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정형외과 수술에서 골대체제로써 Beta-Tricalcium Phosphate 사용에 대한 방사선학적 결과

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Radiologic Outcome of Beta-Tricalcium Phosphate as a Bone Substitute in Orthopaedic Surgery

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<Abstract>

Objectives: To analyze the radiologic results of patients treated with bone defects treated with beta-tricalcium phostphate (β-TCP) in orthopedic surgery. **Methods:** Medical records of 49 patients, consisting of 24 (49.0%) men and 25 (51.0%) women were retrospectively reviewed. Graft incorporation was evaluated based on Irwin's radiologic staging. **Results:** The explanatory power of the total regression equation in Irwin's stage at 3 months postoperatively according to three explanatory variables, namely graft tightness, age at diagnosis, and lesion volume, was 65.6%; the explanatory power of Irwin's stage at 6 months postoperatively according to two variables, namely lesion volume and graft tightness, was 32.9%; and the explanatory power of Irwin's stage at 9 months postoperatively for two variables, namely longitudinal lesion length and graft tightness in the total regression, was 30.8%. **Conclusions:** Graft tightness, lesion volume, age at diagnosis, and longitudinal lesion length are the common factors affecting graft incorporation.

Key Words : Bone Substitute, Beta-tricalcium Phosphate, Bone Transplantation, Radiography, Orthopedics

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Ⅰ. Introduction

Bone graft procedures have been increasingly used in traumatology, tumor surgery, spine surgery, and revision arthroplasty. Autogenous bone grafts provide all three important factors for bone regeneration elements (osteogenesis, osteoinduction, and osteoconduction), therefore, they remain the gold standard. Bone healing is a multilateral course that requires mechanical stability and revascularization. Osteoinduction is defined as the stimulation of primitive, undifferentiated and pluripotent cells that occur in bone-forming cell lines. Osteoconduction is characterized by bone growths through the bone surface or through a bone, channel, or pipe [1]. Therefore, the most ideal bone substitute should not be at a risk of immunological rejection or disease infection and should include the graft in the host bone by being gradually replaced by the regenerated bone. The Bone substitute should fit well with bone defects in a short time period. It must also be osteoinductive, osteoconductive, and absorbent [2][3]. In addition, the ideal bone substitute should be readily available at a reasonable cost and easily sterilizable with good thermal conductivity

Autogenous bone grafts have inherent limitations, such as the need for donor sites and increased morbidity, surgical time and cost, and patient recovery time [4]. Allografts and xenografts can be used as alternatives to autogenous bone grafts. However, they are expensive. In addition, their clinical results are more varied than autografts. Moreover, they are associated with potential risks of bacterial contamination, viral transmission, and immunogenicity [2]. Synthetic bone grafts including ceramics, collagen, non-collagenous proteins, bioactive glasses, and biodegradable polymers have already been performed. Although porous hydroxyapatite, ceramic-based synthetic bone graft is an excellent osteoconductivie scaffold, its inherent drawbacks include slow resorption and brittleness. These limiations can be overcome, with the use of beta-tricalcium phosphate (β-TCP) to provide osteoconduction for bone formation. β-TCP has an excellent biocompatibility and biodegradability and is gradually degraded in the body, and calcium and phosphate ions released into body fluids cause supersaturation at localized sites, promoting adhesion and bone forming cells[2][3].

However, studies reporting radiologic results of β-TCP are insufficient. Therefore, this study aimed to assess the radiologic results of β-TCP as a bone graft substitute in orthopedic surgery for bone defects.

Ⅱ. Methods

1. Participants and data collection

A total of 52 participants underwent orthopedic surgery with β-TCP only for bone defect from January 2018 to August 2018. Inclusion criteria were patients with bone defect after a benign bone tumor curettage, orthopedic instrument removal, or skeletal trauma. Patinets with surgical wound infection or who were pregnant were excluded from the study. Among the 52 patients, 49 with follow-up period of ≥

12 months were enrolled and their data were retrospectively reviewed. Data on sex, age at diagnosis, pre-operative diagnosis, lesion location, curettage performed intraoperatively, additional plate fixation, longitudinal lesion length, bone substitute types, lesion volume, and graft tightness were reviewed. The design and protocol of this study were approved by the Institutional Review Board (IRB) of Chosun University Hospital (IRB No. CHOSUN 2019-09-006-001).

