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Tilted implants for implant-supported fixed hybrid prostheses: retrospective review

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Abstract (J Korean Assoc Oral Maxillofac Surg 2023;49:278-286)

Objectives: This review assessed the performance of implant-supported fixed hybrid prostheses in 21 patients who received a total of 137 implants between 2003 and 2010. The implants were evaluated for marginal bone resorption, complications, success rate, and survival rate based on their vertical angularity, type of bone graft, and measured implant stability.

Materials and Methods: One-way ANOVA and chi-square tests were used to analyze the relationships among long-term evaluation factors and these variables. The mean initial bone resorption in the implant group with a vertical angle of more than 20° was 0.33 mm and mean final bone resorption was 0.76 mm. In contrast, the mean initial bone resorption in the implant group with a vertical angle of less than 10° was 1.19 mm and mean final bone resorption was 2.17 mm.

Results: The results showed that mean bone resorption decreased with an increase in the vertical placement angle of the implants used in fixed hybrid prostheses, as well as in the group without additional bone grafts and those with high implant stability. The success rate of implants placed after bone grafting was found to be higher than those placed simultaneously.

Conclusion: These results suggest that implant-supported fixed hybrid prostheses may be an effective treatment option for edentulous patients, and intentionally placing implants with high angularity may improve outcomes.

Key words: Implant-supported dental prosthesis, Dental implant, Bone transplantation, Bone resorption

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I. Introduction

Implant-supported full-mouth prostheses function more like natural teeth during mastication and have greater stability than conventional dentures[1,2]. There are currently three main types of implant-supported prostheses for fully edentulous patients: full-mouth implant-supported fixed prostheses, implant overdentures, and fixed hybrid prostheses[3,4]. Fixed hybrid prostheses are one-piece implant-supported prostheses with relatively few anterior implants (at least six for the maxilla and four for the mandible) and posterior cantilevers for better bone support. They have been used for more than 20 years in fully edentulous patients with insufficient bone height for implantation, and they carry relatively less risk of damage to anatomic structures such as the maxillary sinus or inferior alveolar nerve. Because fixed hybrid prostheses involve the strategic positioning of supporting implants, clinicians can intentionally tilt the posterior implants to avoid risky structures and provide proper posterior extension.

There can be some questions about how the posterior cantilevers and slightly anterior-crowded implants of fixed hybrid prostheses hold up during mastication. According to a study by Aglietta et al.[5], complications with implant-supported prostheses with posterior cantilevers occurred in approximately 88.9% of patients with 7 years of follow-up, with the most common complications being prosthetic failures such as fracture of the resin pontic and screw loss. That finding raises concerns about the lifespan and durability of the supporting implants, which can be tilted, as described above. Few long-term studies have evaluated the implants that support fixed

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hybrid prostheses, especially with consideration of tilted implants. In this retrospective review, we specifically examine the long-term effects of implant angulation and bone grafting on marginal bone resorption, complications, the success rate, and the survival rate of implants used to support fixed hybrid prostheses for at least 7 years, and we evaluate their prognosis and clinical outcomes.

II. Materials and Methods

1. Study subjects

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (No. B-2211-791-101). The subjects were patients who underwent implant surgery and completed prosthetic treatment between 2003 and 2010 at Seoul National University Bundang Hospital.

1) Inclusion criteria

Patients who received implant surgery for full-mouth fixed hybrid prostheses at Seoul National University Bundang Hospital and had at least 7 years of follow-up after the prostheses were first delivered.

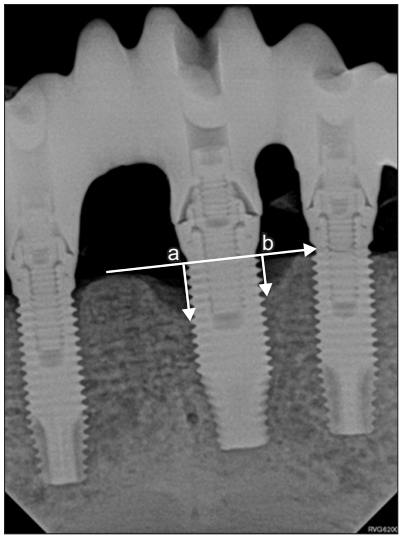

Fig. 1. The mean alveolar bone resorption was measured radiographically using the PACS program. The mesial and distal measurements of the linear distance between the implant shoulder and the bone–implant contact were taken and averaged to determine the mean bone resorption. a: assumed mesial bone resorption. b: assumed distal bone resorption. Mean bone resorption=(a+b)/2.
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2) Exclusion criteria

• Patients were excluded from the study if they received implant surgery for a fixed hybrid prosthesis, but their follow-up records were lost before the prosthesis was completed and delivered.

