The Impact of Adjacent Implants and Prosthesis Types on the Marginal Bone Loss of 1792 Internal Connection Implants: Up to 15 year Retrospective Multi-Center Study

JiHwan Oh

The Graduate School
Yonsei University
Department of Dentistry

The Impact of Adjacent Implants and Prosthesis Types on the Marginal Bone Loss of 1792 Internal Connection Implants: Up to 15 year Retrospective Multi-Center Study

Directed by Professor Sunjai Kim

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This certifies that the Doctoral Dissertation
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Thesis Supervisor: Sunjai Kim

Jong Ki Huh

Jae Seung Chang

Se-Wook Pyo

Young Woo Song

The Graduate School
Yonsei University
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감사의 글

논문을 작성하면서 많은 조언과 지도를 해주신 김선재 교수님, 장재승 교수님, 표세욱 교수님 그리고 심사해주신 허종기 교수님과 송영우 교수님께 깊은 감사드립니다. 2019년 처음 후향 연구를 맡게 되었을 때 가졌던 사명감과 열정을 응원해 주신 교수님이 아니었다면, 끝까지 좋은 결과를 내지 못하였을 것입니다. 방대한 양의 자료를 정리하면서 항상 느꼈던 점은, 그동안 그저 열심히, 무작정 혹은 되는 데로 라는 생각을 가지고 있던 저에게 조금 더 체계적으로 자료를 분류하고 현상과 결과에 대해 애정을 가지고 꼼꼼히 바라보게 해준 귀중한 시간이었습니다.

전공의 생활 동안 통계적인 지식이나 학문적인 배경을 세미나를 통하여 가르쳐 주시고 또한 박사 연구를 진행하면서 조언해 주신 김선재 교수님께 다시 한번 깊은 감사드립니다. 의국을 졸업하고 2년의 임상경험을 타지에서 쌓으면서 느끼고 경험했던, 생각들을 추가로 정리하면서 많은 시행착오가 있었지만, 기다려 주시고 응원해 주셔서 감사합니다. 교수님이 아니었다면 그저 제 마음 속에 해결되지 않는 생각에 머물렀을 것입니다.

또한 함께 의국 생활을 하면서 도움을 준 후배, 그리고 선배 보철과 선생님들께도 감사의 말씀을 전합니다. 항상 옆에서 응원해준 와이프 화영이에게 고맙다는 얘기를 전하며, 마지막으로 행하는 과정에서 조금 더 학문에 이바지 하고자 노력했던, 그리고 논문 작성시 조언과 가르침을 주신 많은 분들에게 다시 한번 감사의 인사를 드립니다.

2023 년 12 월

오지환 올림

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ABSTRACT

The Impact of Adjacent Implants and Prosthesis Types on the Marginal Bone Loss of 1792 Internal Connection Implants: Up to 15 year Retrospective Multi-Center Study

JiHwan Oh, D.D.S., M.S.D.

Department of Dentistry

The Graduate School, Yonsei University

(Directed by Professor Sunjai Kim, D.D.S., M.S.D., Ph.D.)

Purpose of the study: To compare and analyze the marginal bone loss for the correlation between implant continuity, prosthetic type, and adjacent or proximal structure, along with basic factors such as implant location, length, and diameter

Material and methods: This study included all partially edentulous patients who received implant-supported fixed dental prostheses at the Department of

Prosthodontics, Gangnam Severance Dental Hospital, and Hayan Dental Clinic between 2003 and 2020. Comprehensive data collection revolved around patient, surgical, and prosthesis−related variables, further classifying implants based on characteristics and their relation to marginal bone loss (MBL). Using periapical radiographs, the study assessed MBL and established peri−implantitis risk indicators. Statistical methods encompassed the Kaplan−Meier estimation, Linear Mixed Model, Generalized Estimating Equation, and the Cox Proportional Hazard model.

Results: This retrospective analysis assessed 1,792 implants in 804 patients, with an average follow−up of 5.4 years. Survival rates for implant 98.8%. Employing Linear Mixed Models and Generalized Estimating Equations, determinants like position, age, fixture design, diameter, length, Contiguousness, prosthetic type, and adjacent structure were observed to influence marginal bone loss. The study further examined peri−implantitis, noting pronounced disparities in bone loss. The Cox Proportional Hazard model identified prosthetics, implant Contiguousness, and neighboring structures as significant risk factors for peri−implantitis.

Conclusion: IT with microthreads showed increased marginal bone loss than IU with macrothreads. Mesially, upper premolars, molars, and lower molars had greater bone loss than upper anterior teeth, while distally, upper molars had higher MBL. Multiple prosthetics led to more bone loss than single ones and raised peri-implantitis risk. The presence of an Isp(splinted) or a missing tooth on the distal side

increased peri-implantitis risk. The peri-implantitis-associated MBL rate was −0.34mm/year.

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keywords : survival rate, marginal bone loss, peri-implantitis, Contiguousness, marginal bone loss rate

Ⅰ. Introduction

Planning appropriate implant placement at the initial stage of treatment is crucial for designing upper prostheses and their subsequent maintenance. With the development and advancement of dental implants, there are many instances where single implants are placed without damaging natural teeth during the fixed partial denture process to restore previously toothless areas. However, in some cases, oral rehabilitation is achieved through the placement of multiple implants.

Even after the delivery of prosthetics, tracking the loss of the bone surrounding the implant is essential. It can serve as a measure to determine if implant failure is occurring. Moreover, it's crucial to be vigilant with patients at high risk for peri-implantitis. During the recall check-up, it's important to be aware of changes within the mouth. One way to monitor these changes is by periodically verifying through a periapical x-ray. This allows for the early prediction of such changes.