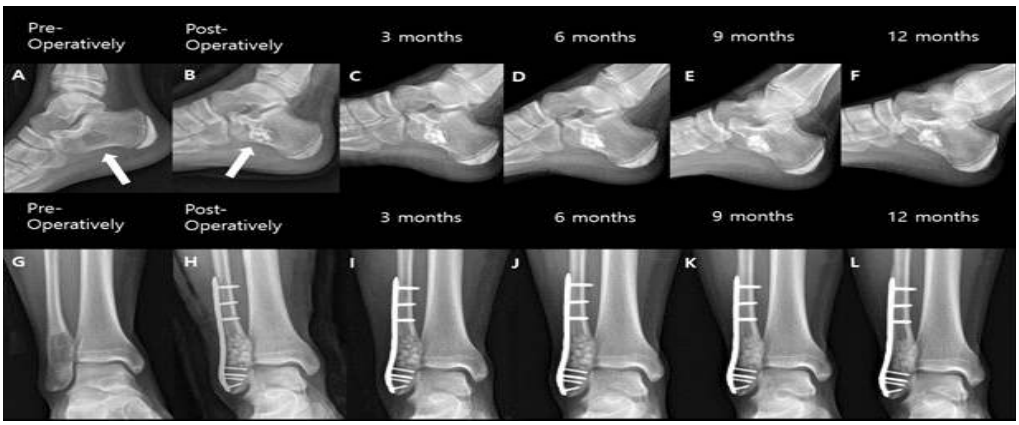
2. Procedures

After the planned benign bone tumor curettage, orthopedic instrument removal, or bone defect preparation due to skeletal trauma, the bone defect site was fully filled with β-TCP (Neo Bone®, SN Biologics Co., Ltd, Seoul, Korea) alone. NeoBone® used in this study was macroporous with a total pore volume of 65% ± 5% and pore size of 300–500 μm. Neo Bone® was manufactured and packaged in granule and block types (rectangular, cylinder, truncated cone, wedge, or round wedge). Patient-specific cuttings were made immediately. Their stability for absorbency and bone formation has been proven using an animal model. NeoBone® was designed to produce granular and block types in the same tray to make a precise bone graft customized with the same size as the traditional graft and processed by post-processing physical properties. Elasticity was secured by overcoming brittleness previously identified as a limitation of the bioactive ceramic bone. While maintaining the appropriate strength to perform its role as a scaffold, Neo Bone® was produced to allow reproduction of spongy bones in the human body through appropriate absorption

3. Radiologic evaluation

Radiologic evaluations were performed using standard anteroposterior and lateral radiographs preoperatively, immediately after surgery, and at 1 (P1), 3 (P3), 6 (P6), 9 (P9), and 12 (P12) months postoperatively. All radiographs were obtained using the same digital X-ray apparatus and evaluated with a digital planning software <Fig. 1>. At each time point, the best quality radiograph was selected for each patient. All measurements were performed in a blinded manner and random order by two authors.

To assess the resorption of β-TCP, a radiographic analysis was performed based on Irwin's radiologic staging [5]. Stage I was determined when the radiolucent zone between the bone cavity and the graft was present and the graft margins were obvious. When radiolucent zone disappeared and graft margins were incorporated, Stae III was determined, with the middle being Stage II. The measurement reliability was assessed by examining the inter-observer agreement using an intra-class correlation coefficient. Intra-observer reliability was assessed for each observer after 2 weeks from the first measurement. Irwin's radiologic staging for inter-observer reliability was 0.84 (range, 0.81-0.92) and for intra-observer reliability was 0.90 (range, 0.85-0.96), indicating the high reproducibility of all measurements.



