the occlusal guard and returned with 2 broken screws.

Table 2 Mean Bone Levels Measured Below Machined Bevel Surface of All Implants (Including All Lengths) and Standard Deviations

Type	Time (mo)	Mean distance (mm)	SD (mm)
Nonsplinted	0	0.75	0.92
	12	0.66	0.79
	24	0.47	0.74
	36	0.44	0.58
Splinted	0	0.76	0.80
	12	0.67	0.80
	24	0.61	0.72
	36	0.68	0.82

Table 3 Mean Bone Levels Measured Below Machined Bevel Surface of 6-mm Implants and Standard Deviations

Type	Time (mo)	Mean distance (mm)	SD (mm)
Nonsplinted	0	0.51	0.65
	12	0.33	0.41
	24	0.10	0.19
	36	0.14	0.22
Splinted	0	0.56	0.65
	12	0.55	0.63
	24	0.51	0.60
	36	0.52	0.64

levels for the nonsplinted crowns were 0.75 ± 0.92 mm below the base of the machined beveled surface. For the nonsplinted group, mean bone levels revealed a gain in bone at 12, 24, and 36 months (0.66 ± 0.79, 0.47 ± 0.74, and 0.44 ± 0.58 mm). This mean cumulative gain in bone for nonsplinted implants (0.09, 0.28, and 0.34 mm) was not statistically significant ($P > .05$) with all implant lengths combined; however, it did suggest a trend ($P = .0569$) toward more bone at 36 months for nonsplinted implants. Mean bone levels for all splinted implants combined revealed little variation from baseline (0.76 ± 0.80 mm) to 12 months (0.67 ± 0.80 mm), to 24 months (0.61 ± 0.72 mm), or to 36 months (0.68 ± 0.82 mm).

Length was identified as a significant factor ($P = .0039$). There were statistically significant differences between splinted and nonsplinted 6-mm-length implants at 24 ($P = .0228$) and 36 months ($P = .0321$). These results are listed in Table 3. A gain in bone level (0.41 and 0.37 mm) was observed for nonsplinted implants at 24 months (0.10 ± 0.19 mm) and 36 months (0.14 ± 0.22 mm) compared with baseline (0.51 ± 0.65 mm). This gain in bone was statistically significant for the nonsplinted 6-mm implants at 24 ($P = .0061$) and 36 ($P = .0144$) months compared with baseline. Bone levels at 12 (0.56 ± 0.65 mm), 24 (0.51 ± 0.60 mm), and 36 (0.52 ± 0.64 mm) months for the splinted 6-mm implants were not statistically different ($P > .05$) from baseline measurements (0.56 ± 0.65 mm).

Screw loosening was the most frequent prosthetic complaint. It was limited to nonsplinted crowns. These were supported by 6-mm implants with one exception (Table 1). One 6-mm-length nonsplinted implant was lost after loading. This implant was successfully

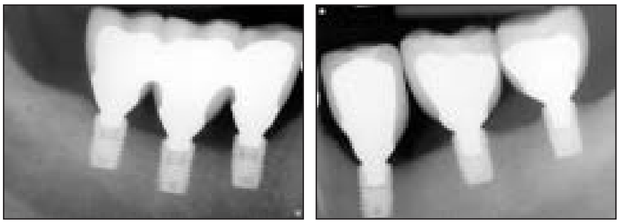

Fig 4 Patient with 6-mm implants showing a high crown-to-implant ratio and clinical crown height.

replaced. This patient had a total of six implants placed. Ongoing bone level measurements for this patient include two pairs of implants only.

One patient experienced porcelain chipping on their splinted side. The prosthesis was returned to the lab for repair. No further porcelain fractures were observed following initial repair. Porcelain fractures were not observed for nonsplinted crowns.

Of the 15 patients who qualified for bone level comparisons, 7 patients preferred the nonsplinted restorations, 4 patients had no preference, and 4 patients preferred splinted restorations. Patients who preferred nonsplinted restorations reported that hygiene was easier. Splinted restorations were the preference of patients who had experienced screw loosening.