Derks and Galindo-Moreno' s research results indicate that if marginal bone loss occurs within 3 years of attaching the prosthesis, peri-implantitis progresses and accelerates.[1] Galindo-Moreno also stated that marginal bone loss of 0.44mm/year is an indication of peri-implant bone loss progression .[2]

This plays a significant role in the diagnosis during a patient's regular clinic visits. It's not just about determining the disease by identifying peri−implantitis factors, such as when marginal bone loss exceeds 3mm. Instead, there's importance in predicting harmful factors present in a patient's oral cavity through the rate of marginal bone loss. By measuring the actual bone loss rate in the oral cavity and taking appropriate measures when that rate exceeds a certain level, excessive bone loss can be prevented.

Among factors related to implants, the role of microthreads has been the subject of meticulous study by numerous researchers. Although still a matter of considerable debate, the incorporation of threads or microthreads extending up to the crestal module of the implant may enhance Bone−Implant Contact (BIC) and aid in preserving marginal bone levels.[4,5]

In implant placement, both contiguous and non−contiguous implant installations can be considered in the treatment plan. In the case of non−contiguous installations, there exists a plethora of studies indicating that factors such as the proximity to adjacent natural teeth and subcrestal depth influence bone loss. [6] Furthermore, contact loss is reported to occur in 32.8% of implant fixed prostheses, leading to an increase in marginal bone loss when such loss of contact occurs.[7] Importantly, the periodontal health of the proximal tooth significantly influences the results of dental implant treatments. The health status of teeth neighboring the implant is pivotal in determining the success or failure of the implant.[8]

On the other hand, research on contiguous implants has involved extensive discussions to elucidate various aspects, such as the distance or depth between implant placements or the concept of platform switching. [9] Recently, the scope has expanded to analyze success rates and marginal bone loss in contiguous implants based on various prostheses choices, including decisions on splinting, non-splinting, or using implant-supported bridges.

The decision on whether to splint or not to splint the upper restoration prosthesis on Contiguously placed implants has been a long-standing debate. Studies have found that, while there's no difference in the success rates and mechanical complications between a 3-unit fixed prosthesis using two implants and a splinted prosthesis with three implants, there is a heightened risk of peri-implantitis with the splinted intermediate implant. Moreover, an increased risk of peri-implantitis is reported when both the mesial and distal sections are splinted.[10,11]

It has been posited that both single units and splinted multi-unit prostheses stand as effective treatment options.[12] Observations indicate no significant difference in marginal bone loss and prosthetic complications between splinted and nonsplinted variants, with a specific caution advised for cantilever and non−splinted multiunit prostheses.[13] In a retrospective study spanning 18 years, it was shown that prostheses anchored to two or three connected implants had survival rates of 96.8% and 97.6%, respectively, with no observed differences in implant loss, prosthesis longevity, or mechanical complications.[14]

In differences among such prosthetics, hygiene is often emphasized. One study highlighted a 4% peri−implantitis rate for splinted prostheses with adequate hygiene, which increased to 48% without proper care.[15] Prostheses attached to three connected implants, particularly the intermediate one, showed a higher peri−implantitis rate.[16] Splinted prostheses in the molar region had notable bone loss but better survival rates than non−splinted types, with no major prosthetic issues.[17] Additionally, it has been reported that there is no difference in bone loss for bridges or splints using two implants.[18]

Due to the variety of implant options used for single, splinted, or 3−unit or 4−unit prostheses in the current long edentulous span of the mandible, it is necessary to analyze marginal bone loss in each of these options, the difference between them when variously defined for the actual contiguous implant and its upper prosthesis, and finally, whether the proximal structure affects marginal bone loss.

This retrospective study aims to compare and analyze the marginal bone loss for the correlation between implant continuity, prosthetic type, and adjacent or proximal structure, along with basic factors such as implant location, length, and diameter.

Ⅱ. Material and Method

This retrospective study was approved by Gangnam Severance Hospital and Yonsei University (Institutional Review Board approval number 3-2020-0181). This study included all partially edentulous patients who received implant-supported fixed dental prostheses at the Department of Prosthodontics, Gangnam Severance Dental Hospital, and Hayan Dental Clinic between 2003 and 2020. One clinician at each institute performed the surgeries and restorative procedures. The exclusion criteria were as follows: (1) psychological disorder, (2) uncontrolled diabetes mellitus, (3) immune suppression, (4) previous radiotherapy to the head and neck region, or (5) parafunctional oral habits, such as teeth clenching and bruxism, (6) implant systems other than the current study design, and (7) immediately loaded implants. Inclusion criteria were that: (1) the patient's age was greater than 18 years old; (2) all patients met the diagnostic criteria for a dentition defect; (3) the patients had no contraindications to surgery; (4) informed consent was provided; and (5) female participants were non-pregnant, non-lactating, and not menstruating. The study used two different implant systems from the same manufacturer. Both implants had the same surface topographies. One had a platform-switching design with microthreads at the implant neck (IT; Warantec, Seoul, South Korea). The implant-abutment connection had a 7° angle to the long axis. The other had a platform−switching design without microthreads and an 11° internal taper angle (IU, Warantec) (Figure 1).

Figure 1. IT implant(IT) and IU implant(IU)

Handwritten and electronic charts from the implant placement surgery to the final periodic recall visits were reviewed to collect patient−related (age and gender), surgery related (implant installation site, implant type, implant diameter, and implant length), and prosthesis−related (prosthesis type) information. Implants were categorized according to their diameter (≤ 4 mm, 4.3 and 4.5 mm or > 4.5 mm), length (≤8.5mm, 10mm, > 10 mm), and design (IT or IU). The installation site was divided into the maxilla, or mandible, and anterior or anterior/premolar/molar areas.