<Figure 1> Upper row: Simple bone cyst of the calcaneus treated by curettage and defect-filling using β-TCP (Neo Bone®, SN Biologics Co., Ltd, Seoul, Korea). (A, B) Pre- and post-operative X-ray showing enlarged chamber in the body of the affected bone (arrow) treated with curettage intraoperatively (C-E) X-rays obtained at 3, 6, and 9 months postoperatively, showing increasing product resorption and cortical thickening. (F) X-ray obtained at 12 months postoperativelt, showing normal cortical thickness in the main part of the cyst and resorbed β-TCP.
Lower row: Fibrous distal fibular dysplasia treated by curettage, defect-filling using β-TCP, and additional plate fixation technique. (G, H) Pre- and post-operative X-ray showing lateral cortical breakage for lesion curettage and complete defect filling without pathologic fracture. (I-L) X-rays obtained at 3, 6, 9, and 12 months postoperatively surgery, showing increasing product resorption and cortical thickening.

4. Statistical Analysis

Collected data were analyzed using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA). Participants's general characteristics were analyzed using a descriptive statistical analysis. The relationship between Irwin's stage for each time point and disease characteristics of participants was calculated using Pearson's correlation coefficient. Multiple stepwise regression analysis was performed to identify factors affecting the Irwin's stage. Multicollinearity, residuals, and singular values were evaluated for independent variables.

Ⅲ. Results

1. Patients' general characteristics, lesion characteristics, and treatment types

Patients' general characteristics were analyzed using a descriptive statistical analysis. Results are shown in <Table 1>. Of 49 patients included in this study, 25 (51.0%) were women and 24 (49.0%) were men. The mean of age at diagnosis was 34.5 ± 22.0 years. Preoperative diagnosis was bone tumor for 33 (67.3%) patients, non-union for 10 (20.4%), and implant removal for 6 (12.2%). Majority of lessions were located in the femur or humerus (23 patients, 46.9%), followed by the hand or foot (18, 36.7%), forearm or tibia (7, 14.3%), and pelvis (1, 2.0%). A total of 33 (67.3%) patients underwent curettageintraoperatively. Additional plate fixation was performed in 27 (55.1%) patients.

The type of bone substitute was as follows: 42 (85.7%) patients with granule type and 7 (14.3%) with block type. Regarding the lesion volume, 29 (59.2%) patients had ≤5 cc, and 20 (40.8%) had ≥5cc. Regarding the graft tightness, 25 (51.0%) patients had loosely mounted, and 24 (49.0%) had tightly seated graft.

2. Relationships among general characteristics, lesion characteristics, and Irwin's stage

Results of the correlation analysis among the participants' general characteristics, lesion characteristics, treatment types, and Irwin's stage at P3, P6, and P9 postoperatively are shown in <Table 2>. Irwin's stage was 1 in all patients at P1 and 3 at P12 postoperatively. The correlation analysis of Irwin's stages at P3, P6, and P9 psotoperatively was performed.

P3 Irwin's stage was statistically significantly negatively correlated with age at diagnosis (r=-.59, p< .01), preoperative diagnosis (r=-.29, p<.05), longitudinal lesion length (r=-.50, p<.01), lesion volume (r=-.58, p<.01), and graft tightness (r=-.68, p<.01). P6 Irwin's stage was statistically significantly negatively correlated with age at diagnosis (r=-.31, p<.05), preoperative diagnosis (r=-.33, p<.05), lesion location (r=-.35, p<.05), additional plate fixation (r=-.28, p<.05), longitudinal lesion length (r=-.50, p<.01), lesion volume (r=-.54, p<.01), and graft tightness (r=-.42, p<.01), but positively correlated with curettage performed intraoperatively (r=.29, p<.05

<Table 1> Basic demographic characteristics of participants (N = 49)

Characteristics	Categories	M(±SD) n(%)
Age (years) at diagnosis		34.5(±22.0) years
	Under 18 years old	17 cases (34.7%)
	Over 18 years old	32 cases (65.3%)
Sex	Male	24 cases (49.0%)
	Female	25 cases (51.0%)
Preoperative diagnosis	Bone tumor	33 cases (67.3%)
	Trauma/nonunion	10 cases (20.5%)
	Implant removal	6 cases (12.2%)
Lesion location	Pelvis	1 case (2.0%)
	Hand/foot	18 cases (36.7%)
	Femur/humerus	23 cases (46.9%)
	Tibia/forearm	7 cases (14.3%)
Curettage performed intraoperatively	Without	16 cases (32.7%)
	With	33 cases (67.3%)
Additional plate fixation	Without	22 cases (44.9%)
	With	27 cases (55.1%)
Type of bone substitute	Granule	42 cases (85.7%)
	Block	7 cases (14.3%)
Lesion volume	< 5 cc	29 cases (59.2%)
	≥ 5 cc	20 cases (40.8%)
Graft tightness	Tight	24 cases (49.0%)
	Loose	25 cases (51.0%)

) and P3 Irwin's stage (r=.59, p<.05).

