

# A retrospective comparison of clinical outcomes of implant restorations for posterior edentulous area: 3-unit bridge supported by 2 implants vs 3 splinted implant-supported crowns

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**PURPOSE.** To compare the clinical outcomes of two types of implant restoration for posterior edentulous area, 3-unit bridge supported by 2 implants and 3 implant-supported splinted crowns. **MATERIALS AND METHODS.** The data included 127 implant-supported fixed restorations in 85 patients: 37 restorations of 3-unit bridge supported by 2 implants (2-IB), 37 restorations of 3 implant-supported splinted crowns (3-IC), and 53 single restorations (S) as controls. Peri-implantitis and mechanical complications that occurred for 14 years were analyzed by multivariable Cox regression model. Kaplan-Meier curves and the multivariable Cox regression model were used to analyze the success and survival of implants. **RESULTS.** Peri-implantitis occurred in 28.4% of 2-IB group, 37.8% of 3-IC group, and 28.3% of S control group with no significant difference. According to the implant position, middle implants (P2) of the 3-IC group had the highest risk of peri-implantitis. The 3-IC group showed a lower mechanical complication rate (7.2%) than the 2-IB (16.2%) and S control group (20.8%). The cumulative success rate was 52.8% in S (control) group, 62.2% in 2-IB group, and 60.4% in 3-IC group. The cumulative survival rate was 98.1% in S (control) group, 98.6% in 2-IB group, and 95.5% in 3-IC group. There was no significant difference in the success and survival rate according to the restoration type. **CONCLUSION.** The restoration type was not associated with the success and survival of implants. The risk of mechanical complications was reduced in 3 implant-supported splinted crowns. However, the middle implants of the 3 implant-supported splinted crowns had a higher risk of peri-implantitis. [J Adv Prosthodont 2022;14:223-35]

## KEYWORDS

Implant 3-unit bridge; Implant splinted crown; Implant prosthesis with pontic; Implant complication

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## INTRODUCTION

Restoration with implant-supported fixed prostheses in the partially edentulous patients have been recognized as a successful treatment option.<sup>1-4</sup> When considering implant restoration for 3-unit edentulous area, one of these treatment options would be chosen: 3 splinted implant-supported crowns or 3-unit bridge supported by 2 implants. Based on biomechanical considerations, 3 implant-supported restorations were recommended because of a better load distribution on each individual implant, and less bending moments may be induced than 2 implant-supported restorations.<sup>5</sup> Several studies have reported a higher success rate of 3 implant-supported prostheses than 2 implant-supported prostheses.<sup>1,6,7</sup> They all confirmed that the prostheses supported by 2 implants tended to have more mechanical problems than those supported by 3 implants. However, these studies included a cantilever design for 2 implant-supported restorations and were conducted for a short observation period of less than 5 years. Eliasson *et al.*<sup>8</sup> reported that 2 implant-supported prostheses showed comparable marginal bone loss and survival rate to 3 implant-supported prostheses in a long-term clinical study for 18 years. However, as in previous studies, a cantilever design was included, and the restorations were not designed exclusively for 3-unit edentulous areas.

Several recent studies have analyzed the biological complications in 3-unit implant restorations. Ravida *et al.*<sup>9</sup> reported that 2 implant-supported 3-unit bridge showed a reduced risk of peri-implantitis and a higher success rate compared to 3 implant-supported splinted crowns. Yi *et al.*<sup>10</sup> found that the middle implants splinted to both mesial and distal adjacent implants in 3 implant-supported splinted crowns were vulnerable to biological complications when they were restored with over contoured prostheses. Yi *et al.*<sup>11</sup> reported that plaque index and buccal pocket depth were decreased in 2 implant-supported 3-unit bridges compared to 3 implant-supported splinted crowns, but both showed comparable success and survival rates.

Although comparison of these two types of 3-unit implant restoration has been made in several studies

as described above, it is insufficient to provide consensus for clinicians on the choice of a restoration type suitable for various clinical situations. Therefore, the purpose of the present study was to compare the two types of implant restoration for posterior edentulous area, 2 implant-supported 3-unit bridges and 3 implant-supported splinted crowns, evaluating the biological and mechanical complications along with success and survival rate analysis and to analyze risk factors.

## MATERIALS AND METHODS

This study was approved by the Seoul National University Dental Hospital Institutional Review Board (No. ERI20017). The study was conducted retrospectively in accordance with STROBE guidelines. The data included all patients treated with 2-implant supported 3-unit bridge or 3-implant supported splinted crown restoring posterior free-end partial edentulous area at Seoul National University Dental Hospital from 2008 to 2015. The patient records were screened according to the following criteria.

### Inclusion Criteria

1. Patients treated with Osstem Dental Implant (US II, bone level, external connection; TS II, bone level, internal connection; SSII, tissue level; Osstem Implant, Seoul, Korea) restoring 3-unit partial edentulous posterior area
2. Implant restorations supported by 2-3 implants placed on the same visit day
3. Implant restorations which have occlusion with natural teeth
4. Implants restored with screw-retained prostheses

### Exclusion Criteria

1. Patients with insufficient clinical records or radiographs
2. Patients with irregular maintenance care: a full mouth plaque score  $\geq 25\%$
3. Patients who have systemic diseases or conditions
4. Patients who smoke greater than or equal one more cigarette a day
5. Patients who received jaw reconstruction after

- jaw resection
- 6. Implants re-installed after failure
- 7. Implants used for implant-assisted removable prostheses
- 8. Implants supporting cantilever bridge