• Implants that failed before the first delivery of the fixed hybrid prosthesis due to early osseointegration failure were excluded from the study.

• Implants that were installed for a fixed hybrid prosthesis but ultimately not included in the final design of the prosthetic structure were also excluded from the study.

2. Marginal bone resorption

Marginal bone resorption of the implants was measured using intraoral peri-apical radiography (Heliodent Sirona; Sirona Dental Systems Inc.) and a radiographic analysis program (PACS; INFINIT Co.) at Seoul National University Bundang Hospital. The distance from the shoulder of each implant to the uppermost point forming the implant–bone contact was measured separately from the mesial and distal sides, and the mean value of those two measurements was considered to be the mean marginal bone resorption of the implant.(Fig. 1) The peri-apical radiograph taken immediately after implant surgery was set as the initial radiograph. Initial bone resorption was measured by comparing the peri-apical radiograph taken about a year after implant surgery with the initial radiograph, and final bone resorption was measured by comparing the peri-apical radiograph taken at the final examination with the initial radiograph.

3. Complications

The occurrence of biological and prosthetic complications from the implants was investigated.(Table 1)

Table 1. Complications observed

Biological complications	Prosthetic complications
Peri-implantitis	Screw loosening
Infection	Screw fracture
Nerve injuries	Fixture fracture
Wound dehiscence	Food impaction
Implant thread exposure	Crown fracture
	Abutment fracture
	Abnormal changes in occlusion
	Pontic failure
	Denture fracture

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4. Implant survival/success rate

The implant survival/success rate was analyzed based on Health Scale for Dental Implants, 2007, presented by the International Congress of Original Implantologists[6]. We defined implant survival as meeting the condition for either "satisfactory survival" or "compromised survival."

5. Evaluation of different variables

1) Implant angulation

All of the selected implants were divided into three groups based on their vertical angle, as measured on radiographs (Fig. 2); Group 1: Implants with a vertical angle of 10° or less, Group 2: Implants with a vertical angle more than 10° and less than 20°, Group 3: Implants with a vertical angle of 20° or more.

For each group, the marginal bone resorption, occurrence of complications, success rate, and survival rate of the implants were evaluated, and the statistical significance of differences in those factors between the groups was investigated.

2) Bone graft

Results were also compared between implants installed with and without bone grafting. When bone grafting was performed, implants that were installed simultaneously with the bone graft and those installed after a delay were also compared. Patients in this study were treated with bone grafting materials such as auto tooth bone graft, Bio-Oss (Geistlich Pharma AG), Biocera-F (BIOTEM), and Orthoblast II (Isotis Orthobiologics), and with membrane products such as Bio-Gide (Geistlich Pharma AG), OSSIX plus (Orapharma), and Bio-ARM (ACE Surgical Supply Co.), but comparisons among the different grafting materials and membrane products were not conducted.

3) Implant stability

Almost half the implants considered in this study were tested with an Osstell ISQ kit (Osstell), which uses a resonance frequency analysis (RFA) to measure the stability of implants. In this study, primary stability was measured immediately after implant installation, and secondary stability was measured at the second surgery, when the healing abutment was connected. The initial and secondary stability measured using the ISQ kit was compared between the group with a score of 60 or higher and the group with a stability of less than 60 points.

6. Data analysis

Data analysis was performed using IBM SPSS Statistics (ver. 25.0; IBM). One-way ANOVA testing was conducted to analyze the relationships between marginal bone resorption and the vertical angle of the implant, whether bone grafting was performed, the delayed or simultaneous positioning of implants with bone grafts, the initial and secondary stability.