1. Definition of Contiguous implant and prosthetics

The Contiguous implants was classified into two categories for comparing the amount of MBL, as follows: (Figure 2)

1. Contiguous(C) : where other implants exist in the mesial and distal dentition of the implant being analyzed

2. Non−contiguous (N): implants do not exist in the mesial and distal dentition of the implant being analyzed

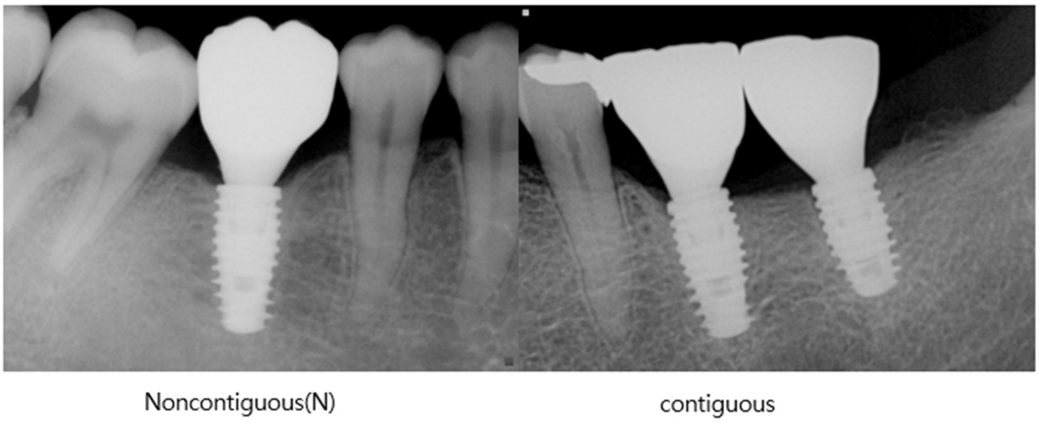

Figure 2. Non-contiguous(N) and Contiguous(C) Implant

The prosthesis type was classified into four categories based on the adjacent dentition or restorations for comparing the amount of MBL, as follows: (Figure 3)

1. Single: Restorations on single implant

2. Splint: Restorations on two splint prosthetics using two implants

3. Multiple: 3-unit or 4-unit prosthesis using more than 3 implants

4. Bridge (pontic between implants): Implant supported bridge using two implants consisting of pontics

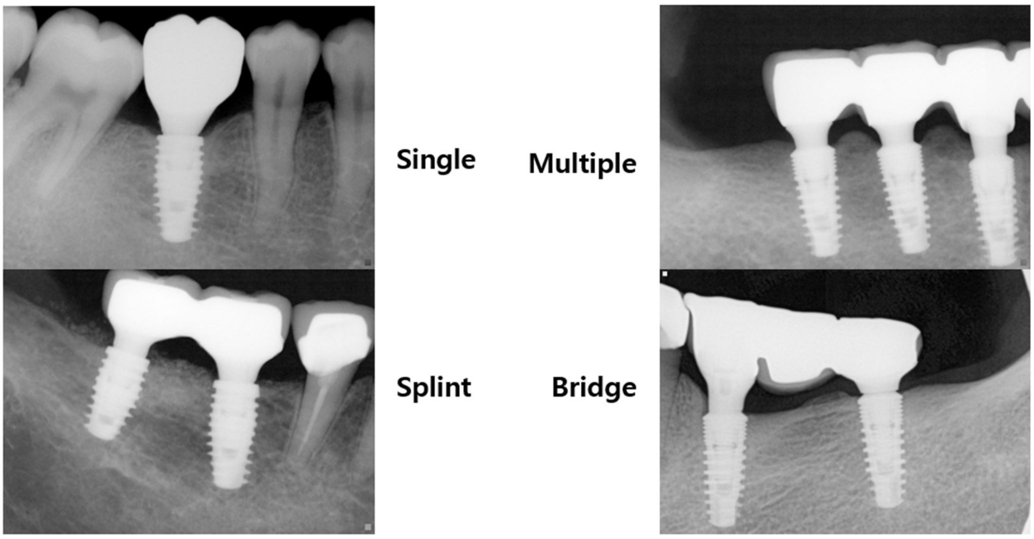

Figure 3. Prosthesis type classified into four categories

2. Proximal structure

The proximal structure (or adjacent structure) was classified into six categories based on the adjacent dentition or implant for comparing the amount of MBL, as follows (Figure 4)

Isp (Implant splinted): where adjacent implants and prosthetics are connected

Ise (Implant separated): adjacent implant existed but prosthetics not connected

C (Cantilever): adjacent area is an cantilever

M (Missing): adjacent area is an edentulous area

P (Pontic): adjacent area is an Pontic area

T (Tooth): adjacent area is an Tooth

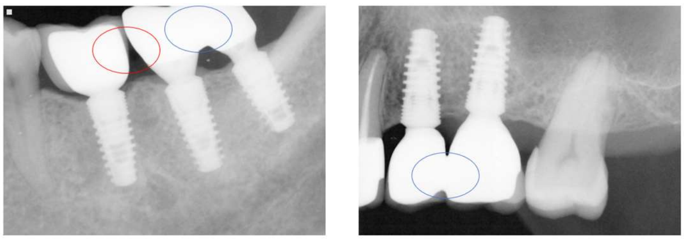

Figure 4. Proximal structures. The red circle refers to the Ise, and the blue circle refers to the Isp

3. Assessment of data

Implant survival was defined as follows: the implant remained in the patient's mouth, and the restoration functioned normally during the last periodic visit. Therefore, removed and buried (submerged and not functional) implants were classified as failures.

IU implants have only recently been introduced to clinical use as compared with IT implants; therefore, IU implants have had shorter follow-up recalls than IT implants. Cumulative survival rates were calculated separately for each implant system. Periapical radiographs, which were taken at the delivery of the final prostheses and each periodic recall visit, were used to analyze the amount of peri-implant marginal bone changes. When the periapical radiographs were not taken at every fixed interval of visits (i.e. 1 year); a time interval of 6 months was used to input only single measured value in a single time interval. Missing values in the time interval were imputed using the last-observation-carried-forward method. Distance calibration was performed for every radiograph to compensate for the angular distortion of radiographs. The amount of marginal bone loss was defined as the distance between the most outer edge of implant platform and the most-coronal bone-to-implant contact point on both the mesial and distal sides of the implants. An image processing and analysis software (Image J, NIH.gov) was used for all the measurements. All the measurements were performed by a single operator(Figure 5).

