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A prospective multicenter clinical study on the efficiency of detachable ball- and spring-retained implant prosthesis

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PURPOSE. This prospective clinical study was conducted to evaluate the clinical usefulness of the freely detachable zirconia ball- and spring-retained implant prosthesis (BSRP) through a comparative analysis of screw- and cement-retained implant prosthesis (SCRP). **MATERIALS AND METHODS.** A multi-center, randomized, prospective clinical study evaluating the clinical usefulness of the detachable zirconia ball- and spring-retained implant prostheses was conducted. Sixty-four implant prostheses in 64 patients were examined. Periodic observational studies were conducted at 0, 3, 6, and 12 months after delivery of the implant prosthesis. Factors such as implant success rate, marginal bone resorption, periodontal pocket depth, plaque and bleeding index, and prosthetic complications were evaluated, respectively. **RESULTS.** During the 1-year observation period, all implants survived without functional problems and clinical mobility, showing a 100% implant success rate. Marginal bone resorption was significantly higher in the SCRP group than in the BSRP group only at the time of implant prosthesis delivery (P = .043). In all observation periods, periodontal pocket depth was slightly higher in the BSRP group than in the SCRP group, but there was no significant difference (P > .05). The modified plaque index (mPI) scores of both groups were moderate. Higher ratio of a score 2 in modified sulcus bleeding index (mBI) was observed in the BSRP group in the 6- and 12-months observation. **CONCLUSION.** Within the limitations of this study, the newly developed zirconia ball- and spring-retained implant prosthesis could be considered as an applicable and predictable treatment method along with the existing screw- and cement-retained prosthesis. [J Adv Prosthodont 2023;15:202-13]

KEYWORDS
Dental implant; Implant prosthesis; Retrievability; Retention structure; Prospective study

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INTRODUCTION

Ever since Brånemark implemented the concept the osseointegration of titanium dental implants in 1952, various types of dental implant fixtures and prosthetic structure has been invented. As a result of numerous trials, a typical modern dental implant consisting of a fixture, an abutment, and an upper prosthesis is prevalently used. From the perspective of prosthetic systems developed and used so far, dental implant prosthesis can be divided into screw-retained, cement-retained, and screw- and cement-retained prostheses depending on the retention mechanism of abutments and upper prostheses.[1,2] Screw-retained implant prosthetic systems are advantageous due to their retrievability, which allows for favorable removal and reinstallation, and therefore long-term maintenance. Moreover, as it does not require the use of dental cement, there is no threat of harmful soft tissue reactions caused by the remaining cement.[3-5] However, due to its structure, a screw hole is formed, which may have some disadvantages. It is challenging to form an ideal occlusion, the aesthetics of the prosthesis is likely to be harmed, and there are possibilities of mechanical complications such as the fracture or loosening of the prosthetic screw.[4,6,7] In addition, since the retrievability of the prosthesis occurs at the abutment level, there is also a limitation in that the mucosal barrier is destroyed during repeated attachment and detachment, leading to the deposition of microorganisms around the implant.[8] On the other hand, in the case of the cement-retained type, there are no screw holes on the occlusal surface, so it is possible to make an aesthetic prosthesis, and it is easy to form an ideal occlusion. Even in cases where the angle of implant placements is not favorable, cement-retained prostheses compensate for this constraint to a certain degree.[6,9,10] However, due to the residual cement at the site of the prosthesis, biological complications such as inflammation, edema, and marginal bone resorption can be occurred. Another disadvantage is in the difficulty of long-term maintenance as it is difficult to detach the implant prosthesis once the final cement material is applied.[3]

In the case of the screw- and cement-retained type (SCRP), the above two cases are mixed. The upper prosthesis with screw holes is attached to the abutment using cement, and then the prosthesis and abutment can be removed together by unscrewing.[2] The residual cement can be removed thoroughly after unscrewing. So, there is no soft tissue inflammation due to the residual cement and the maintenance of the prosthesis is favorable due to its retrievability. However, there are disadvantages given that the formation of screw holes is inevitable.[2,11] Moreover, the compensation level of the implant placement angle is very limited and soft tissue destruction may occur during the removal and reattachment of the prosthetic appliance.

For nearly 70 years, dental implants have shown high success rates and been used immensely for the recovery of oral structure aesthetics and masticatory function. According to a study on implant survival rate, observing the average progress of 13.4 years, an implant survival rate of nearly 94.6% was recorded.[12] Despite the bright sides, side effects such as inflammation due to the remaining cement and mechanical complications were also constantly reported.[13,14] As a result, the need for improvement of the existing implant prosthetic system has been raised.