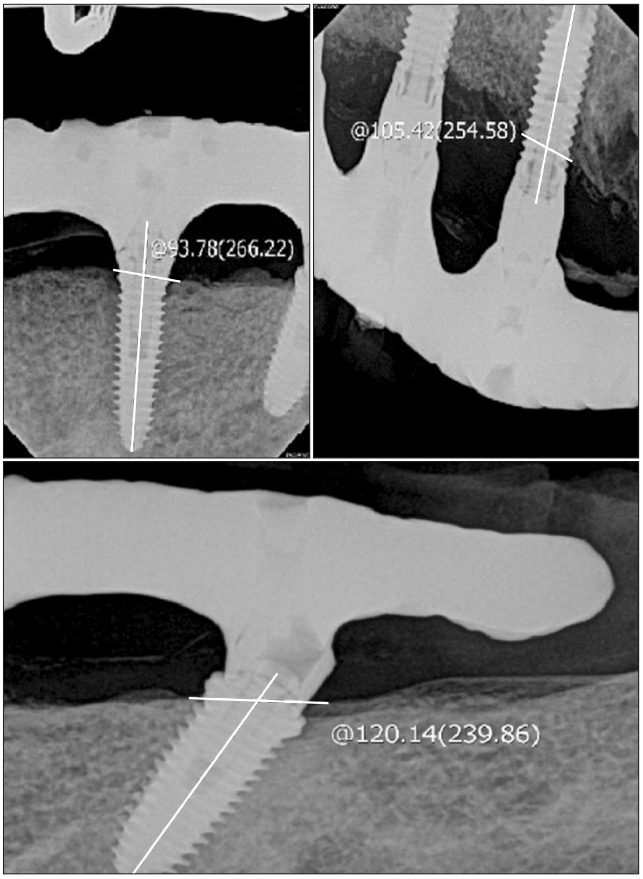

Fig. 2. Implant angulation was measured on peri-apical view radiographs using tools in a radiographic analysis program (PACS; INFINIT Co.). Through the program, two lines were drawn to represent the alveolar ridge line and the line that divides the implant fixture in half, and then the angle formed by those two lines was analyzed. The upper left side of the figure shows an implant with angulation of less than 10°, which was sorted to Group 1. The upper right side of the figure shows an implant in Group 2 because the angulation is between 10° and 20°. The lower part of the figure shows an implant with a vertical angle of more than 20°, so it was sorted to Group 3.
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Chi-square testing was conducted to analyze the occurrence of complications, the success rate, and the survival rate according to each of the variables. In the analyses of delayed/simultaneous placement of implants with bone grafts and initial/secondary stability, a non-parametric test (Mann–Whitney) was used because the groups in each comparison differed significantly in size.

III. Results

1. Study subjects

We included 21 patients with 137 implants in the final study sample. The following implant products were used: Ti-Unite (Nobel Biocare), Osstem US & TS II (Osstem Implant Co.), AVANA II (Osstem Implant Co.), and CMI (Neobiotech Co.). We did not conduct comparisons among those products in this study. The implants had varying sizes, with diameters of 3.3 mm (n=8), 3.75 mm (n=5), 4 mm (n=99), and 5 mm (n=25) and lengths of 10 mm (n=9), 11.5 mm (n=62), 13 mm (n=59), and 15 mm (n=7).

2. Marginal bone resorption

The mean overall values of marginal bone resorption associated with the different variables are shown in Table 2. The mean initial bone resorption, as measured in the peri-apical radiograph taken about a year after prosthetic loading was first applied, was approximately 1.01 mm. The mean final bone resorption, as measured in the latest peri-apical radiographic examination, was approximately 1.80 mm. In the groups sorted by implant angulation, bone resorption tended to decrease as the vertical angle of the implants increased. Implants in Group 3 had only about one-third the initial (0.33 mm) and final (0.76 mm) bone resorption of the implants in Group 1 (1.19 mm and 2.17 mm, respectively). Implants that shared a fixed-hybrid prosthesis with tilted implants (Group 2 or Group 3) did not show a significant change in marginal bone resorption, remaining around the mean value for all implants. Marginal bone resorption also tended to be lower for implants with a recorded stability of 60 or higher, as measured initially or secondarily. In terms of bone grafting, bone resorption was significantly reduced when bone grafting was not performed with implant placement, showing a mean reduction of more than 1 mm at the final evaluation. The diameter and length of the implant fixture did not show any significant interaction with marginal bone resorption.