P9 Irwin's stage was statistically significantly negatively correlated with age at diagnosis (r=-.35, p<.05), lesion location (r=-.31, p<.05), additional plate fixation (r=-.33, p<.05), longitudinal lesion length (r=-.50, p<.01), lesion volume (r=-.49, p<.01), and graft tightness (r=-.48, p<.01), but positively correlated with that of P3 (r=.58, p<.01) and P6 Irwin's stage (r=.54, p<.01).

3. Irwin's stage predictors

To evaluate the explanatory power of variables for Irwin's stage according to period and to identify variables with stronger predictive power, stepwise multiple linear regression analysis was performed <Table 3>. First, the statistical significance of the model was tested to determine the effects of eight independent variables (age at diagnosis, preoperative diagnosis, lesion location, curettage performed intraoperatively, additional plate fixation, longitudinal lesion length, lesion volume, and graft tightness) on Irwin's stage based on time period. As a result, the regression model including graft tightness, age at diagnosis, and lesion volume was statistically significant for Irwin's stage at P3 (F=31.511, p<0.001). The regression model containing the lesion volume and graft tightness only was statistically significant for Irwin's stage at P6 (F=12.765, p<.001). Finally, the regression model including the longitudinal lesion length and graft tightness was statistically significant for Irwin's stage at P6 (F=11.670, p<.001). To test regression analysis assumption of independent variables, uniform variance, normal distribution, and residual multicollinearity were confirmed. Results revealed that the tolerance of P3 Irwin's stage range were 0.684-1.000 for P3, 0.608-0.938 for P6, and 0.667-1.000 for P9. Variance inflation factor (VIF) for independent variables did not exceed 10 (1.000-1.645) for each model. There was no problem with multicollinearity either. These results indicate the absence of multicollinearity between independent variables. Residual independence was examined usin the Durbin-watson test, demonstrating results close to 2 (P3 Irwin's stage, 1.900; P6 Irwin's stage, 2.040; P9 Irwin's stage, 2.051), indicating the lack of autocorrelation. Therefore, residuals were normally distributed, meeting the homoscedasticity assumption.

Factors affecting Irwin's stage differed depending on the measurement period. Graft tightness was considered the most important factor in each period. Lesion volume, age at diagnosis, and longitudinal lesion length were also important factors. For Irwin's stage after 3 months, graft tightness (β=-.511, p<.01) showed 44.4% explanatory power, identified as the most important variable. The explanatory power increased by 17.4% when age at diagnosis was added. It was further increased by 3.8% when lesion volume was added (β=-.254, p<.01). The explanatory power of the total regression equation for P3 Irwin's stage according to these three explanatory variables was 65.6%. The explanatory power of lesion volume (β =-.451, p<.01) was 27.4%, an important variable for Irwin's stage after 6 months. When graft

tightness (β=-.275, p=.03) was added, the explanatory power increased by 5.5%. Thus, the explanatory power of P6 Irwin's stage according to these two variables (lesion volume and graft tightness) was 32.9%. Finally, in the regression equation for P9 Irwin's stage, longitudinal lesion length was the most important explanatory variable (β=-.357, p=.01). When graft tightness (β =-.330, p=.02) was added, the explanatory power was increased by 7.7%. The explanatory power of P9 Irwin's stage for these two variables (longitudinal lesion length and graft tightness) in total regression was 30.8%.

In fact, the Irwin's stage tended to improved earlier with younger age at diagnosis, smaller lesion volume, and shorter longitudinal lesion length. Moreover, graft tightness could affect results as operator controlled factors.