Recently, a detachable implant prosthetic system using a zirconia ball and elastic spring has been developed and its clinical application cases have been reported.[15,16] This system consists of the implant fixture, abutment, cap, and upper prosthesis. Nitinol spring, a shape memory alloy inside the cap allows for the detachment and reattachment of the prosthesis. Cement is used to attach the cap and prosthesis but after cementation, the remaining cement could be removed easily. The prosthesis can be easily removed using a crown remover due to the properties of nitinol spring in the cap. So, the prosthesis can be detached if desired by the dentist, securing its retrievability.[15,16] Since the attachment and detachment of the prosthesis are performed while the abutment is maintained on the fixture, there is also an advantage in preventing mechanical destruction of the mucosal barrier during attachment and detachment and generation of stress due to screw tightening.[17-21] Because there's no hole, or the size of hole is very small, the prosthesis is aesthetically and occlusally advantageous. Therefore, it may be regarded as a prosthet-

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ic system which could be secure from the risk of destruction of mucosal barrier upon detachment and screw holes being visible. However, clinical evaluation and comparative studies with traditional implant prosthetic systems are still lacking.

This study aims to compare the freely detachable implant prosthetic system using a zirconia ball and elastic spring (BSRP) with the screw- and cement-retained implant prosthetic (SCRP) system which is frequently used in clinical trials and to examine its clinical usefulness.

MATERIALS AND METHODS

This research is designed to compare the clinical usefulness of ball- and spring-retained implant prosthetic (BSRP) system with the screw- and cement-retained implant prosthetic (SCRP) system by multi-center, single-blinded, randomized and controlled clinical study. All research materials and protocol were approved by the Institutional Review Board of Pusan National University Dental Hospital (IRB No. PNUDH-2017-035-MD) and Yonsei University Dental Hospital (IRB No. 2-2017-0061).

Table 1 and Table 2 show the demographic and clinical characteristics of the study population for each implant prosthetic system. 64 subjects (male: 31, female: 33) were recruited from patients in need of implant prosthetic repair who visited the department of prosthodontics of Pusan National University Dental Hospital and Yonsei University Dental Hospital from January 2018 to December 2020. The subjects enrolled were fully aware of the objectives, risks, and benefits of the study in advance and voluntarily agreed to participate in the study. Moreover, patients were recruited according to the inclusion and exclusion criteria in Table 3. Patients who required implant placement and were mentally and physically healthy

Table 1. Demographic characteristics of subjects and distribution of implant placement

Groups		SCRP		BSRP	
Number of subjects (n)		32		32	
Age		58.67 ± 9.93		59.25 ± 8.58	
Sex	Male	11		20	
	Female	21		12	
		Maxilla	Mandible	Maxilla	Mandible
Implant location	Anterior	1	1	1	-
	Premolars	5	2	8	2
	Molars	7	16	11	10
	Total (n)	13	19	20	12

SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis.

Table 2. Distribution of implant fixtures according to the implant length and diameter

Length (mm)	Diameter (mm)								Total (n)
	SCRP				BSRP				
	3.5	4.0	4.5	5.0	3.5	4.0	4.5	5.0	
7.0	-	-	-	-	-	-	-	1	1
8.0	-	-	-	4	-	-	-	2	6
8.5	-	-	-	3	-	-	-	5	8
10.0	-	5	1	9	2	6	8	7	38
11.5	-	1	3	5	-	1	-	-	10
13.0	-	1	-	-	-	-	-	-	1
Total (n)	-	7	4	21	2	7	8	15	64

SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis.

Table 3. Inclusion and exclusion criteria

	Inclusion criteria	Exclusion criteria
General	• Age > 19 years old • Good physical and mental condition • Indicate voluntary participation and sign the consent form • In the case of women of childbearing potential, if they agree to use contraception during the clinical trial participation period (more than 6 months after the procedure)	• Patients with uncontrolled metabolic diseases (e.g. diabetes, osteomalacia, thyroid disease) • Smoking more than 20 cigarettes per day • General contraindications on the current dental treatment and surgical treatment • Radiation or chemotherapy for malignant tumor within the last 5 years • Currently pregnant or planning to become pregnant during the clinical trial period
Local	• Loss of one or more teeth in the maxilla or mandible, requiring dental implant restoration • Successful initial fixation of the placed implant • Both Full Mouth Bleeding on Probing (FMBoP) and Full Mouth Plaque Index (FMPI) are less than or equal to 25%	• Untreated acute and chronic periodontitis • Inadequate oral hygiene or lack of motivation for proper oral care

and over 19 years of age were screened as preliminary subjects. Among the screened preliminary subjects, only those who had successful initial fixation of the implants were finally enrolled as subjects. Among them, those with uncontrolled chronic and systemic diseases, those who underwent radiotherapy or chemotherapy for tumor treatment, heavy smokers, and those with contraindications to dental treatment and surgery were excluded to block the possibility of influencing the study results. Blocked randomization by a computer-generated random number list was used to prevent unbalanced allocating of both groups and to minimize bias.