The amount of MBL was defined as the distance between the outer edge of the implant platform and the most coronal bone−to−implant contact point on both the mesial and distal sides of the implant. All measurements were performed by a single operator. Clinically, the diagnosis of peri−implantitis requires the following: (1) bleeding on probing or suppuration; (2) more than 6 mm of probing depth; and (3) more than 3 mm of marginal bone loss compared to the initial bone level. In the current study, previous probing depth was not always obtained; therefore, an implant with ≥2 mm of marginal bone loss from prosthetic delivery and bleeding on probing was used to diagnose as risk indicators for peri−implantitis.

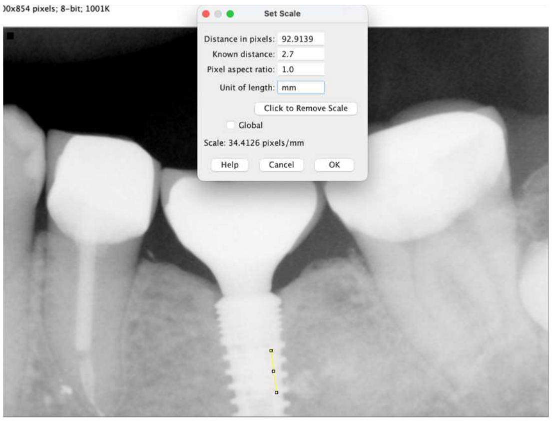

Figure 5. Using Image J, Mesial and Distal marginal bone measurement

4. Statistical analysis

For the statistical analysis, the survival rate of the IT and IU implants was assessed using the Kaplan-Meier estimation. To measure Marginal Bone Loss (MBL) and to examine interactions over time, both the Linear Mixed Model (LMM) and the Generalized Estimating Equation (GEE) were utilized. Risk factors for peri-implantitis were scored using a binary system, with 0 indicating a healthy implant and 1 indicating a diseased implant. The year when a particular event occurred was recorded, and this data was used to construct a Cox Proportional Hazard model. Finally, the rate of bone loss in the peri-implantitis group was analyzed using general regression.

Ⅲ. RESULT

1. Demographic data

In total, 1,792 implants were placed in 804 patients, comprising 1,387 IT implants and 405 IU implants. On average, each patient received 2.2 implants. The mean follow-up period was 5.4 years. Treatments utilized implant-supported fixed prostheses. The longest recorded follow-up spanned 15 years post-prosthesis installation for 11 IT implants and 6 years for 6 IU implants. Demographic details can be found in Table 1.

TABLE 1. Demographic data

Characteristics		N
Position	Maxillary anterior	195
	Maxillary premolar	293
	Maxillary molar	464
	Mandibular anterior	38
	Mandibular anterior	168
	Mnadibular molar	634
Fixture	IT	1387
	IU	405
Age	18 to 39	158
	40 to 49	258
	50 to 59	452
	60 to 69	513
	70 to 89	411
Sex	M	806
	F	986
Diameter	≤4	103
	4< Diameter ≤4.5	1448
	4.5 <	241
Length	≤8.5	430
	10	831
	10<	531
contiguous of implant	noncontiguous(N)	728
	contitguous(C)	1058
Fixed prosthesis	single	564
	splint	767
	multiple	192
	bridge	263
Proximal structure(Mesial/Distal)	cantilever	41 / 44
	Implant seperated(Ise)	84 / 76
	Implant splinted(Isp)	512 / 488
	Missing	5 / 582
	Pontic	194 / 115
	Tooth	950 / 481

3. Survival rate

Total implant survival rate was 98.9% and IT implant showed a survival rate of 99.0% with 16 failures, while IU implant exhibited a survival rate of 98.8% with 4 failures. The results of the test for equality of survival distributions indicated a significance level of 0.089. There is no significant difference in the survival rates in fixtures and other variables (Figure 6, Table 2).

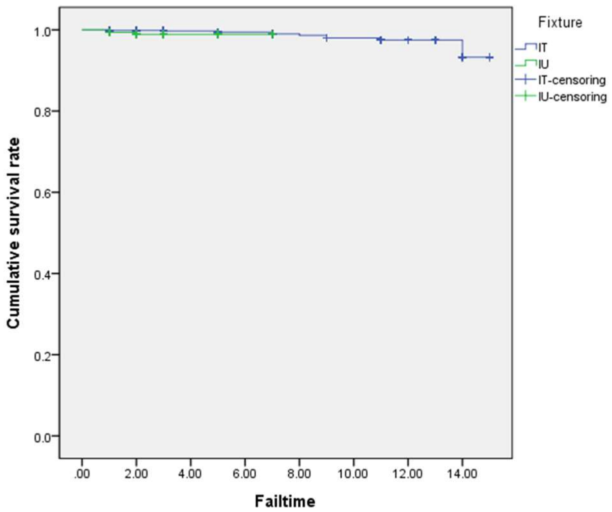

Figure 6. Survival rate of IT and IU implant

Table 2. Log Rank test

	Chi square	p
Log Rank (Mantel-Cox)	2.885	.089

3. Linear Mixed Model

The results from implementing the Linear Mixed Model (LMM) to analyze interactions over time are as follows (Table 3). The factors such as fixture, position, age, implant length, Contiguousness, prosthetic type, and proximal structure were statistically significant in terms of interactions over time.