<Table 2> Correlation among variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Sex (1)	1												
Age at diagnosis (2)	.11	1											
Pre-Operative diagnosis (3)	-.01	.35*	1										
Lesion location (4)	.04	.18	.24	1									
Curettage performed preoperatively (5)	.01	-.28	-.86**	-.20	1								
Additional plate fixation (6)	-.06	.10	-.01	.24	-.19	1							
Longitudinal lesion length (7)	-.15	.21	.31*	.45**	-.32*	.31*	1						
Type of bone substitute (8)	.05	.37**	.49**	-.01	-.46**	.02	.01	1					
Lesion volume (9)	-.02	.53**	.42**	.31*	-.40**	.25	.57**	.25	1				
Graft tightness (10)	-.14	.27	-.07	.21	.01	.43**	.42**	-.30*	.32*	1			
P3 Irwin's stage (11)	-.02	-.59**	-.29*	-.24	.28	-.26	-.50**	-.13	-.58**	-.68**	1		
P6 Irwin's stage (12)	.18	-.31*	-.33*	-.35*	.29*	-.28*	-.52**	.03	-.54**	-.42**	.59**	1	
P9 Irwin's stage (13)	-.15	-.35*	-.24	-.31*	.22	-.33*	-.50**	-.02	-.49**	-.48**	.58**	.54**	1

*. Correlation is significant at the 0.05 level (two-tailed)
**. Correlation is significant at the 0.01 level (two-tailed)

<Table 3> Variables influencing Irwin's stage

		B	SE	β	adj R2	t	p	VIF	F
P3 Irwin's stage	Tightness of graft	−.508	.089	−.511	.444	−5.683	<.01	1.128	31.511 (p<.001)
	Age at diagnosis	−.007	.002	−.315	.618	−3.124	<.01	1.419	
	Lesion volume	−.257	.104	−.254	.656	−.2.477	<.01	1.463	
P6 Irwin's stage	Lesion volume	−.499	.138	−.451	.274	−3.620	.01	1.110	12.765 (p<.001)
	Graft tightness	−.299	.136	−.275	.329	−2.203	.03	1.110	
P9 Irwin's stage	Longitudinal lesion length	−.007	.003	−.357	.231	−2.696	.01	1.218	11.670 (p<.001)
	Graft tightness	−.325	.130	−.330	.308	−2.491	.02	1.218	

* Dummy variables: Grafte tightness: 1 = tight, 2 = loose; Lesion volume: 1 = < 5 cc, 2 = ≥ 5 cc.

Ⅳ. Discussion

Many biomaterials and surgical techniques have been developed to manage bone defects. Knowledge on the properties and characteristics of biomaterials should be considered to achieve a predictable result and clinical success in the regenerative procedure. β-TCP is an osteoconductive calcium phosphate with chemical composition most similar to the human bone. It has better absorption than hydroxyapatite (HA) [6]. Weaknesses of traditional β-TCP include weak mechanical strength and fast absorption. The more porous β-TCP undergoes biodegradation within 6 weeks after its introduction into the bone defect. Since its compression and tensile strength are very similar to those of the cancellous bone, it can be used in regions without mechanical load [7]. Its osteoconductivity and biocompatibility are also better than the conventional bone cement with PMMA. Thus, β-TCP can be inserted to a bone defect or a screw insertion site in case of fracture fixation [8]. Another major component, polyphosphate, is immensely concentrated in osteoblasts and is involved in the mineralization of bone metabolism [9]. Different from HA with slow biodegradation, β-TCP is biodegraded fast in vivo [10][11].

An ideal synthetic biomaterial should be biocompatible, resorbable, cost-effective, and easy to use, showing a minimal fibrotic reaction, can undergo remodeling, and support new bone formation [12]. From a mechanical point of view, synthetic bone graft substitutes should have a comparable strength to that of the cortical/cancellous bone being replaced [13]. Other synthetic biomaterials are currently used for bone regeneration and can be classified into three groups depending on its composition: metallic, ceramic, and polymeric [13,14,15].