In the following study, BSRP, EZ crown; Samwon DMP, Yangsan, Korea) was used in the experimental group while SCRP type transfer abutment (Transfer Abutment; Osstem Implant Co., LTD, Seoul, Korea) was used among the control group. BSRP consists of the abutment fixed to the implant and the cap which is cemented with the prosthesis (Fig. 1). The cap of BSRP has three zirconia balls protruding from the inside and consists of a nitinol spring that surrounds the zirconia balls. The BSRP abutment has a retention groove in the tapered cylinder for the zirconia ball inside the cap to be seated. Nitinol springs keep the zirconia balls protruding from the inside of the cap. Also, the BSRP abutment and cap can be seated by finger pressing or occlusal force and can be removed by inserting a screwdriver into the cap.

To fabricate prostheses using two groups of abutments, each abutment was tightened to 35 Ncm on the implant fixture using a torque wrench (KTW001; Cowellmedi Co., Busan, Korea) according to the guidelines provided by the manufacturer. The cap containing three zirconia balls and nitinol spring was secured to the abutment of BSRP. Then, silicone impressions were taken at the level of abutments of SCRP group and caps of BSRP group, and a working model was produced. This model was scanned with a table top scanner (3Shape E3; 3Shape A/S, Copenhagen, Denmark) and computer-aided design software (Exocad DentalCAD; Exocad GmbH, Darmstadt, Ger-

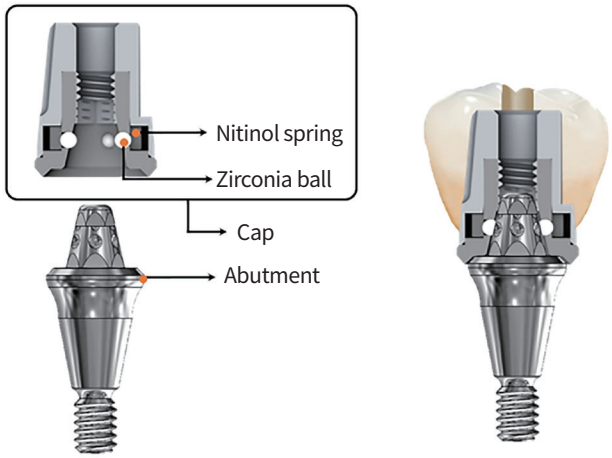

Fig. 1. Structure of ball- and spring-retained abutment.

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many) was imported. The final zirconia (LUXEN Enamel; Dental Max Co., Seoul, Korea) prosthesis was processed with a milling machine (Trione Z; Dio Implant Co., Busan, Korea) and then sintered according to the manufacturer's guidelines. The contact, marginal fit, occlusion, and esthetics of the prosthesis were evaluated and adjusted prior to final bonding. Finally, the prosthesis was attached with self-adhesive resin cement (G-CEM; GC Co., Tokyo, Japan) on each abutment and cap. To remove excess subgingival cement, the marginal area of both groups was cleaned and polished with the abutments and caps removed from the implants. After that, the abutment of the SCRP group was fixed with a screw at the fixture again and the cap of the BSRP group was freely fixed at the abutment using inner zirconia balls and spring (Fig. 2). The screw hole of the occlusal surface was sealed with polytetrafluoroethylene thread seal tape (Teflon tape; Daehan F&F, Gimpo, Korea) and composite resin (Filtek Z350 XT; 3M ESPE, St. Paul, MN, USA) (Fig. 3).