Table 3. Linear Mixed Model

		univariate		multivariate	
		F	p	F	p
Mesial	Fixture * Time	5.142	0.023*	8.707	0.003*
	position * Time	6.390	<.001*	2.504	0.028*
	institute * Time	.017	.895	19.548	<.001*
	Age * Time	2.685	0.03*	1.185	.315
	sex * Time	1.104	.293	1.936	.164
	diameter * Time	.793	.453	1.305	.271
	Length * Time	7.938	<.001*	4.451	0.012*
	contiguous * Time	23.636	<.001*	1.775	.183
	prosthetics * Time	18.282	<.001*	16.192	<.001*
	proximal * Time	5.466	<.001*	1.035	.395
Distal	Fixture * Time	8.556	0.003*	10.526	0.001*
	position * Time	2.491	0.029*	1.505	.184
	institute * Time	.041	.839	10.452	0.001*
	Age * Time	2.009	.090	.942	.438
	sex * Time	.278	.598	.154	.695
	diameter * Time	1.306	.271	.773	.462
	Length * Time	1.132	.323	1.826	.161
	contiguous * Time	17.177	<.001*	2.426	.119
	prosthetics * Time	13.636	<.001*	9.186	<.001*
	proximal * Time	4.162	0.001*	1.457	.200

4. Generalized Estimating equation

The results of the GEE analysis to verify the correlation of factors over time are as follows(Table 4, 5).

Table 4. Generalized estimating equation at mesial area

			Univariate			Multivariate		
			beta	SE	p	beta	SE	p
Mesial	position	[Mandibular molar] * Time	-.023	.0083	**.005***	.000	.0123	.995
		[Mandibular premolar] * Time	-.030	.0192	.120	-.008	.0158	.612
		[Mandibular anterior] * Time	-.015	.0195	.430	-.017	.0197	.375
		[Maxillary molar] * Time	-.047	.0101	**<.001***	-.027	.0135	**.047***
		[Maxillary premolar] * Time	-.022	.0099	**.023***	-.004	.0121	.747
		[Maxillary anterior] * Time	0^a			0^a		
	fixture	[IU] * Time	.020	.0071	**.006***	.026	.0085	**.002***
		[IT] * Time	0^a			0^a		
	age	[70s and 80s] * Time	-.011	.0106	.318	-.005	.0111	.668
		[60s] * Time	-.022	.0107	**.036***	-.008	.0116	.486
		[50s] * Time	-.025	.0099	**.012***	-.013	.0107	.235
		[40s] * Time	-.025	.0125	**.046***	-.019	.0132	.159
		[Under 40] * Time	0^a			0^a		
	length	[less than 8.5mm] * Time	-.024	.0125	.059	-.022	.0180	.229
		[10mm] * Time	-.019	.0082	**.023***	-.018	.0110	.110
		[over than 10mm] * Time	0^a			0^a		
	continuity	[contiguous] * Time	-.025	.0077	**.001***	-.019	.0129	.151
		[noncontigous] * Time	0^a			0^a		
	prosthetics	[bridge] * Time	-.036	.0291	.214	-.036	.0291	.214
		[multiple] * Time	-.062	.0177	**<.001***	-.062	.0177	**<.001***
		[splint] * Time	-.011	.0130	.415	-.011	.0130	.415
		[single] * Time	0^a			0^a		

Table 5. Generalized estimating equation at distal area

			Univariate			Multivariate		
			beta	SE	p	beta	SE	p
Distal	position	[Mandibular molar] * Time	-.012	.0093	.207	.005	.0130	.727
		[Mandibular premolar] * Time	-.012	.0193	.534	.006	.0192	.741
		[Mandibular anterior] * Time	-.008	.0179	.645	-.018	.0183	.338
		[Maxillary molar] * Time	-.030	.0110	**.006***	-.018	.0152	.243
		[Maxillary premolar] * Time	-.021	.0124	.097	-.006	.0150	.687
		[Maxillary anterior] * Time	0^a			0^a		
	fixture	[IU] * Time	.028	.0075	**<.001***	.031	.0091	**.001***
		[IT] * Time	0^a			0^a		
	age	[70s and 80s] * Time	-.003	.0135	.831	.000	.0137	.973
		[60s] * Time	-.015	.0133	.260	-.002	.0143	.873
		[50s] * Time	-.023	.0131	.085	-.013	.0135	.338
		[40s] * Time	-.018	.0155	.257	-.011	.0162	.506
		[Under 40] * Time	0^a			0^a		
	length	[less than 8.5mm] * Time	-.011	.0133	.420	.016	.0172	.356
		[10mm] * Time	-.006	.0087	.463	.006	.0141	.661
		[over than 10mm] * Time	0^a			0^a		
	continuity	[contiguous] * Time	-.024	.0083	**.005***	-.021	.0168	.219
		[noncontigous] * Time	0^a			0^a		
	prosthetics	[bridge] * Time	-.014	.0158	.375	-.007	.0143	.622
		[multiple] * Time	-.047	.0201	**.018***	-.038	.0190	**.047***
		[splint] * Time	.000	.0172	.986	.006	.0130	.646
		[single] * Time	0^a			0^a		

4.1. Position

At mesial area, based on the upper anterior teeth (1), there is a significant difference in the upper premolar (2), upper molar (3), and lower molar (6) regions, with −0.02mm/year ($p = 0.023$), −0.05mm ($p < 0.05$), and −0.02mm/year ($p = 0.005$) respectively. In multivariate analysis, based on the upper anterior teeth (1), there is a significant difference of −0.03 mm/year ($p = 0.047$) in the upper molar (3) region (Figure 7).

At distal area based on the upper anterior teeth (1), there is a significant difference of −0.03mm/year ($p = 0.006$) in the upper molar (3) region.