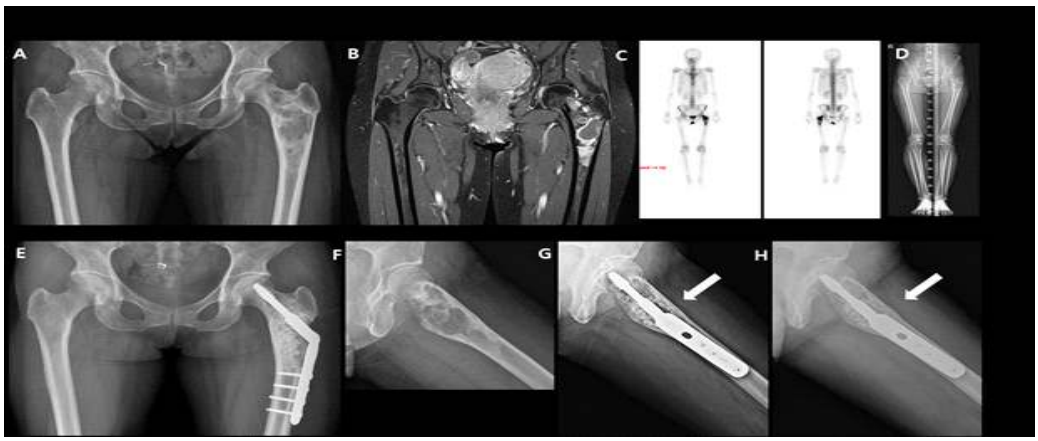
A significant negative correlation between the defect size and the incorporated bone and defect size ratio has already been reported [3]. Bone width was an important factor associated with less graft incorporation. The relationship between

graft incorporation with age was complicated. Age itself is not independently an important factor, but as the size of defects increases, aging has a more negative effect on new bone formation [6]. Larger size defects and affected bones and aging appear to be important negative factors for synthetic graft incorporation [16]. The addition of the bone marrow has been estimated to improve graft incorporation. The long-term graft persistence of other graft materials, such as hydroxyapatite, acted as a stress factor, resulting in late fractures [16]. The acceptance of these substitutes by host tissues is affected by two important features: pore diameter and porosity or interconnectivity.

The optimal pore size for bone ingrowth is 100 μm, whereas pore sizes of >200 μm can promote the development of mature osteon [4]. Porosity should be higher than 50–60%. The minimum interconnection size should be higher than 50–100 μm, and the average pore size should be between 100 and 500 μm [17]. Dead-end pockets limit the vascular supply to the in-growing bone; therefore, interconnectivity is essential. This pore size was advantageous for bone formation. The form of hydroxyapatite determines its clinical usefulness. The size of the bone defect determines the proper size of the implant. In this study, the block form was used due to the large defect size. Nagahara et al. assessed the resorption rates of hydroxyapatite and β-TCP [18]. Their results indicated that the resorption rate of β-TCP was faster than that of hydroxyapatite. The bioceramic resorption mechanism is believed to involve two processes: solution- and cell-mediated disintegration [19]. Both solution- and cell-mediated disintegration appear to affect the β-TCP resorption. However, HA is thought to be relevant only to solution-mediated disintegration. The β-TCP microstructure can promote cell-mediated disintegration mainly caused by osteoclasts [20]. Histological evaluation revealed the presence of numerous osteoclasts on the β-TCP surface. However, little osteoclasts were detected in HA. Tanaka et al. have assessed implantation in patients with β-TCP blocks with 75% and 60% porosities in the medial open wedge high tibia osteotomy [21]. In their study, almost complete β-TCP resorption was achieved within 3.5 years. However, Oh et al. reported that the mean absorption of β-TCP spacers was 49.6% only at 12 months postoperatively [22]. Thus, the absorptivity of β-TCP can depend not only on the implant location but also on its porosity, volume, and shape.

In the present study, changes in the radiological bone cavity appearance following a bone defect filling were quantified using a β-TCP bone graft substitute only (Neo Bone®, SN Biologics Co., Ltd, Seoul, Korea) in 49 orthopedic surgeries. After 1 year, the bone defect was normalized in all patients. Inside the bone cavity, radiographic appearance was improved in 22 (44.9%) patients at P3. Five patients remained at Irwin's Stage 1 at P6. However, all patients had Irwin's Stage 3 at P12 postoperatively.