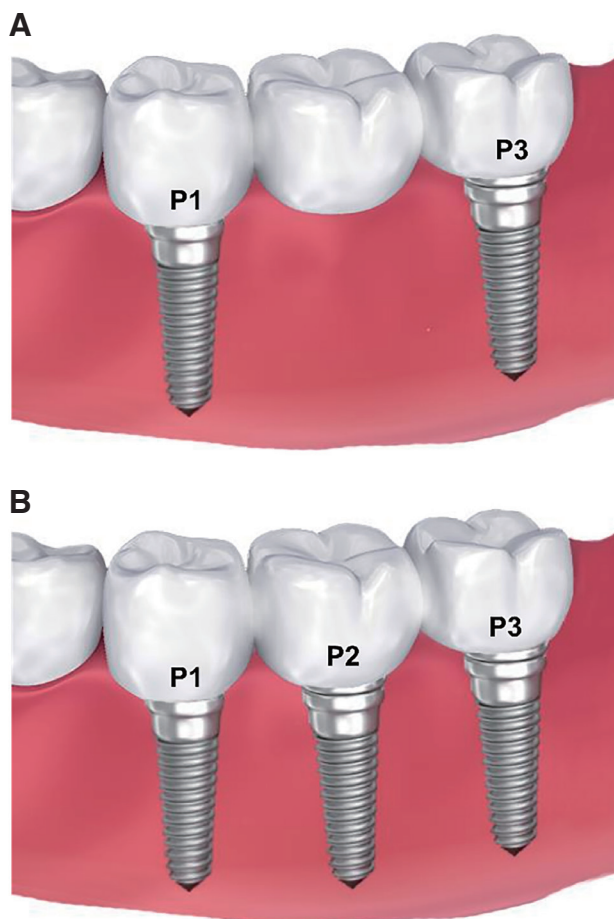
The following categories were included for this study: restoration type (single, restored independently adjacent to other implant (control); 3-unit bridge supported by 2 implants (2-IB); 3 implant-supported splinted crown (3-IC)) (Fig. 1); implant position (P1, mesial implant; P2, middle implant between mesial and distal adjacent implants; P3, distal implant) (Fig. 1); implant description (connection type (bone level external connection (BL-E); bone level internal con-

ical connection (BL-I); tissue level (TL)); immediate placement; 1-stage or 2-stage protocol; emergence angle (EA); emergence profile (EP); diameter; length; crown height; crown/implant (C/I) ratio); and patient description (age, gender, history of periodontitis). EA and EP were measured on the mesial and distal aspects respectively, and categorized in 3 groups: EA1, both mesial and distal EA < 30°; EA2, one of mesial or distal EA < 30°, the other ≥ 30°; EA3, both mesial and distal EA ≥ 30°; EP1 both mesial and distal EP were concave or straight; EP2, one of mesial or distal EP was concave or straight, and the other was convex; EP3, both mesial and distal EP were convex.

The radiographic measurement protocol of the EA, EP, C/I ratio, crown length and the MBL were previously reported.<sup>10,12</sup> The image processing program was used (Image J; National Institutes of Health, Bethesda, MD, USA).<sup>13</sup> Intraoral radiographs were taken using paralleling technique a year after prostheses insertion and at follow-up visit. All radiographic files were anonymously numbered, and one calibrated and blinded examiner performed all measurements (Y.Y.). The intra-rater reliability was calculated measuring the consistency of 3 measurements of 30 specimens selected by simple random selection and showed high level of reliability (Cronbach's  $\alpha$ , Intra-class Correlation Coefficient = 0.98).

The current guideline for the diagnosis of peri-implantitis was defined in the 2017 World Workshop on the classification of periodontal and peri-implant diseases and conditions<sup>14</sup>: presence of bleeding on probing (BOP) and/or suppuration; increased probing depth (PD); presence of detectable bone loss exceeding the measurement error (mean 0.5 mm). In the present study, peri-implantitis was diagnosed where, in comparison to the initial examination at the first year following prosthesis insertion, a radiographic measurement of bone loss superior to 0.5 mm was concomitant with an increased PD, BOP and/or suppuration.

The following mechanical complications were included: screw loosening, defined as prosthesis mobility in osseointegrated implants without implant component fracture; screw fracture, defined as where a fracture screw was observed. No fractures of other components (abutments or implants) were observed



**Fig. 1.** Illustration of restoration types presented in the study; (A) 3-unit bridge supported by 2 implants (2-IB); (B) 3 implant-supported splinted crown (3-IC).

during the observation period.

The time of occurrence was calculated by measuring the time elapsed from the prosthesis delivery to the occurrence of the complication. Data were recorded at the implant and the patient level. Multiple events that occurred in an implant or in a patient were considered and recorded once in the complication experience. Repeated events were recorded once, and the time of occurrence was measured from the date of the first event. For the estimation of cumulative hazard rates, data were censored at the date of the last follow-up visit.<sup>12</sup>

The success of implant was defined as the implants without peri-implantitis or mechanical complications. A survival of implant was defined as the implant present in the oral cavity without loss of osseointegration or implant fracture.

A statistical software (IBM SPSS Statistic, v25.0; IBM Corp, Armonk, NY, USA) was used for analysis. Kaplan-Meier curves and the multivariable Cox regression model were used to analyze the success and survival of implants. Univariate analysis was performed for each variable to assess its association with success and survival of implants. Covariates which had  $P \leq .20$  in univariate analysis were selected for multivariate analysis. The Cox proportional hazard model was conducted considering confounding factors and presented as hazard ratio (HR) and 95% confidence interval (CI).

## RESULTS

The distribution of implants and patients is presented in Table 1. The observation period ranged from 6- to 14-year (mean follow-up period  $8.35 \pm 2.52$  years). A total of 85 patients (43 men, 42 women, mean age of  $55.2 \pm 9.52$  years old) with 238 implants were included in this study. A total of 127 restorations were recorded: 37 restorations were 2-implant supported 3-unit bridge (2-IB, 74 implants), 37 restorations were 3-implant supported splinted crowns (3-IC, 111 implants), and 53 single restorations were recorded as controls. P1 implants (85 implants) were placed on the premolar area, and P3 implants (97 implants) were placed on the molar area. P2 implants (56 implants) were placed on the molar (50 implants) or pre-

molar area (6 implants) in some cases.