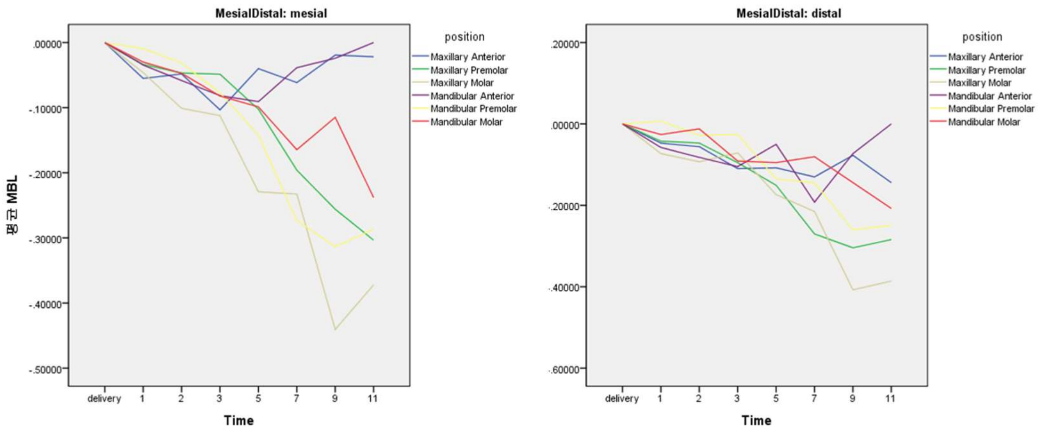

Figure 7. Mean marginal bone loss (position) over time

4.2. Age

At mesial area based on implants placed between the ages of under 40 (1), implants placed in the 40s(2) , 50s(3) , and 60s(4) show relative significant differences of −0.03mm/year(p=0.046), −0.03mm/year (p=0.012), and −0.02mm/year (p=0.036) respectively (Figure 8).

At distal area, there is no statistical difference.

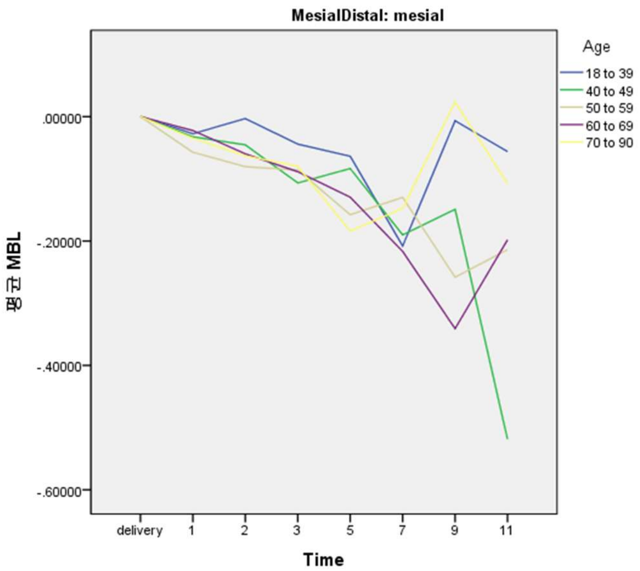

Figure 8. Mean marginal bone loss (age) over time at mesial area

4.3. Fixture

At mesial area, based on IT (1), there's a significant difference of +0.02mm/year(p=0.006) in IU (2). In multivariate analysis, a significant difference of +0.03mm/year(p=0.002) was observed.

At distal area based on IT (1), there's a significant difference of +0.03mm/year (p <0.05) in IU (2). In multivariate analysis, a significant difference of +0.03mm/year(p=0.001) was observed (Figure 9).

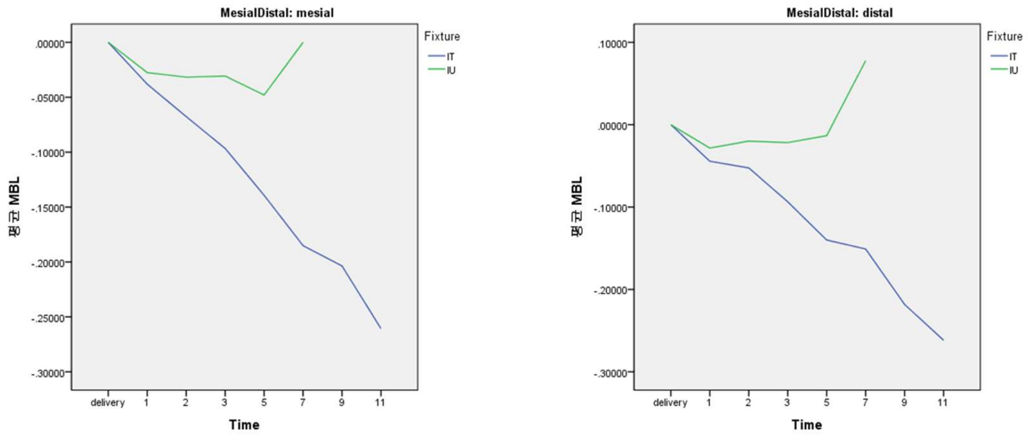

Figure 9. Mean marginal bone loss (Fixture) over time

4.4. Diameter and Length

The diameter and length of the implant generally don't have statistical significance. However, for Mesial's Marginal bone loss, Based on a length of more than 10 mm, there's a significant difference of −0.02mm/year ($p = 0.023$) at 10mm (Figure 10).

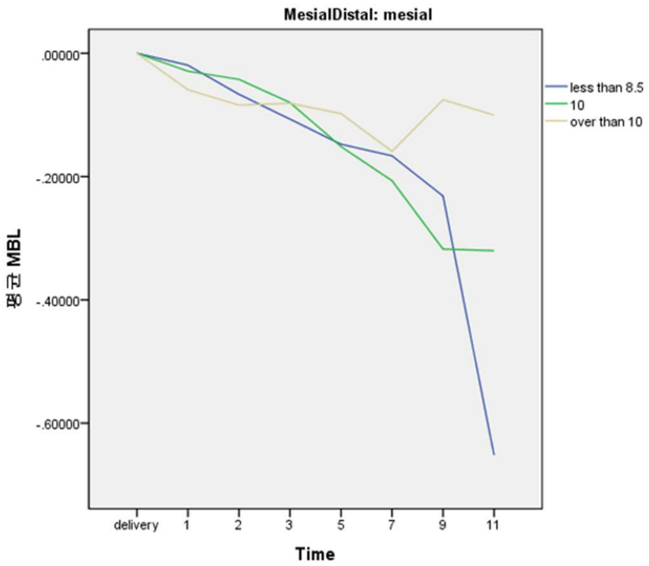

Figure 10. Mean marginal bone loss (Length) over time at mesial area

4.5. Contiguousness

At mesial area, compared to noncontiguous (1), implants that were contiguously placed (2) showed a significant difference of −0.03mm/year (p=0.001). In multivariate, no statistical difference was observed.