3. Complications

The occurrence of complications associated with the different variables is shown in Table 3. The overall occurrence of complications in this study was 52.6%. In the groups sorted by implant angulation, the implants in Group 2 had the high-

Table 2. Mean initial and final bone resorption of implants according to different variables

Variable	Group	Mean initial bone resorption (mm)	Mean final bone resorption (mm)
Overall mean		1.01±1.13	1.80±1.99
Implant vertical angle	Group 1 (vertical angle <10°) (n=88)	1.21±1.18	2.17±2.25
	Group 2 (vertical angle 10°-20°) (n=30)	0.87±1.06	1.27±1.25
	Group 3 (vertical angle >20°) (n=19)	0.33±0.54	0.76±0.80
Implant stability	Primary stability ≥60 (n=89)	0.96±0.90	1.75±2.18
	Primary stability <60 (n=12)	1.67±1.84	2.63±2.13
	Secondary stability ≥60 (n=93)	1.01±1.03	2.06±2.18
	Secondary stability <60 (n=5)	1.77±1.65	3.48±1.90
Bone graft	Placed with bone graft (n=57)	1.41±1.24	2.36±2.61
	Placed without bone graft (n=80)	0.72±0.95	1.39±1.25
	Simultaneous placement with bone graft (n=56)	1.45±1.28	2.43±2.64
	Delayed placement after bone graft (n=5)	1.32±0.92	1.58±1.07
Implant diameter	3.3 mm (n=8)	2.65±1.32	3.22±1.32
	3.75 mm (n=5)	2.18±1.58	2.52±1.66
	4 mm (n=99)	1.06±1.03	1.58±1.70
	5 mm (n=25)	1.66±0.77	1.92±.294
Implant length	10 mm (n=9)	0.55±0.65	2.25±4.79
	11.5 mm (n=62)	1.01±1.10	1.72±1.55
	13 mm (n=59)	1.07±1.23	1.84±1.82
	15 mm (n=7)	0.84±1.07	1.08±1.26
Implants sharing FHP with tilted implants	Implants sharing same FHP with group 2 tilted implants (n=73)	1.11±1.21	2.16±2.22
	Implants sharing same FHP with group 3 tilted implants (n=57)	0.99±1.03	1.65±1.71

(FHP: fixed-hybrid prosthesis)
Values are presented as mean±standard deviation.
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est complication occurrence of 60.0%, about 10.0% higher than the lowest mean complication occurrence in Group 1. Based on the recorded implant stability quotient (ISQ) implant stability, all 5 implants with low secondary stability (<60) suffered complications, whereas implants with high secondary stability had a mean complication occurrence of 59.1%. Primary implant stability did not interact significantly with complications. Exactly half of the implants in this study that were placed without bone grafting suffered complications, which was a 5.7% lower rate than found in implants placed with bone grafting. Of the 5 implants that were installed after a delay following bone grafting, only one suffered a complication. Implants with a diameter of 4 mm had the lowest complication occurrence (46.5%), and implants with a length of 10 mm had the lowest complication occurrence (33.3%).

4. Implant survival and success rates

The survival and success rates for the implants are shown in Table 2. The overall survival rate for the implants in this study was 94.9%, and the success rate was 60.6%. In terms of implant angulation, Group 1, containing implants with a vertical angle of less than 10°, was the only group with a survival rate lower than 100.0%, with only half of those implants being successful. All of the implants in the other groups survived, and Group 3 had the highest success rate (89.4%). Most of the implants with recorded ISQ stability survived, with a survival rate of at least 93%. However, only half of the implants with a primary stability score less than 60 were successful, and only one of the 5 implants with a secondary stability score less than 60 met the success criteria. As in the occurrence of complications, implants with a length of 10 mm had the highest success rate, with 8 out of 9 of them being successful. In terms of diameter, the implants with the widest diameter (5 mm) in this study had a success rate of 68.0%, but that was only 4.4% higher than the success rate for implants with a diameter of 4 mm.