During the observation period, peri-implantitis occurred in 32.8% of implants (28.3% of S group, control; 28.4% of 2-IB group; and 37.8% of 3-IC group) and 43.5% of patients. In univariate analysis, restoration type has no significant influence on peri-implantitis (Table 2). However, the implant position in the 3-IC restoration was related to risk of peri-implantitis: middle implants (P2) of the 3-IC group had the highest risk of peri-implantitis (Fig. 2). In the multivariate analysis of peri-implantitis, emergence angle (EA) and emergence profile (EP) of implant prostheses had a significant effect on the peri-implantitis risk: EA3 group and EP3 group had a higher risk of peri-implantitis than EA 1 and EP1 groups, respectively (EA3: HR 1.71; 95% CI [1.06-2.76]), EP3: HR 2.61; 95% CI [1.75-7.69], Table 2).

The prevalence of mechanical complication was 13.0% of implants (20.8% of S (control) group, 16.2% of 2-IB group, and 7.2% of 3-IC group) and 24.7% of patients. Screw loosening was the most frequent, occurring in 11.3% of implants and 22.4% of patients, and occurred simultaneously in the implants supporting one prosthesis: 5 prostheses of 2-IBs (10 implants, 13.5%) and 2 prostheses of 3-ICs (6 implants, 5.4%). Reoccurrence of screw loosening was observed in 10 implants, all of which were single restorations (S group). Screw fracture was observed in 1.7% of implants and 2.4% patients. All the fractured screws were retrieved and replaced with new screws. No abutment or implant fracture and deformation was observed during the observation period. The risk of mechanical complications differed according to the restoration type (Table 3). No significant difference was observed depending on the implant position (Fig. 2). In the multivariate analysis of overall mechanical complications, 3-IC group showed the lowest risk of mechanical complications (HR 0.36; 95% CI [0.14-0.93]), which was consistent in the risk of screw loosening (HR 0.24; 95% CI [0.08-0.69]). There was no parameter that significantly affected the risk of screw fracture (Table 3).

The cumulative success rate was 59.2% at the implant level (52.8% in S (control) group, 62.2% in 2-IB group, and 60.4% in 3-IC group) and 43.5% at the patient level (Table 4). The success rate of implants did

**Table 1.** Distribution of implants and patients

|  |                   | N (%)        | P1 (N) | P2 (N) | P3 (N) |
|--|-------------------|--------------|--------|--------|--------|
| <b>Implant level (A total of 238 implants)</b> |                   |              |        |        |        |
| Restoration type                               | Single (control)  | 53 (22.3%)   | 11     | 19     | 23     |
|  | 2-IB*             | 74 (31.1%)   | 37     |        | 37     |
|  | 3-IC*             | 111 (46.6%)  | 37     | 37     | 37     |
| Connection type                                | BL-E <sup>†</sup> | 210 (88.2%)  |        |        |        |
|  | BL-I <sup>†</sup> | 19 (8.0%)    |        |        |        |
|  | TL <sup>†</sup>   | 9 (3.8%)     |        |        |        |
| Bone augmentation                              | No                | 124 (52.1%)  |        |        |        |
|  | Yes               | 114 (47.9%)  |        |        |        |
| Immediate placement                            | No                | 201 (84.5%)  |        |        |        |
|  | Yes               | 37 (15.5%)   |        |        |        |
| 1-stage or 2-stage                             | 1-stage           | 161 (67.6%)  |        |        |        |
|  | 2-stage           | 77 (32.4%)   |        |        |        |
| Emergence angle (EA)                           | EA1 <sup>‡</sup>  | 52 (21.3%)   |        |        |        |
|  | EA2 <sup>‡</sup>  | 72 (30.3%)   |        |        |        |
|  | EA3 <sup>‡</sup>  | 114 (47.9%)  |        |        |        |
| Emergence profile (EP)                         | EP1 <sup>‡</sup>  | 14 (5.9%)    |        |        |        |
|  | EP2 <sup>‡</sup>  | 97 (40.8%)   |        |        |        |
|  | EP3 <sup>‡</sup>  | 127 (53.4%)  |        |        |        |
| Diameter                                       | Min - Max         | 3.3 - 6.0    |        |        |        |
|  | Mean (SD)         | 4.58 (0.53)  |        |        |        |
| Length   | Min - Max         | 7.0 - 13.0   |        |        |        |
|  | Mean (SD)         | 10.71 (1.17) |        |        |        |
| Crown height                                   | Min - Max         | 4.52 - 17.52 |        |        |        |
|  | Mean (SD)         | 11.19 (2.48) |        |        |        |
| Crown/Implant (C/I) ratio                      | Min - Max         | 0.39 - 2.06  |        |        |        |
|  | Mean (SD)         | 1.06 (0.26)  |        |        |        |
| <b>Patient level (A total of 85 patients)</b>  |                   |              |        |        |        |
| Age  | Min-Max           | 30 - 76      |        |        |        |
|  | Mean (SD)         | 55.2 (9.52)  |        |        |        |
| Gender   | Female            | 42 (49.4%)   |        |        |        |
|  | Male              | 43 (50.6%)   |        |        |        |
| History of periodontitis                       | No                | 3 (3.0%)     |        |        |        |
|  | Yes               | 82 (82.8%)   |        |        |        |

\*2-IB: 2-implant supported 3-unit bridge, \*3-IC: 3-implant supported splinted crown; <sup>†</sup>BL-E: bone level-external connection, <sup>†</sup>BL-I: bone level-internal conical connection, <sup>†</sup>TL: tissue level; <sup>‡</sup>EA and <sup>‡</sup>EP were measured on the mesial and distal aspects respectively, <sup>‡</sup>EA1: both < 30°; <sup>‡</sup>EA2: one < 30°, the other ≥ 30°; <sup>‡</sup>EA3: both ≥ 30°; <sup>‡</sup>EP1: both concave or straight profile; <sup>‡</sup>EP2: one is concave or straight, and the other is convex profile; <sup>‡</sup>EP3: both convex profile