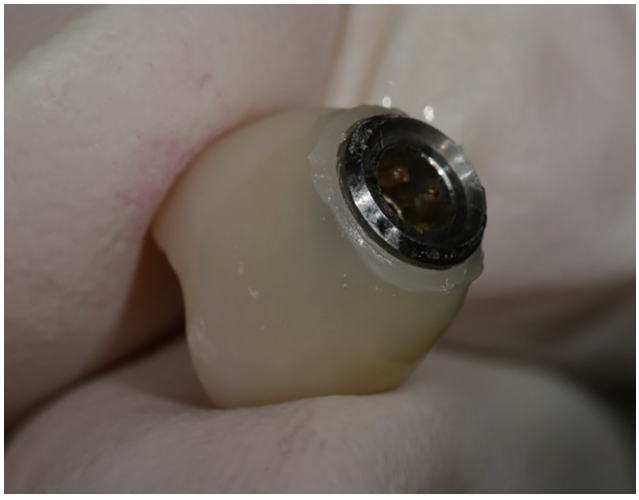


Fig. 2. Residual cement observed when the cap and prosthesis were separated from abutment right after cementation in BSRP system. After separation, residual cement can be easily removed.

Periodic observation to evaluate the two prosthetic systems was done at baseline, 3, 6, 12 months of follow-up with the baseline set on the time of the prosthesis delivery. Clinical and radiological experiments were conducted to assess the clinical usefulness of the abutments of both groups. Cumulated implant survival rate was evaluated according to the report of the 1998 Toronto Consensus Conference on Implant Success.[22] (a) The implants should not preclude the functional and aesthetic prostheses that are satisfactory to both patients and dentists; (b) the implants should not cause pain, discomfort, paresthesia, or inflammation and apical radiographs should not show radiolucency attributable to the implant; (c) individual implants should have immobility under clinical examinations; (d) vertical marginal bone loss is $\leq$ 1.6 mm for one year after implant placement and the mean marginal bone loss is $\leq$ 0.2 mm annually after the first year of function.

Marginal bone loss was evaluated on each follow up date with a radiological photo taken by the portable x-ray (Port II; Genoray Co., Seongnam, Korea) using the parallel photographing technique. To assess the bone loss near the implant site, imaging program (i-Solution; IMT i-Solution inc., Vancouver, Canada) was used to measure the implant length, mesial and distal bone loss, and an average number was calculated thereafter. Mesial and distal bone loss was

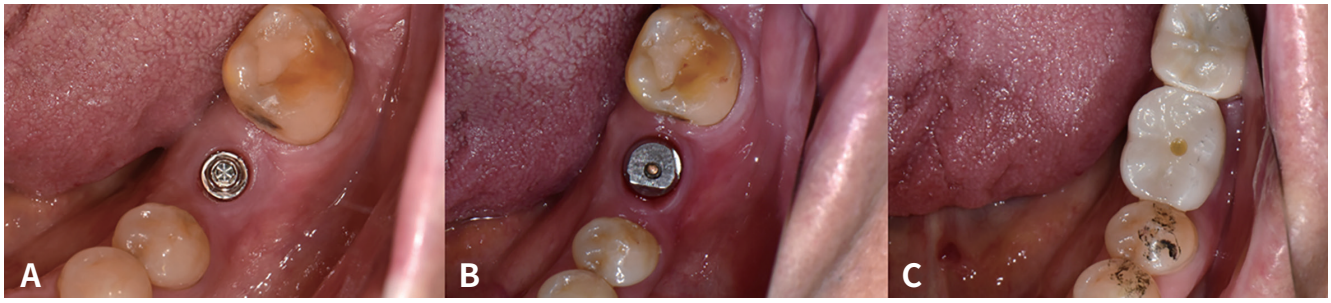
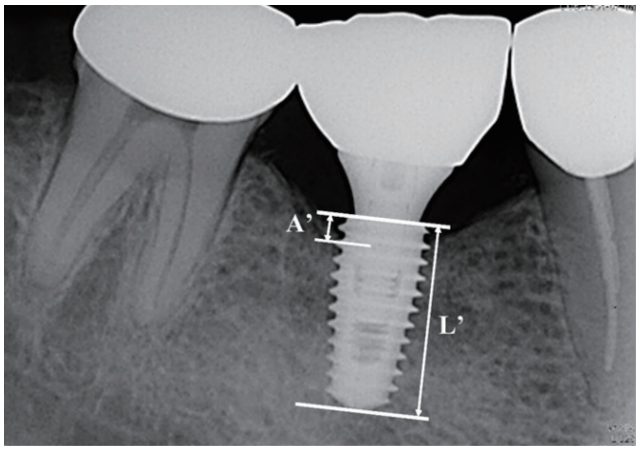


Fig. 3. Setting procedure of the final prosthesis. (A) Properly selected abutment was connected to the fixture, (B) Cap was attached on the abutment, (C) Fabricated zirconia crown was cemented on the cap with resin cement.

measured up to the bone level based on the implant platform and was calibrated using the proportional expression between the actual implant length and the measured implant length based on the image measurement program (Fig. 4).