At distal area, compared to noncontiguous (1), implants that were contiguously placed (2) showed a significant difference of −0.02mm/year (p=0.005). In multivariate, no statistical difference was observed (Figure 11).

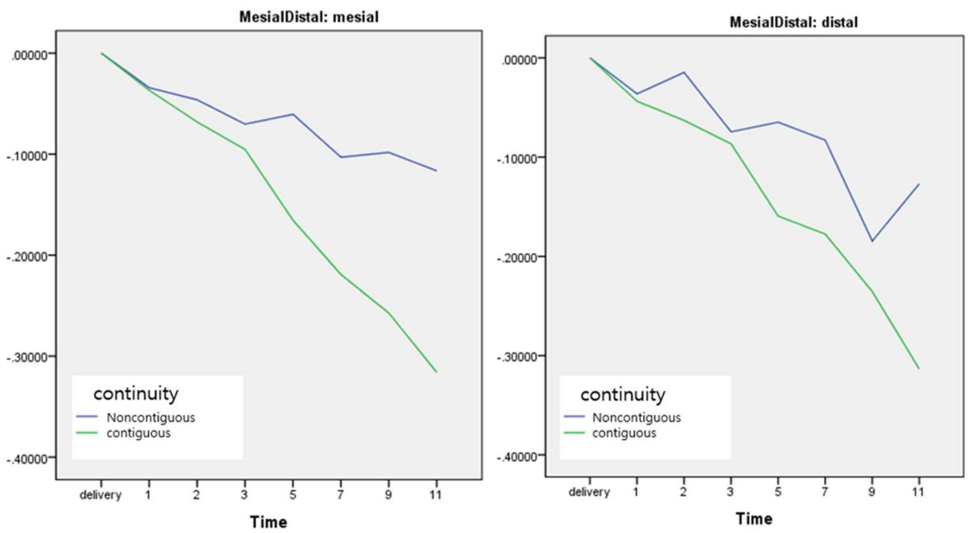

Figure 11. Mean marginal bone loss (Contiguousness) over time

4.6. Prosthetics

At mesial area based on a single (1), there's a significant difference of −0.06mm/year ($p < 0.05$) for multiple (3). In multivariate analysis, a significant difference of −0.05mm/year ($p = 0.014$) was observed.

At distal area , based on a single (1), there's a significant difference of −0.05mm/year ($p = 0.018$) for multiple (3). In multivariate analysis, a significant difference of −0.04mm/year ($p = 0.047$) was observed.

Implants in the middle of multiple prosthetics and implants at each end of multiple prosthetics both show a significant statistical difference when compared to Noncontiguous and single prosthetics (Figure12, Table 6).

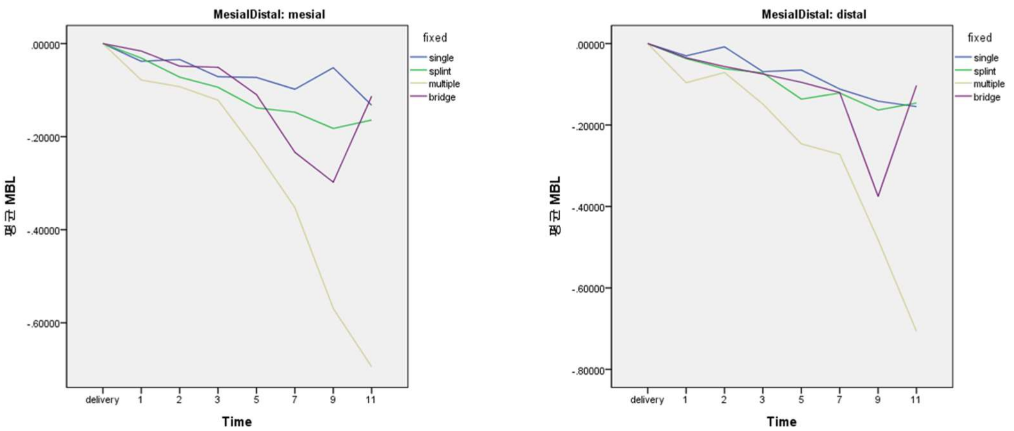

Figure 12. Mean marginal bone loss (Prosthetics) over time

Table 6. Generalized estimating equation for Contiguousness and prosthetics(univariate)

		beta	SE	p
mesial	[Middle of multiple] * Time	-.068	.0314	.031*
	[End of multiple] * Time	-.056	.0215	.009*
	[C + splint] * Time	-.016	.0083	.048*
	[N + Bridge] * Time	-.001	.0128	.965
	[C + Single] * Time	-.007	.0100	.504
	[N + Single] * Time	0^a		
distal	[Middle of multiple] * Time	-.070	.0313	.024*
	[End of multiple] * Time	-.049	.0221	.026*
	[C + splint] * Time	-.013	.0095	.158
	[N + Bridge] * Time	.000	.0133	.991
	[C + Single] * Time	-.010	.0125	.429
	[N + Single] * Time	0^a		

N: noncontiguous; C: contiguous

4.7. Proximal structure

In univariate results, based on a tooth (6), both mesial and distal in Isp(3) showed significant differences of −0.03mm/year (p = 0.008) and −0.03mm/year (p = 0.006) respectively (Figure 13, Table 7).