**Table 2.** Univariate and multivariate analysis for peri-implantitis

|                          | N <sup>c</sup> (%) | Univariate analysis | Multivariate analysis |                       |
|--------------------------|--------------------|---------------------|-----------------------|-----------------------|
|                          |                    | P <sup>§</sup>      | P <sup>¶</sup>        | HR (95% CI)           |
| Implant level            | 78 (32.8%)         |                     |                       |                       |
| Restoration type         |                    | 0.56                |                       |                       |
| S (control)              | 15 (28.3%)         |                     |                       |                       |
| 2-IB                     | 21 (28.4%)         |                     |                       |                       |
| 3-IC                     | 42 (37.8%)         |                     |                       |                       |
| Connection type          |                    | 0.98                |                       |                       |
| BL-E                     | 69 (32.9%)         |                     |                       |                       |
| BL-I                     | 6 (31.6%)          |                     |                       |                       |
| TL                       | 3 (33.3%)          |                     |                       |                       |
| Emergence angle (EA)     |                    | 0.00*               |                       |                       |
| EA1                      | 12 (23.1%)         |                     |                       | 1                     |
| EA2                      | 21 (29.2%)         |                     | 0.21                  | 1.02 (0.59-1.60)      |
| EA3                      | 45 (39.5%)         |                     | 0.02**                | 1.71 (1.06-2.76)      |
| Emergence profile (EP)   |                    | 0.00*               |                       |                       |
| EP1                      | 3 (21.4%)          |                     |                       | 1                     |
| EP2                      | 17 (17.5%)         |                     | 0.71                  | 0.79 (0.23-2.71)      |
| EP3                      | 58 (45.7%)         |                     | 0.01**                | 2.61 (1.75-7.69)      |
| Bone augmentation        |                    | 0.58                |                       |                       |
| No                       | 43 (34.7%)         |                     |                       |                       |
| Yes                      | 35 (30.7%)         |                     |                       |                       |
| Immediate placement      |                    | 0.86                |                       |                       |
| No                       | 67 (33.3%)         |                     |                       |                       |
| Yes                      | 11 (29.7%)         |                     |                       |                       |
| 1-stage or 2-stage       |                    | 0.76                |                       |                       |
| 1-stage                  | 49 (30.4%)         |                     |                       |                       |
| 2-stage                  | 29 (37.7%)         |                     |                       |                       |
| Crown height             |                    | 0.73                |                       |                       |
| C/I ratio                |                    | 0.94                |                       |                       |
| Diameter                 |                    | 0.05*               | 0.13                  | 0.40 (0.91-2.15)      |
| Length                   |                    | 0.57                |                       |                       |
| Patient level            | 37 (43.5%)         |                     |                       |                       |
| Age                      |                    | 0.15*               | 0.98                  | 0.96 (0.93-1.08)      |
| Gender                   |                    |                     |                       |                       |
| Female                   | 17 (40.5%)         | 0.50                |                       |                       |
| Male                     | 20 (46.5%)         |                     |                       |                       |
| History of periodontitis |                    |                     |                       |                       |
| No                       | 0 (0.0%)           | 0.19*               |                       | 1                     |
| Yes                      | 37 (45.1%)         |                     | 0.39                  | 21.60 (0.02-2.33E+04) |

<sup>§</sup>P-value calculated from univariate analysis of each covariate; \*covariate selected for multivariate analysis ( $P < .20$ ); <sup>¶</sup>P-value calculated from multivariable analysis; \*\*significant influence derived Cox proportional hazard regression analysis ( $P < .05$ ); N<sup>c</sup>: cumulative events during the study period.