Minor complication occurred in one patient. One patient was suspected with postoperative non-displaced fracture at the anterior cortex of the femoral neck and was treated by curettage



<Figure 2> Fibrous dysplasia of the proximal femur treated by curettage, defect-filling using ß-TCP (Neo Bone®, SN Biologics Co., Ltd, Seoul, Korea), as well as additional compressive hip screw and plate fixation technique. (A-D) Preoperative X-ray, MRI, whole-body bone scan, and lower extremity scanography showing left proximal femur, intertrochanteric, and subtrochanteric osteolytic bone lesions with intramedullary cystic changes and impending pathologic fractures. MRI showing this bone lesion is highly suggestive of fibrous dysplasia with the size of 4.6 × 11.2 × 3.8 cm, mild bony expansion, and endosteal scalloping without cortical disruption. (E) Postoperative X-ray showing large-sized lateral cortical breakage for lesion curettage and additional plate fixation with complete defec-filling using ß-TCP. (F-H) Pre- and postoperative left hip lateral view X-ray showing anterior femoral neck cortical breakage during the curettage procedure, although fracture healing can be achieved without additional operation after 3 months.

and dynamic hip screw fixation for fibrous dysplasia of the femoral neck and intertrochanteric bone lesion. The patient was retrospectively examined during a radiographic conference 3 months later <Fig. 2>. No intervention was required. Postoperative wound secretion or acute/subacute osteomyelitis was not observed.

Regardless of observation points, age at diagnosis, lesion volume, longitudinal lesion length, and graft tightness are common factors associated with Irwin's stage. In particular, graft tightness might occur due to suppressed fibrotic tissue ingrowth and enhanced osteocyte homing when the boundary between the host bone and bone substitute is limited. However, the exact reason needs to be investigated further. For the tight bone graft, the block type should be cut into a little oversized and carefully fitted to ensure a tight fit when machining in the operation room. When the granular type is used, it should be wet using blood or saline solution to prevent caking of the powder. It should be gradually inserted from the inside with appropriate pressure to the impactor to minimize empty space.

Occasionally, pathologic fractures from the screw hole in the previous surgical site may be observed after an implant removal. Early bone healing with appropriate bone substitute grafts for bone defects after plate or nail removal may help prevent this risk.

This study has some limitations. First, it is a retrospective study that does not determine the sample size as the researcher intended. Second,

the follow-up period was relatively short. However, despite these limitations, this study introduces criteria that can be used to evaluate the effect of bone substitutes and shows that β-TCP alone, Neo Bone®, was absorbed into the host bone within a relatively early period.

Ⅴ. Conclusion

Factors affecting Irwi's stage reflecting radiological results were somewhat different depending on the measurement period. Common factors affecting each period were grafat tightness, lesion volume, age at diagnosis, and longitudinal lesion length. Short-term follow-up showed that patients treated with β-TCP alone, Neo Bone®, absorbed most of the medication within 12 months without any serious complications.

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<국문초록>

Objectieves: 본 논문의 목적은 정형외과 수술 중 골결손에 대하여 β-TCP를 이용하여 치료 받은 대상자의 방사선학적 결과를 평가하기 위함이다. Methods: 총 49명의 대상자 중 24명 (49.0%)는 남자 였으며, 25명 (51%)는 여자였다. 요인 분석을 위하여 의무 기록 검토가 시행되었다. 각 시기별로 골대체재의 흡수 정도는 Irwin 의 방사선학적 체계에 따라서 평가되었다. Results: 술 후 3개월 째, 세 가지 측정 변수인 골대체제 이식 견고성, 진단 당시 나이, 병변의 부피에 의한 회귀 모형의 설명력은 65.6% 였다. 술 후 6개월 째, 두 가지 측정 변수인 병변의 부피, 골대체제 이식 견고성에 의한 회귀 모형의 설명력은 32.9% 였다. 술 후 9개월 째, 두 가지 측정 변수인 병변의 장축 길이, 골대체제 이식 견고성에 의한 회귀 모형의 설명력은 30.8% 였다. Conclusions: 골대체제 이식 견고성, 병변의 부피, 진단 당시 나이 그리고 병변의 장측 길이가 골대체제의 흡수에 영향을 미치는 인자였다.