5. Implant angulation

Based on the classification criteria for implant angulation used in this study, 88 implants (64.2%) were classified into Group 1, 30 implants (21.9%) into Group 2, and 19 implants (13.9%) into Group 3.(Table 4) The mean initial and final bone resorption for each group was 1.21 mm and 2.17 mm, respectively, in Group 1, 0.87 mm and 1.27 mm, respectively, in Group 2, and 0.33 mm and 0.76 mm, respectively, in Group 3, indicating that bone resorption decreased from Group 1 to Group 3. Each of these groups showed a significant difference between their initial and final bone resorption (P<0.05). In terms of complications, the frequency was 50.0% in Group 1, 60.0% in Group 2, and 52.6% in Group 3, and the differences among them were not significant (P=0.638). The survival and success rates for the implants were 92.0% and 50.0%, respectively, in Group 1, 100.0% and 73.3%, respectively, in Group 2, and 100.0% and 89.4%, respectively, in Group 3. The survival rate for the implants in Group 1 was thus lower than that in the other two groups, and the success rate generally increased from Group 1 to Group

Table 3. Complication occurrence and survival/success rate of implants according to different variables

Variable	Group	Complication occurrence (%)	Survival rate (%)	Success rate (%)
Overall rate		52.6	94.9	60.6
Implant vertical angle	Group 1 (vertical angle <10°) (n=88)	50.0	92.0	50.0
	Group 2 (vertical angle 10°-20°) (n=30)	60.0	100.0	73.3
	Group 3 (vertical angle >20°) (n=19)	52.6	100.0	89.4
Implant stability	Primary stability ≥60 (n=89)	46.0	93.2	61.7
	Primary stability <60 (n=12)	41.6	100.0	50.0
	Secondary stability ≥60 (n=93)	59.1	93.5	62.3
	Secondary stability <60 (n=5)	100.0	100.0	20.0
Bone graft	Placed with bone graft (n=57)	55.7	93.4	47.5
	Placed without bone graft (n=80)	50.0	96.0	71.0
	Simultaneous placement with bone graft (n=56)	58.9	92.8	46.4
	Delayed placement after bone graft (n=5)	20.0	100.0	60.0
Implant diameter	3.3 mm (n=8)	100.0	100.0	25.0
	3.75 mm (n=5)	100.0	100.0	20.0
	4 mm (n=99)	46.5	93.9	63.6
	5 mm (n=25)	52.0	96.0	68.0
Implant length	10 mm (n=9)	33.3	88.8	88.8
	11.5 mm (n=62)	54.8	96.8	64.5
	13 mm (n=59)	47.5	94.9	52.5
	15 mm (n=7)	100.0	85.7	57.1

Table 4. Data analyzed to evaluate implants with different vertical angles

	Group 1 (vertical angle <10°) (n=88)	Group 2 (vertical angle 10°-20°) (n=30)	Group 3 (vertical angle >20°) (n=19)	*P*-value
Mean initial bone resorption (mm)	1.21±1.18	0.87±1.06	0.33±0.54	0.005
Mean final bone resorption (mm)	2.17±2.25	1.27±1.25	0.76±0.80	0.003
Complication occurrence (%)	50.0	60.0	52.6	0.638
Survival rate (%)	92.0	100.0	100.0	0.128
Success rate (%)	50.0	73.3	89.4	0.002

Values are presented as mean±standard deviation or %.
One-way ANOVA testing was conducted to analyze significant differences in bone resorption, and chi-square testing was used for the other groups.
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Table 5. Data analyzed to evaluate implants placed with/without a bone graft

	Implant placed with bone graft (n=57)	Implant placed without bone graft (n=80)	*P*-value
Mean initial bone resorption (mm)	1.41±1.24	0.72±0.95	<0.001
Mean final bone resorption (mm)	2.36±2.61	1.39±1.25	0.003
Complication occurrence (%)	55.7	50.0	0.504
Survival rate (%)	93.4	96.0	0.490
Success rate (%)	47.5	71.0	0.005

Values are presented as mean±standard deviation or %.
One-way ANOVA testing was conducted to analyze significant differences in bone resorption, and chi-square testing was used for the other groups.
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3. The survival rate did not differ significantly among the groups, but the success rate did (*P*=0.002).