**Table 3.** Univariate and multivariate analysis for mechanical complications

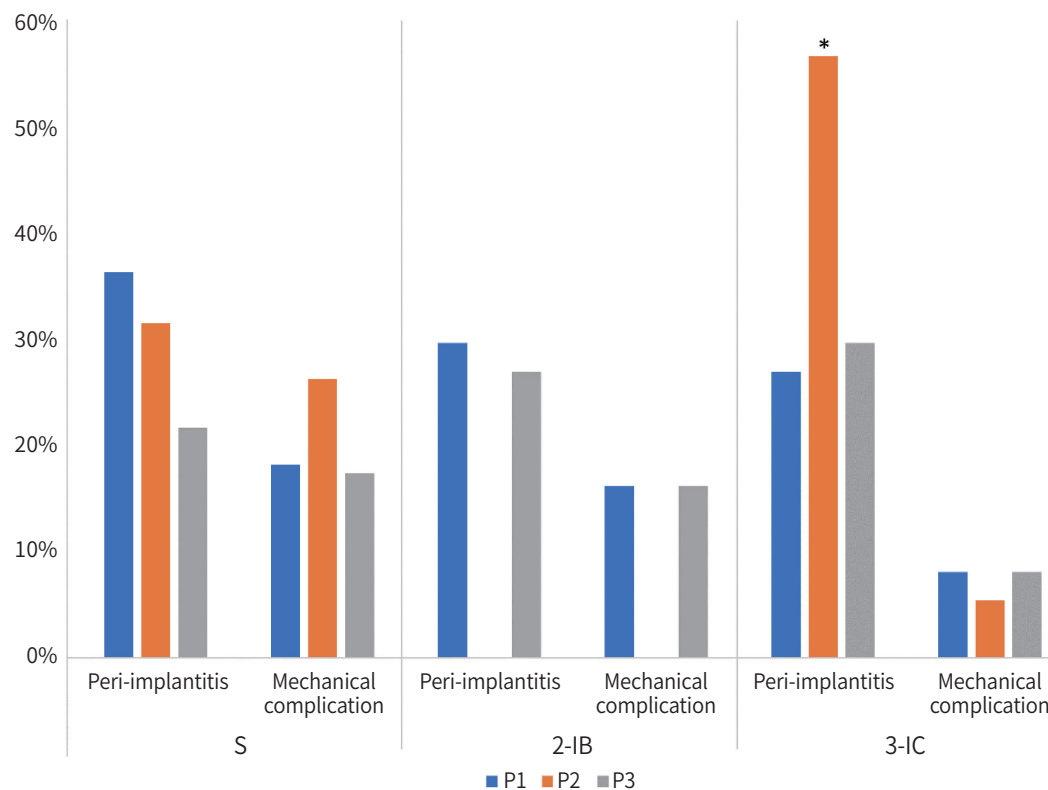
|                  | Mechanical complication |                           |  | Screw loosening    |                           |  | Screw fracture     |                           |  |
|------------------|-------------------------|---------------------------|--|--------------------|---------------------------|--|--------------------|---------------------------|--|
|                  | N <sup>c</sup> (%)      | Univariate P <sup>§</sup> | Multivariate analysis P <sup>¶</sup> HR (95% CI) | N <sup>c</sup> (%) | Univariate P <sup>§</sup> | Multivariate analysis P <sup>¶</sup> HR (95% CI) | N <sup>c</sup> (%) | Univariate P <sup>§</sup> | Multivariate analysis P <sup>¶</sup> HR (95% CI) |
| Implant level    | 31 (13.0%)              |                           |  |                    |                           |  |                    |                           |  |
| Restoration type |                         | 0.02*                     |  |                    | 0.01*                     |  |                    | 0.50                      |  |
| S (control)      | 11 (20.8%)              |                           | 1 (20.8%)  |                    |                           | 1 (20.8%)  | 0 (0.0%)           |                           |  |
| 2-IB             | 12 (16.2%)              | 0.53                      | 0.77 (0.34-1.75)                                 | 10 (13.5%)         | 0.40                      | 0.69 (0.29-1.63)                                 | 2 (2.7%)           |                           |  |
| 3-IC             | 8 (7.2%)                | 0.03**                    | 0.36 (0.14-0.93)                                 | 6 (5.4%)           | 0.01**                    | 0.24 (0.08-0.69)                                 | 2 (1.8%)           |                           |  |
| Connection type  |                         | 0.14*                     |  |                    | 0.13*                     |  |                    | 0.83                      |  |
| BL-E             | 27 (12.9%)              |                           | 1 (11.0%)  |                    |                           | 1 (1.9%)   | 4 (1.9%)           |                           |  |
| BL-I             | 4 (21.1%)               | 0.10                      | 4.36 (0.24-17.61)                                | 4 (21.1%)          | 0.07                      | 2.82 (0.94-8.47)                                 | 0 (0.0%)           |                           |  |
| TL               | 0 (0.0%)                | 0.98                      | 0.00 (0.00-)                                     | 0 (0.0%)           | 0.98                      | 0.00 (0.00-)                                     | 0 (0.0%)           |                           | 1  |
| Crown height     |                         | 0.91                      |  | 27 (11.3%)         | 0.61                      |  | 4 (1.7%)           | 0.06*                     | 0.51 (0.26-1.95)                                 |
| C/I ratio        |                         | 0.70                      |  | 27 (11.3%)         | 0.89                      |  | 4 (1.7%)           | 0.10*                     | 0.82 (0.00-1.14E04)                              |
| Diameter         |                         | 0.02*                     | 0.10 1.86 (0.89-3.86)                            | 27 (11.3%)         | 0.02*                     | 0.30 1.56 (0.68-3.58)                            | 4 (1.7%)           | 0.89                      |  |
| Length           |                         | 0.58                      |  | 27 (11.3%)         | 0.51                      |  | 4 (1.7%)           | 0.90                      |  |
| Patient level    | 21 (24.7%)              |                           |  |                    |                           |  |                    |                           |  |
| Age              |                         | 0.25                      |  | 19 (22.4%)         | 0.65                      |  | 2 (2.4%)           | 0.05                      | 0.05 (0.71-1.01)                                 |
| Gender           |                         | 0.81                      |  |                    | 0.46                      |  |                    |                           |  |
| Female           | 10 (23.8%)              |                           |  | 8 (19.0%)          |                           |  | 2 (4.8%)           |                           | 1  |
| Male             | 11 (25.6%)              |                           |  | 11 (25.6%)         |                           |  | 0 (0.0%)           | 0.17                      | 0.97 (0.00-)                                     |

<sup>§</sup>P-value calculated from univariate analysis of each covariate; \*covariate selected for multivariate analysis (P < .20); <sup>¶</sup>P-value calculated from multivariate analysis; \*\*significant influence derived Cox proportional hazard regression analysis (P < .05); N<sup>c</sup>: cumulative events during the study period.

not significantly differ according to the restoration type (Fig. 3). Of the parameters included in the study, only EP had a significant impact on the implant success rates: EP3 had a higher risk of failure than EP1 (HR 4.87; 95% CI [1.19-19.94]). There was no difference of success rate according to the implant position in 2-IB group, but middle implants (P2) in 3-IC group had the

highest risk of failure (Fig. 4).

The cumulative survival rate was 97.1% at the implant level (98.1% in S (control) group, 98.6% in 2-IB group, and 95.5% in 3-IC group) and 92.9% at the patient level. There was no significant difference in the survival rate according to the restoration type (Fig. 3).



**Fig. 2.** Comparison of peri-implantitis and mechanical complications according to implant position (P1, P2, and P3) for each restoration type. P2\* of 3-IC had a significantly higher peri-implantitis risk than P1 and P3. S, single (control); 2-IB, 3-unit bridge supported by 2 implants; 3-IC, 3 implant-supported splinted crown.