$A = A' \times L / L'$

A: actual marginal bone resorption
A': marginal bone resorption on digital subtraction image
L: actual length of implant
L': length of implant on digital subtraction image

Fig. 4. Measurement of marginal bone loss.

Probing depth was measured by calculating the average depth measured at the 6 points (disto-facial, facial, mesio-facial, disto-lingual, lingual, mesio-lingual) near the implant site using the periodontal probe. The probing depth measured by the periodontal probe was used as an indicator of peri-implant severity with the bone loss percentage and was classified as the following (Table 4).[23]

Modified Plaque Index (mPI) and Modified Sulcus Bleeding Index (mBI) were scored from 0 - 3 according to the following criteria presented by Mombelli *et al*.[24] on each observation date (Table 4).

Complications were investigated on the type and frequency of mechanical and biological issues on each periodic observation date. Complications that occurred repeatedly from the same implant were counted as individual complications.

The significances of marginal bone loss and probing depth were determined using the independent *t*-test. Chi-square test was performed to analyze peri-implant inflammation, and plaque and bleeding indices. The analysis was performed using a statistical software (IBM SPSS ver. 25.0; IBM Co., Armonk, NY, USA) and a significance level of 5%.

Table 4. Criteria for clinical evaluation

Clinical evaluation	Classification	Clinical correlation
Peri-implant severity	Early	- PD ≥ 4 mm - Bone loss < 25% of implant length
	Moderate	- PD ≥ 6 mm - Bone loss 25 - 50% of implant length
	Severe	- PD ≥ 8 mm - Bone loss > 50% of implant length
mPI	0	No detection of plaque
	1	Plaque is only recognized by probing across the smooth margin of the implant prosthesis
	2	Plaque can be checked by the naked eye
	3	Abundance of soft matter
mBI	0	No bleeding when passing the periodontal probe along the mucosal margin adjacent to the implant
	1	Isolated bleeding spots are visible
	2	Blood forms a red line on mucosal margin
	3	Heavy or profuse bleeding

PD, probing depth; mPI, modified plaque index; mBI, modified sulcus bleeding index.

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RESULTS

Dental implants were placed on 64 subjects and, patients were given either a SCRP or a BSRP abutment and prosthesis depending on their group. A cumulative implant survival rate of the 64 implants made was measured. On each periodic observation date, a clinical and radiological examinations were given. There were no complications and both groups showed 100% cumulative survival rate of implant.

The average and standard deviation of implant marginal bone loss is shown in Table 5. The marginal bone loss at baseline, 3, 6 and 12 months in the SCRP was 0.55 ± 0.84 mm, 0.34 ± 0.36 mm, 0.38 ± 0.52 mm and 0.46 ± 0.63 mm, respectively. The marginal bone loss in BSRP was measured as 0.23 ± 0.30 mm, 0.33 ± 0.43 mm, 0.27 ± 0.33 mm and 0.33 ± 0.47 mm, respectively. In the baseline data, statistically significant difference (P = .043) was reported.

The variance of marginal bone loss was calculated by measuring the differences in marginal bone loss of each periodic observation date compared to the baseline (Fig. 5). A positive number indicates that the marginal bone level has decreased compared to the baseline and a negative number suggests that the level has increased. In SCRP, the marginal bone level of baseline has increased. However, there were no statistical differences (P > .05) or clinically meaningful changes.

The average and standard deviation of probing depth is shown in Table 6. On each periodic observation date, the probing depth of SCRP was observed to be 2.18 ± 0.78 mm, 2.37 ± 0.96 mm, 2.68 ± 1.19 mm, 2.62 ± 1.06 mm and the BSRP was observed to be 2.22 ± 0.69 mm, 2.58 ± 0.71 mm, 2.82 ± 0.85 mm, 2.86 ± 0.81 mm. There were no significant differences between groups for probing depth at each periodic observation date (P > .05). Both groups showed probing depths of under 4 mm and less than 25 percent bone loss and were classified as mild.

Table 5. Average marginal bone loss

	Marginal bone loss (mm)		
	SCRP	BSRP	*P* value
Bl	0.55 ± 0.84	0.23 ± 0.30	.043
3 mo	0.34 ± 0.36	0.33 ± 0.43	
6 mo	0.38 ± 0.52	0.27 ± 0.33	> .05
12 mo	0.46 ± 0.63	0.33 ± 0.47	

SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis; Bl, baseline; 3 mo, 3 months; 6 mo, 6 months; 12 mo, 12 months.