6. Bone grafting

Table 5 compares the results of implant placement with and without a bone graft. Of the 57 implants placed with a bone graft, the mean initial bone resorption was 1.41 mm, and the final bone resorption was 2.36 mm. For the 80 implants placed without a bone graft, the mean initial and final bone resorption were 0.72 mm and 1.39 mm, respectively. Those results suggest that marginal bone resorption was higher in implants placed with a bone graft, with a significant difference in both initial and final bone resorption. The success rate for implants placed with a bone graft was also significantly lower, 47.5% compared with 71.0% for implants placed without a bone graft. We found no significant relationship between bone grafting and the survival rate or occurrence of complications with the implants. Additionally, the group of implants placed with a delay after the bone graft and the group of implants placed simultaneously with the bone graft did not differ significantly in any variables.(Table 6)

7. Implant stability

Table 7 shows that records of initial and secondary stability measured by the Osstell kit were available for 101 implants. The mean initial and final bone resorption measurements for implants with a primary stability score of 60 or higher were 0.96 mm and 1.75 mm, respectively. For implants with a primary stability below 60, the corresponding measurements were 1.67 mm and 2.63 mm, respectively. Similarly, the mean initial and final bone resorption measurements for implants with a secondary stability score of 60 or higher were 1.01 mm and 1.77 mm, respectively. For implants with low secondary stability, the measurements were 2.06 mm and 3.48 mm. A significant relationship was found only between secondary stability and final bone resorption. Primary stability did not show a significant relationship with the occurrence of complications, survival rate, or success rate. In contrast, secondary stability showed a significant relationship with both the occurrence of complications and the success rate.

IV. Discussion

Before this study, the value of fixed hybrid prostheses was questionable due to the potential negative effects on their supporting implants, and these might have been expressed as an inappropriate level of bone resorption. However, the results of this study show that the mean bone resorption around the evaluated implants was only 1.01 mm in a year after implant installation and 1.80 mm at the final evaluation, with a mean follow-up period of 10 years and 6 months after loading.

Tilting of the posterior implants, which was previously thought to be a potentially unstable feature of fixed hybrid prostheses, actually had the opposite effect in this study.

Table 6. Data analyzed to evaluate implants with delayed/simultaneous placement with bone graft

	Implant placed simultaneously with bone graft (n=56)	Implant with delayed placement after bone graft (n=5)	*P*-value
Mean initial bone resorption (mm)	1.45±1.28	1.32±0.92	0.929
Mean final bone resorption (mm)	2.43±2.64	1.58±1.07	0.674
Complication occurrence (%)	58.9	20.0	0.093
Survival rate (%)	92.8	100.0	0.536
Success rate (%)	46.4	60.0	0.560

Values are presented as mean±standard deviation or %.
Mann–Whitney testing was conducted to analyze significant differences in bone resorption, and chi-square testing was used for the other groups.
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Table 7. Data analyzed to evaluate implants with initial/secondary stability measured with an Osstell kit

	Primary stability ≥60 (n=89)	Primary stability <60 (n=12)	*P*-value for primary stability	Secondary stability ≥60 (n=93)	Secondary stability <60 (n=5)	*P*-value for secondary stability
Mean initial bone resorption (mm)	0.96±0.90	1.67±1.84	0.42	1.01±1.03	2.06±2.18	0.09
Mean final bone resorption (mm)	1.75±2.18	2.63±2.13	0.15	1.77±1.65	3.48±1.90	0.04
Complication occurrence (%)	46.0	41.6	0.77	59.1	100.0	0.01
Survival rate (%)	93.2	100.0	0.35	93.5	100.0	0.55
Success rate (%)	61.7	50.0	0.43	62.3	20.0	0.06

Values are presented as mean±standard deviation or %.
Mann–Whitney testing was conducted to analyze significant differences in bone resorption, and chi-square testing was used for the other groups.
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Group 3 implants, which were installed with a vertical angle of more than 20°, had about one-quarter of the marginal bone resorption of Group 1 at their first-year radiographic evaluation. Several previous studies have shown that tilting an implant does not affect its survival or marginal bone resorption[7-13]. However, we found that intentional tilting not only did not affect implant survival, but also reduced the mean peri-implant bone resorption. This result can be explained by the findings of other studies[12-17] that focused on the advantages of intentional tilting, such as the ability to insert longer implants into high-quality alveolar bone[12,13] and widening the inter-implant distance for better bone and blood supply and increased anterior-posterior spread[14,15]. Finite element analyses have also shown that appropriate angulation of the implants can effectively reduce stress on the prosthesis[16,17]. Taken together, these previous studies and the results of this study suggest that strategically tilting implants to obtain a better extension and high-quality bone supply can produce better outcomes than upright implants in certain circumstances.