## DISCUSSION

In the present study, the long-term outcomes of implants on the posterior edentulous area were evaluated depending on the restoration type, 2-implant supported 3-unit bridges (2-IB) and 3-implant supported splinted crowns (3-IC). The difference from previous studies is that in the present study, implants of the same company (Osstem Implant, Seoul, Korea) were investigated, restorations with cantilevers were excluded, and only screw-retained type prostheses were included, for exclusion of unpredictable influencing factors.

No significant difference in the risk of peri-implantitis was found according to the restoration type. However, the middle implants (P2) of the 3-IC group had a higher risk of peri-implantitis than P1 or P3 implants. This is in line with the previous 5-year retrospective study in which the splinted middle group showed a

higher risk of peri-implantitis (53.8%) than mesial (25.5%) or distal implants (30.4%), and the risk was significantly higher with overcontoured prostheses.<sup>10</sup> In the present study, the EA3 group with both mesial and distal EA  $\geq 30^\circ$  and the EP3 group in which both mesial and distal EP were convex were identified as peri-implantitis risk indicators. With respect to implant position in the 3-IC group, these results suggest that over-contoured implant prostheses increase the risk of peri-implantitis, and the risk may be further increased in the middle implants of the 3 implant-supported splinted crowns. It also emphasizes the importance of accessibility for oral hygiene. Overcontoured prostheses make oral hygiene difficult for patients, especially in the middle implant splinted to mesial and distal adjacent implants. This suggests that proper prosthetic design could reduce the vulnerability to biological complications in 3 implant-supported splinted crowns. Souza *et al.* found that wider abut-



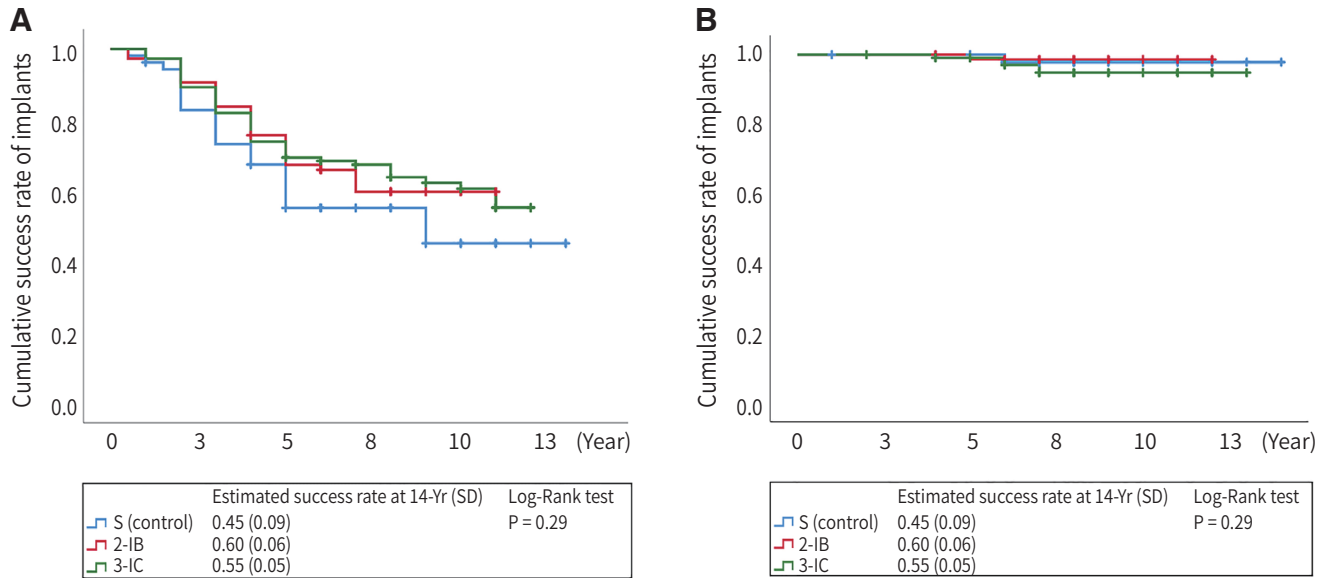
**Table 4.** Univariate and multivariate success and survival analysis

| Features      |                          | Univariate analysis       |                            |
|---------------|--------------------------|---------------------------|----------------------------|
|               |                          | Success (P <sup>§</sup> ) | Survival (P <sup>§</sup> ) |
| Implant level | Restoration type         | 0.32                      | 0.43                       |
|               | Connection type          | 0.83                      | 0.51                       |
|               | Emergence angle (EA)     | 0.06*                     | 0.30                       |
|               | Emergence profile (EP)   | 0.00*                     | 0.24                       |
|               | Bone augmentation        | 0.09*                     | 0.60                       |
|               | Immediate placement      | 0.40                      | 0.26                       |
|               | 1-stage or 2-stage       | 0.31                      | 0.24                       |
|               | Crown height             | 0.91                      | 0.19*                      |
|               | C/I ratio                | 0.88                      | 0.46                       |
|               | Diameter                 | 0.05*                     | 0.13*                      |
|               | Length                   | 0.55                      | 0.43                       |
| Patient level | Age                      | 0.06*                     | 0.33                       |
|               | Gender                   | 0.40                      | 0.41                       |
|               | History of periodontitis | 0.62                      | 0.63                       |