Table 6. Average probing depth

	Probing depth (mm)		
	SCRP	BSRP	*P* value
Bl	2.18 ± 0.78	2.22 ± 0.69	> .05
3 mo	2.37 ± 0.96	2.58 ± 0.71	
6 mo	2.68 ± 1.19	2.82 ± 0.85	
12 mo	2.62 ± 1.06	2.86 ± 0.81	

SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis; Bl, baseline; 3 mo, 3 months; 6 mo, 6 months; 12 mo, 12 months.

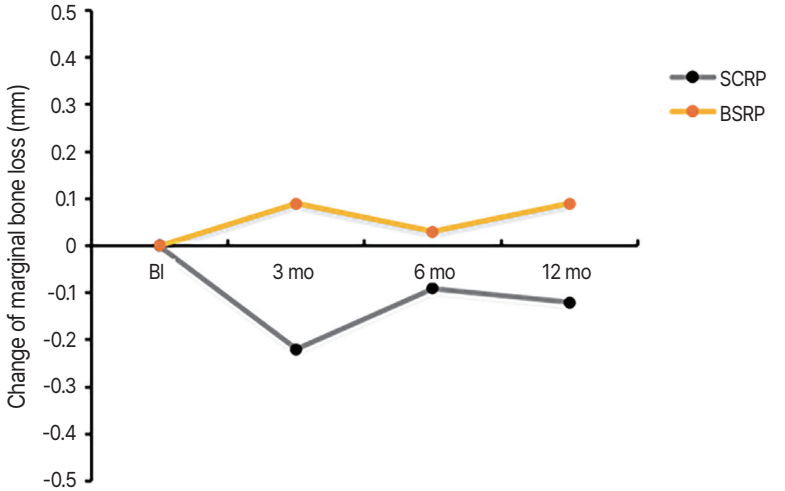

Fig. 5. Change of marginal bone loss. SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis; Bl, baseline; 3 mo, 3 months; 6 mo, 6 months; 12 mo, 12 months.

mPI and mBI were given scores from 0 - 3 and were expressed with an occurrence rate in percentile (Table 7). On each periodic observation date, the mPI of implant was evaluated. In both groups, over 90% of subjects were given a score of 0 or 1 showing little amounts of plaque. Some subjects within 10% of population scored 2 points. No subject scored 3 points, which indicates moderate plaque levels.

Over 90% of subjects in the SCRP group scored 0 or 1 in terms of mBI during the 12 months of follow up. In the BSRP group, there was an increase in the number of participants who scored a 2 after the 6 months period and the percentage went over 10%.

Three types of complications were reported during the 12 months of follow-up in the order of screw loosening, impaction of food debris, and screw fracture (Table 8). Screw loosening was a frequent complication in the BSRP group. Prior to the installation of the prosthesis, screw loosening occurred in three cases within 3 months, one case within 6 months and seven cases within 12 months. Its function was restored with torque tightening. Impaction of food debris occurred in both groups. The incidence of food debris impaction in BSRP was two cases in the 3 months period, one case in each 6 months and 12 months period. In terms of SCRP, one case of food debris impaction was reported in 3 and 6 months period. Screw fracture was reported once in the 6 months period of the BSRP and reported 2 times in the 12 months period of the SCRP.

Table 7. Modified plaque index (mPI) and modified sulcus bleeding index (mBI)

Occurrence rate (%)									
	Score	SCRP				BSRP			
		Bl	3 mo	6 mo	12 mo	Bl	3 mo	6 mo	12 mo
mPI	0	100	80.6	59.4	77.4	100	62.5	56.3	53.1
	1	-	16.1	34.4	19.4	-	31.3	40.6	46.9
	2	-	3.2	6.3	3.2	-	6.3	3.1	-
	3	-	-	-	-	-	-	-	-
mBI	0	100	87.5	93.5	71.9	100	78.1	71	62.5
	1	-	12.5	6.5	21.9	-	15.6	12.9	25
	2	-	-	3.2	6.3	-	6.3	16.1	12.5
	3	-	-	-	-	-	-	-	-

mPI, modified plaque index; mBI, modified bleeding index; SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis; Bl, baseline; 3 mo, 3 months; 6 mo, 6 months; 12 mo, 12 months.