This study found that, in the context of implant-supported fixed hybrid prostheses, most outcomes were clearly better for implants placed without a bone graft. In other words, implants that did not require additional bone support from grafting materials had a higher success rate and reduced marginal bone resorption than those that did. Because fixed hybrid prostheses have the advantage that the supporting implants have relatively free positioning and angulation, it might be more effective to find a site with favorable bone support for the implants rather than relying on bone grafting materials. If bone grafting is necessary for a particular patient, the clinician should consider both delayed and immediate placement of the implant. Two previous studies[18,19] have compared the success rates and marginal bone loss of those two methods and found that delayed placement after bone grafting generally produces better outcomes. We also found that implants placed after a delay had better outcomes than those placed simultaneously, although the difference in this study was not statistically significant due to the small number of implants (n=5) placed with a delay after a preceding bone graft. Ultimately, the decision between these two methods should take into account multiple factors, including the patient's preference.

The ISQ, measured using an Osstell ISQ kit in this study, is a measure of implant stability obtained through RFA, a useful tool for predicting the success of implants[20,21]. The Osstell ISQ scale classifies implants with values of 70 or higher as having high stability, values of 60-69 as having medium stability, and values below 60 as having low stability. The results of this study show that implants with low measured stability had almost twice the mean marginal bone loss of those with adequate stability. Additionally, secondary stabil-

ity measurements had better reliability than primary stability measurements because they had a significant relationship with the occurrence of complications. Given that the durability of a fixed hybrid prosthesis depends on the stability of its supporting implants, stability measured using an RFA-based instrument on at least two occasions can serve as an important prognostic indicator for the installed implants.

One major limitation of this study is that it was conducted retrospectively and included many different types of implants from various companies. Implant technology has developed significantly during the past few decades, with updates to production and clinical performance occurring almost annually. As a result, even implants produced in the same time period or by the same company can show various mean clinical outcomes due to differences in features, advantages, and disadvantages. Future studies should provide a detailed clinical comparison of the implants used or be conducted using a small number and variety of implants.

This study also has several methodologic limitations, such as the use of radiography to measure marginal bone resorption. Although radiography is one of the few options available for measuring alveolar bone changes, Benn[22] pointed out that it is difficult to accurately assess alveolar changes through radiography without certain details, such as a repositionable film holder, specific techniques, and an automatic measuring system. In this study, we did not have a clear, reproducible method for obtaining and measuring radiographic images of marginal bone resorption, so future studies should include a more detailed and reproducible environment for radiographic evaluation. Additionally, fixed hybrid prostheses are one-piece structures, making it difficult to match prosthetic complications in the upper structure with problems in the lower implants. To accurately identify the causes of complications, it would be beneficial if future studies used computerized analyses of the stress distribution of the prosthesis to evaluate the implants underneath fixed hybrid prostheses.

V. Conclusion

In certain circumstances, such as when straight implant placement would risk damage to anatomic structures, intentionally tilting the implants for a fixed hybrid prosthesis can produce favorable long-term outcomes by improving the bone supply and increasing the anterior-posterior span. If possible, implant installation without bone grafting is recommended for fixed hybrid prosthesis. If bone grafting is necessary, the results from delayed and simultaneous positioning of the implant did not differ significantly. It is advisable to take at least two measurements of implant stability between installation and the insertion of the final fixed hybrid prosthesis structure.

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Authors' Contributions

W.H.S. participated in data collection, performed statistical analysis and wrote manuscript. P.Y.Y. and Y.K.K. participated in data collection and study design. N.H.C. participated in drafting of the manuscript. All authors read and approved the final manuscript.

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Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (No. B-2211-791-101), and the written informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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