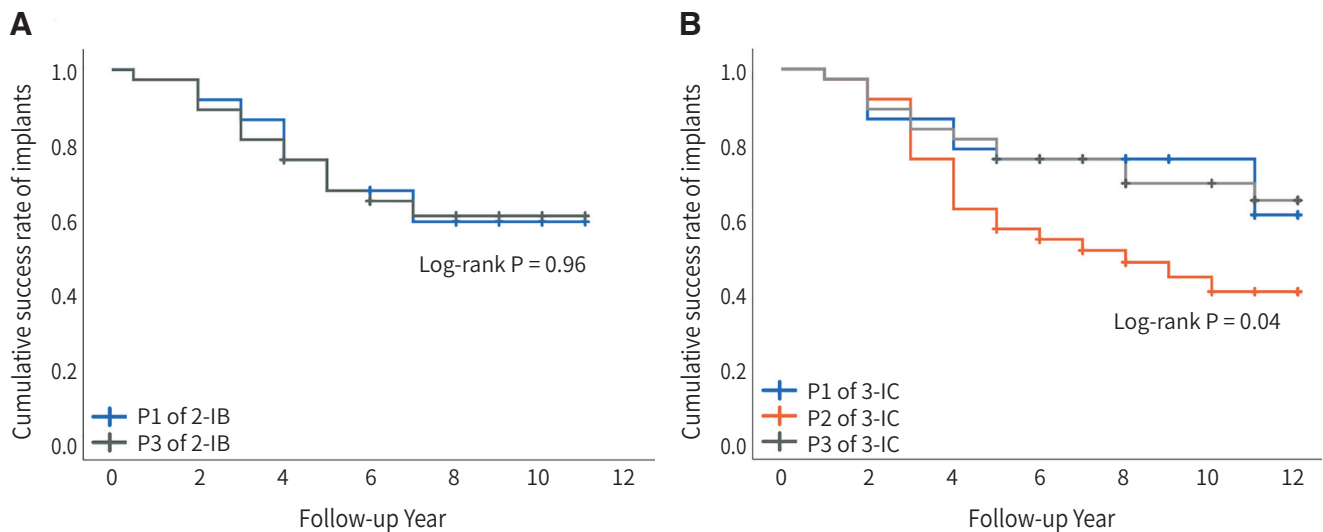
  

| Features                 |           | Multivariate success analysis |                |                   | Multivariate survival analysis |                |                   |
|--------------------------|-----------|-------------------------------|----------------|-------------------|--------------------------------|----------------|-------------------|
|                          |           | N <sup>c</sup> (%)            | P <sup>¶</sup> | HR (95% CI)       | N <sup>c</sup> (%)             | P <sup>§</sup> | HR (95% CI)       |
| Implant level            |           | 141 (59.2%)                   |                |                   | 231 (97.1%)                    |                |                   |
| Restoration type         | S         | 28 (52.8%)                    |                |                   | 52 (98.1%)                     |                |                   |
|                          | 2-IB      | 46 (62.2%)                    |                |                   | 73 (98.6%)                     |                |                   |
|                          | 3-IC      | 67 (60.4%)                    |                |                   | 106 (95.5%)                    |                |                   |
| Connection type          | BL-E      | 123 (58.6%)                   |                |                   | 204 (97.1%)                    |                |                   |
|                          | BL-I      | 12 (63.2%)                    |                |                   | 18 (94.7%)                     |                |                   |
|                          | TL        | 6 (66.7%)                     |                |                   | 9 (100.0%)                     |                |                   |
| Emergence angle (EA)     | EA1       | 36 (69.2%)                    |                | 1                 | 52 (100.0%)                    |                |                   |
|                          | EA2       | 43 (59.7%)                    | 0.73           | 1.08 (0.70-1.66)  | 70 (97.2%)                     |                |                   |
|                          | EA3       | 62 (54.4%)                    | 0.45           | 1.11 (0.82-2.12)  | 109 (95.6%)                    |                |                   |
| Emergence profile (EP)   | EP1       | 12 (85.7%)                    |                | 1                 | 14 (100.0%)                    |                |                   |
|                          | EP2       | 73 (75.3%)                    | 0.39           | 1.88 (0.44-8.00)  | 96 (99.0%)                     |                |                   |
|                          | EP3       | 56 (44.1%)                    | 0.03**         | 4.87 (1.19-19.94) | 121 (95.3%)                    |                |                   |
| Bone augmentation        | No        | 67 (54.0%)                    |                | 1                 | 121 (97.6%)                    |                |                   |
|                          | Yes       | 74 (64.9%)                    | 0.07           | 0.68 (0.45-1.03)  | 110 (96.5%)                    |                |                   |
| Immediate placement      | No        | 116 (57.7%)                   |                |                   | 194 (96.5%)                    |                |                   |
|                          | Yes       | 25 (67.6%)                    |                |                   | 37 (100.0%)                    |                |                   |
| 1-stage or 2-stage       | 1-stage   | 102 (63.4%)                   |                |                   | 155 (96.3%)                    |                |                   |
|                          | 2-stage   | 39 (50.6%)                    |                |                   | 76 (98.7%)                     |                |                   |
| Crown height             |           |                               |                |                   |                                | 0.30           | 0.85 (0.63-1.16)  |
|                          | C/I ratio |                               |                |                   |                                |                |                   |
|                          | Diameter  |                               | 0.48           | 1.69 (0.40-7.15)  |                                | 0.23           | 3.13 (0.49-19.94) |
| Patient level            |           | 37 (43.5%)                    |                |                   | 79 (92.9%)                     |                |                   |
|                          | Age       |                               | 0.06           | 0.97 (0.94-1.01)  |                                |                |                   |
|                          | Gender    | Female                        | 20 (47.6%)     |                   |                                | 38 (90.5%)     |                   |
| Male                     |           | 17 (39.5%)                    |                |                   | 41 (95.3%)                     |                |                   |
| History of periodontitis | No        | 2 (66.7%)                     |                |                   | 3 (100.0%)                     |                |                   |
|                          | Yes       | 35 (42.7%)                    |                |                   | 76 (92.7%)                     |                |                   |

<sup>§</sup>P-value calculated from univariate analysis of each covariate; \*covariate selected for multivariate analysis (P < .20); <sup>¶</sup>P-value calculated from multivariate analysis; \*\*significant influence derived Cox proportional hazard regression analysis (P < .05); N<sup>c</sup>: cumulative number of successful or surviving implants and patients during the study period.