DISCUSSION

For this clinical prospective study, the majority of complications involved nonsplinted prostheses supported by 4 × 6-mm implants. These findings make sense when compared with a previous in vitro comparison of splinted and nonsplinted implants.[13] Statistically significant differences were found for splinted and nonsplinted groups when 6-mm-length implants were subjected to oblique loading.[13] For this in vitro study, splinted 6-mm implants distributed strains more evenly.[13] This observation suggests biomechanical differences between splinting and not splinting and agrees with a previous treatment planning summary recommending splinting of posterior implants to reduce the incidence of screw loosening.[14]

The incidence of screw loosening for the nonsplinted 6-mm-length implants may be at least partially explained by their placement in patients with considerable bone resorption. This leads to greater interarch distance, increased crown-to-implant ratio, and increased clinical crown height. Conventional prosthodontics has long considered a 1:1 crown-to-root ratio as a minimum standard. For the present study, crown-to-implant ratios were as high as 2:1 for these very short implants (Fig 4), yet bone levels remained stable (Table 3). There has been previous evidence that crown-to-implant ratios as great as 2:1 do not adversely affect bone level changes around short implants.[15,16]

The screw loosening observed in the present study may have been more related to clinical crown height, which reached 12 mm for some patients (Fig 4). A finite element study showed that 30-degree off-axis loading on a crown 12 mm in height almost doubled the amount of stress compared with a crown 6 mm in height.[17] Since increased crown height caused increased stress, the authors concluded that increased crown height is likely to affect the components as well.[17] Nissan et al also tested the influence of various crown heights as well as crown-to-implant ratios using strain gauges cemented to a photoelastic model.[18] Although both increased crown-to-root ratio and increased crown height created less favorable stress distribution with off-axis loading, the authors concluded that clinical crown height was a more significant factor for biomechanical outcomes such as screw loosening, fracture, or implant failure.[18] Results of finite element stress analyses showing stress distributions concentrated in crestal bone regardless of implant length contributed to their conclusion.[19]

In addition to screw loosening, one patient lost a 6-mm-length implant on their nonsplinted side after loading. Failures are more likely to occur in areas of advanced bone resorption.[5] For the present study, this is where the 6-mm implants were placed. Yet, all splinted 6-mm implants survived. It may be that splinting was a positive factor in the success of very short implants. Pieri et al also reported high success rates for splinted 6-mm implants.[12]

Overall, splinted restorations in this study were highly successful, with the exception of porcelain chipping for one patient on the splinted side. The involved prosthesis was supported by 4 × 8-mm implants. Fabrication error, bruxism, porcelain type, or opposing occlusion are some of the factors related to porcelain chipping.[20] For the present study, these factors were similar bilaterally; however, no chipping occurred on nonsplinted restorations. This may reflect a difference in the level of framework accuracy between splinted and nonsplinted restorations and provide support for not splinting adjacent implants. Achieving a passive fit for splinted restorations has been shown to be more difficult and could have played a role in the minor porcelain fractures observed.[21]

In the absence of complications, individual restorations were preferred by patients over splinted restorations due to ease of hygiene. Statistical analysis of bone level changes failed to show significant differences between splinted and nonsplinted implants at baseline, 1, 2, or 3 years when all implant lengths were combined. These results agree with radiographic findings from a previous prospective evaluation of splinted and nonsplinted implants ranging in length from 10 to 13 mm.[10]

The present study revealed a trend toward increased bone levels for nonsplinted implants as compared with baseline. Interestingly, this increase in bone was statistically different for 6-mm nonsplinted implants at 24 and 36 months compared with baseline, whereas bone levels for the splinted 6-mm implants were not different from baseline. This gain in bone for the nonsplinted 6-mm implants was less than half a millimeter and may not be clinically significant. Further studies would help corroborate this nonintuitive finding.

CONCLUSIONS

According to the results of this prospective 3-year study of splinted ipsilateral and nonsplinted contralateral implants in 15 patients: *(1)* peri-implant bone levels around splinted and nonsplinted implants were not statistically different for implants greater than 6 mm in length; *(2)* nonsplinted 6-mm implants revealed a gain in bone at 24 and 36 months compared with baseline; *(3)* all screw loosening only occurred on the nonsplinted side for 5 of 15 patients; and *(4)* implant loss after loading occurred for one 6-mm nonsplinted implant.

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