Table 8. Number of mechanical and biological complications during periodic observation

Complications (n)		SCRP				BSRP			
		Bl	3 mo	6 mo	12 mo	Bl	3 mo	6 mo	12 mo
Mechanical	Screw loosening	-	-	-	-	-	3	1	7
	Screw fracture	-	-	-	2	-	-	1	-
	Implant fracture	-	-	-	-	-	-	-	-
	Prosthesis fracture	-	-	-	-	-	-	-	-
	Decementation	-	-	-	-	-	-	-	-
Biological	Peri-implantitis	-	-	-	-	-	-	-	-
	Impaction of food debris	-	1	1	-	-	2	1	1
	More than 1.5 mm crestal bone loss	-	-	-	-	-	-	-	-
	Suppuration	-	-	-	-	-	-	-	-
	Gingivitis	-	-	-	-	-	-	-	-

SCRP, screw- and cement-retained prosthesis; BSRP, ball- and spring-retained prosthesis; Bl, baseline; 3 mo, 3 months; 6 mo, 6 months; 12 mo, 12 months.

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DISCUSSION

In order to connect the upper prosthesis to the implant fixture, screws or cement were generally used. The screw-retained implant prosthesis allows for detachment and reattachment which makes it advantageous for repair when a loss of contact with adjacent teeth or a fracture of upper prosthesis occurs. However, it is fragile in terms of mechanical complications such as the loosening of screws or fractures. Moreover, a screw hole has to be made on the occlusal surface which makes it detrimental in terms of occlusal contact and aesthetics. On the other hand, the cement retaining method does not require screw holes. Thus, it is desirable in terms of proper occlusal contact. However, if excess cement is not properly removed, soft tissue inflammation can occur, leading to various complications. In particular, if the prosthetic margin is set subgingival to secure aesthetics, the risk of cement remaining around implant abutment increases. Therefore, the SCRP that combines the advantages of both systems is frequently used in clinical practice. However, in the case of this system, retrievability is obtained at the abutment level similar to screw-retained implant prosthesis. Therefore, with the removal and reattachment of the prosthesis with abutment, the destruction of the mucosal barrier around implant abutment can be occurred, and mechanical stress is given with repetitive screw tightening. After all, the system is almost similar to screw-retained implant prosthesis, only with different materials and manufacturing methods.

To overcome the many disadvantages of the existent implant prosthesis systems, a new type of implant prosthetic system, the BSRP which utilizes zirconia balls and nitinol shape memory alloy with favorable mechanical characteristics was introduced.[16,25,26] It uses the property of the nitinol spring, which restores its original shape when the load is removed and is characterized in that the upper prosthesis can be attached and detached relatively easily and quickly. Moreover, the remaining cement could be easily removed under this system after attaching the upper prosthesis to the cap because it can be separated from the abutment to remove the remaining cement. Because the abutment is not taken out with the prosthesis, it does not destroy the mucosal barrier around the abutment, and because the upper prosthesis can be detached without releasing the abutment, it does not cause deformation in the screw of the abutment. Therefore, this system is considered very biologically and mechanically advantageous. In addition, since the prosthesis will be cemented on the cap, there is an advantage in that passive fitting of the prosthesis is possible.[19,27,28]

In this 1-year prospective study, all implants showed 100% survival rate without functional problems and clinical mobility. This reapproves that, as proven in the previous research result,[27,29] the change in retention structure and method of the implant prosthesis does not impact the initial 1-year survival rate of implant.

In terms of marginal bone loss, there was no significant difference between the SCRP group and the BSRP group in the rate of marginal bone change at 3, 6, and 12 months, which are variables in this study. In particular, there was a difference between the two groups at the bone level when the implant prosthesis was connected on the fixture (P = .043), which was measured at the time of delivery of the implant prosthesis, which was not significant in this study because the difference in bone resorption was not derived as a result. In addition, in some cases, it was measured that the bone rather increased when measuring the value of the surrounding bone level of each implant. Adell *et al*.[30] reported that this was caused by increased radiation transmittance due to 'corticalization', and it was not known whether the cause was an increase in bone volume or mineral content.

The condition of the soft tissue surrounding the implant is an important factor in evaluating the long-term prognosis of the implant. Gingival probing depth around the implant is considered a reliable method to assess tissue destruction at the implant site.[31] Gingival probing depth is strongly related to the loss of supporting bone around the implant. In this study, values of 3.0 mm or less were measured in all implants and classified as mild according to the criteria for peri-implantitis presented in a paper published by Froum and Rosen.[23] There were no significant differences between groups at each periodic observation date (P > .05).