**Fig. 3.** Kaplan-Meier cumulative hazard plots, (A) cumulative success rate; and (B) cumulative survival rate of single group (S, control), 2-implant supported 3-unit bridge (2-IB), and 3-implant supported 3-unit splinted crown (3-IC).



**Fig. 4.** Kaplan-Meier analysis of implant success according to implant position (A) 2-implant supported 3-unit bridge (2-IB); (B) 3-implant supported splinted crown (3-IC); P1, mesial implant; P2, middle implant; P3, distal implant.

ment designs induced an apical displacement of the peri-implant biologic width resulting more bone loss compared to the narrow and straight abutments, and slim abutments could facilitate the maintenance of peri-implant health.<sup>15</sup> This is consistent with the results of the current study, which found the risk of over contoured prostheses.

The restoration type was identified to affect the occurrence of mechanical complications: the 3-IC group had a lower risk of mechanical complications (7.2%) than the 2-IB (16.2%) as well as single control group (20.8%). This result is consistent with the previous studies, which concluded that 3-unit bridge supported by 2 implants tend to have more mechanical prob-

lems than 3 implant supported splinted crowns.<sup>6,7</sup> The present study also found that the risk of screw loosening was reduced in the 3-IC group than in the 2-IB group. This is in line with Karlsson *et al.*<sup>16</sup> which reported that the screw loosening only occurred in restorations supported by 2 implants and not observed in more extensive restorations. The mechanical benefits of splinting implants have been reported in several literatures.<sup>17-19</sup> The greater the number of implants splinted, the more evenly the stress would be distributed across more implants, reducing the stress applied to individual implants. Accordingly, for mechanical considerations, 3 implant-supported splinted crowns may be recommended rather than 2 implant-supported 3-unit bridge. However, in determining the restoration type, not only the mechanical advantages but also the biological aspect should be taken into the account. In the present study, for comprehensive evaluation of mechanical and biological complications, success and survival rates according to the restoration type were analyzed.

The findings of the present study were not consistent with that of Alhammadi *et al.*<sup>20</sup> who reported implants supporting 3-unit fixed bridge showed greater marginal bone loss and more frequent technical complications than single implants. This difference may be attributed to the fact that variables such as diameters or lengths of the implant were not included in their study although they included not only posterior but also anterior implant fixed restorations.

In the previous studies, external connection type implants had higher risk of peri-implantitis than internal connection type implants.<sup>10</sup> Internal connection implants had a higher risk of abutment fracture than external connection implants.<sup>21</sup> In the current study, no significant difference was not found according to the implant connection types, but rather, the restoration type had a greater effect on the clinical outcomes.

The success rate of implants up to 14 years were 59.2%: 62.2% in the 2-IB group, 60.4% in the 3-IC group, and 52.8% in the single control group. This result is consistent with the findings of Ravidá *et al.* who found the success rate for non-splinted single crown to be 52.5% and 61.5% for 3-implant supported splinted crowns, but 81.1% for 2-implant support-

ed 3-unit bridge.<sup>9</sup> In the present study, the EP3 was identified as a risk indicator for loss of success, and there was no significant difference in the success rate according to the restoration type, as in the study by Yi *et al.*<sup>11</sup> In the 3-IC group, however, the middle implants (P2) had the lowest success rate compared to other implant positions. This is in line with the result of peri-implantitis analysis, which revealed that the middle implants had the highest risk. Inferred from this, it seems that the risk of biological complications is more contributing to the success of implants than mechanical complications. This may be related to the fact that the incidence of peri-implantitis (32.8%) was higher than that of mechanical complications (13.0%), as in the previous studies.<sup>9,11,22</sup> However, Ioannidis *et al.*<sup>23</sup> reported that more technical complications (24.2%) than biological complications (15.2%) were observed with Astra OsseoSpeed TX implants during the 5-year observation period. There are major issues due to the lack of a consensus on mechanical or technical complication and different diagnostic and research criteria used for each study. Therefore, the success rate comparison should be carefully evaluated.

The survival rates up to 14 years were 98.6% in the 2-IB group, 95.5% in the 3-IB group, and 97.1% in the single control group, without significant difference. This is in line with the study by Yi *et al.*,<sup>11</sup> which showed a 100 % survival rate in all groups, but their short study period (53 to 58 months) should be taken into account. Ravidá *et al.*<sup>9</sup> reported that 2-implant supported 3-unit bridge had a significantly higher survival rate (100%) than 3-implant supported splinted crowns (88.5%). Similar results were also found in the present study, but there was no significant difference. This may be due to the amount of restoration and implant data collected. Therefore, further studies including more restoration and implant data would be needed.

The limitation of the current study was that 82% of the patients presented a history of periodontitis, which can be identified as a critical indicator of peri-implantitis risk,<sup>14</sup> so the outcomes in the patients with no history of periodontitis can be different. Also, this study has inherent limitations of retrospective study: uncontrollable parameters such as diets, occlusal forces and parafunctional habits of patients;

data collection should depend solely on the patients' clinical charts, so unrecorded information cannot be included as parameters such as the measurements of attached gingiva and soft tissue thickness, bucco-lin-gual position or angulation, vertical distance and horizontal distance between the implants. Further studies considering these factors are needed to confirm the current results.

## CONCLUSION

Within the limitations of the retrospective study design, the current study revealed that the restoration type was not associated with the success and survival of implants. The risk of mechanical complications was reduced in 3-implant supported 3-unit splinted crowns (3-IC). However, the middle implants of the 3-implant supported 3-unit splinted crowns had a higher risk of peri-implantitis.

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