As a result of comparing the implant soft tissue condition of the two groups using the mPI and mBI measurements in this study, the modified plaque index of the two groups was generally observed to be in good oral condition with a score of 0 to 1 in every periodic observation date. It was confirmed that the retention structure of the implant prosthesis did not negatively affect oral hygiene. Modified sulcus bleeding index showed that the BSRP group had a higher percentage of a score of 2 compared to that of the SCRP group. Lang *et al.*[32] reported that the bleeding, which occurs when probing with 0.25 N, could be diagnosed as inflammation of the mucosal barrier and that the bleeding does not occur at a healthy implant site. They also reported bleeding in 67% of cases of peri-implant mucositis and 91% of cases of peri-implantitis. Bleeding upon probing around the implant site is a predictive factor in evaluating the progressive loss of attachment, and no bleeding upon probing is a negative predictor suggesting that the implant site is healthy.[33] Smithloff and Fritz[34] reported that bleeding upon probing occurs alongside symptoms of implant failure, such as radiographic bone loss and increased probing depth. However, in this study, there was only bleeding during probing, and no results of marginal bone resorption or increased probing depth were found. It is predicted that screw loosening, a relatively frequently observed complication in the BSRP group, may have caused a slight mobility to the abutment and irritated the soft tissue around the implant site.

Pjetursson *et al*.[35] reported that only 66.4% of implant-supported fixed dental prostheses had no complication during the 5-year observation and that the most frequent complications were fracture of veneer material (13.5%), peri-implantitis (8.5%), loss of prosthetic screw hole packing material (5.4%), abutment or screw loosening (5.3%) and loss of retention of cement-retained prosthesis (4.7%). In this study, the abutment loosening was evaluated as a major complication in the BSRP group, and food debris impaction and screw fracture were additionally observed. On the other hand, in the SCRP group, screw fractures and food debris impaction were observed.

In this study, as in the previous studies,[27,29] abutment loosening occurred more frequently in the BSRP group compared to the SCRP group. The BSRP abutment is manufactured to be compatible with Morse taper fixtures of various manufacturers, and therefore slight displacement may occur at the implant-abutment connection.[27] According to a mechanical experiment study by Park *et al*.[36] and Kim *et al*.,[37] the interchangeable abutment showed a significantly higher torque loss than the abutment manufactured by the same manufacturer as the implant after cycle loading, so the use of the same company's product was recommended for preventing screw loosening. On the other side, this may be overcome by manufacturing an implant fixture and BSRP abutment in one piece as suggested by Shin *et al*.[29].

In both SCRP and BSRP groups, screw fracture was observed in 3 cases. It is known that the implant screw is the most vulnerable part among the components of the implant and is fractured before other components, making it difficult to have fractures in other parts.[38] However, screw fracture indicates that too much harmful force is being applied to the implant and screw. To prevent this, it is necessary to form an ideal occlusal relationship, adjust eating habits, or modify the design of the prosthesis.

Impaction of food debris was observed in both the SCRP and BSRP groups. Jemt *et al*.[39] reported that this is an unimportant complication that has been caused in 4 of 28 patients who have received a single tooth implant prosthesis in the 15-year follow-up. They also reported that this occurs more often in people with long faces. Wei *et al*.[40] reported that food debris impaction is caused by the migration of adjacent teeth and that loss of proximal contact due to movement of proximal teeth occurs in nearly 60% of all implant prostheses regardless of whether the adjacent teeth is a maxillary/mandibular or premolars/molars. Independent from the retention structure of the implant prostheses, impaction of food debris, a frequent complication, is a physiological phenomenon which has been long unresolved. It is difficult to entirely solve this complication but the dentist should try to reduce the occurrence rate.

In this study, the clinical usefulness of the BSRP group was confirmed through comparison with the SCRP group. However, this study has several limitations. A small number of samples from each implant group was involved. Also, an evaluation of alveolar

bone and soft tissue condition before implant placement and a surgical method were not considered for this evaluation. It was also observed over a short period of only 12 months. Therefore, further observations are needed to evaluate the long-term stability of the BSRP group.

CONCLUSION

In this study, SCRP and BSRP were compared under a 1-year follow-up clinical study to find the clinical usefulness of the retained implant prosthesis using zirconia ball and nitinol spring. In all implants, a 100% survival rate was observed without functional problems and clinical mobility. However, in the BSRP group, screw loosening was frequently reported as a complication and there should be further research to solve this problem. Under the limitations of this study, the newly introduced detachable implant prosthesis utilizing a zirconia ball and nitinol spring is shown to be an applicable and predictable treatment method along with the existing SCRP. However, additional long-term clinical studies with larger samples are needed to establish more reliable evidence.

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