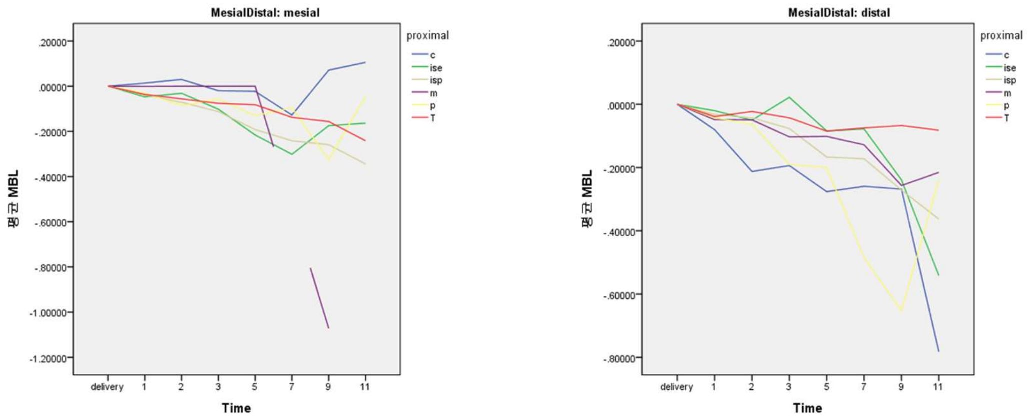

Figure 13. Mean marginal bone loss (Proximal structure) over time

Table 7. Generalized estimating equation for Proximal structures

		beta	SE	p
mesial	[cantilever] * Time	.025	.0196	.198
	[Ise(seperated)] * Time	−.014	.0137	.293
	[Isp(splint)] * Time	−.025	.0093	.008*
	[missing] * Time	−.103	.0300	.001*
	[pontic] * Time	−.001	.0159	.956
	[Tooth] * Time	0[a]		
distal	[cantilever] * Time	−.050	.0292	.088
	[Ise(seperated)] * Time	−.018	.0143	.212
	[Isp(splint)] * Time	−.029	.0105	.006*
	[missing] * Time	−.018	.0090	.052
	[pontic] * Time	−.023	.0246	.342
	[Tooth] * Time	0[a]		

5. Peri−implantitis

The group with peri−implantitis shows an average MBL graph with an annual decrease of −0.34mm/year (in cases without PI, it's −0.02mm/year) (Figure 14, Table 8).

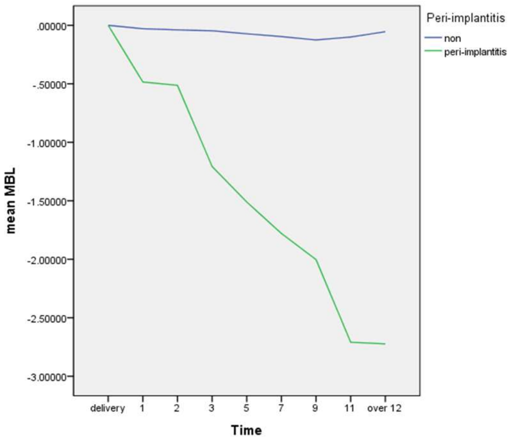

Figure 14. Mean marginal bone loss (peri-implantitis) over time

Table 8. Generalized estimating equation for peri-implantitis(PI)

	beta	SE	p
[PI] * Time	-.339	.0217	**<.001***
[no PI] * Time	-.020	.0019	**<.001***

No statistical significance was found in the Cox Proportional Hazard model for other factors and peri−implantitis. However, significance was observed in Prosthetics. Compared to Single, Multiple has a 6.17 times higher risk. And compared to Splint, Multiple has a 2.66 times higher risk (Table 9, Figure 15).

Table 9. Cox Proportional Hazard model for prosthetics

	beta	SE	Wald	p	Exp(B)	95.0% CI
Single			11.596	.008*		
Splint	.862	.563	2.345	.126	2.368	0.786-7.135
Multiple	1.820	.582	9.781	.002*	6.173	1.973-19.317
Bridge	1.030	.709	2.110	.146	2.800	0.698-11.232

	beta	SE	Wald	p	Exp(B)	95.0% CI
Splint			6.310	.054		
Multiple	.979	.395	6.137	.013*	2.662	1.227-5.774
Bridge	.189	.565	.111	.739	1.208	0.399-3.658

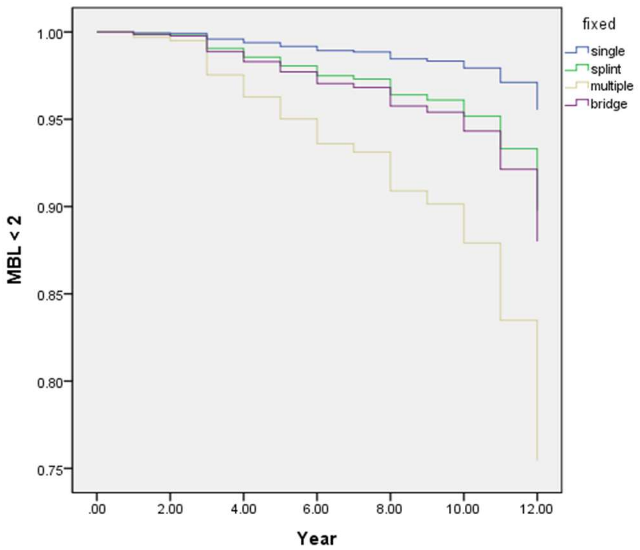

Figure 15. survival function of prosthetics

when compared with Noncontiguous and single prosthetics, implants in the middle and at each end of multiple prosthetics show 5.75 and 4.39 times higher risks respectively (Table 10, Figure 16).

Table 10. Cox Proportional Hazard model for Contiguousness and prosthetics

	beta	SE	Wald	p	Exp(B)	95.0% CI
Nonconsecutive single			10.401	.015*		
implants at each end of multiple prosthetics	1.478	.631	5.484	.019*	4.385	1.273 - 15.110
consecutive splint	.621	.563	1.216	.270	1.860	0.617 - 5.605
Nonconsecutive bridge	.527	.765	.475	.491	1.694	0.378 - 7.590
consecutive single	-11.656	324.046	.001	.971	.000	0 - 5.835
Implants at middle of multiple prosthetics	1.749	.675	6.713	.010*	5.747	1.531 - 21. 575

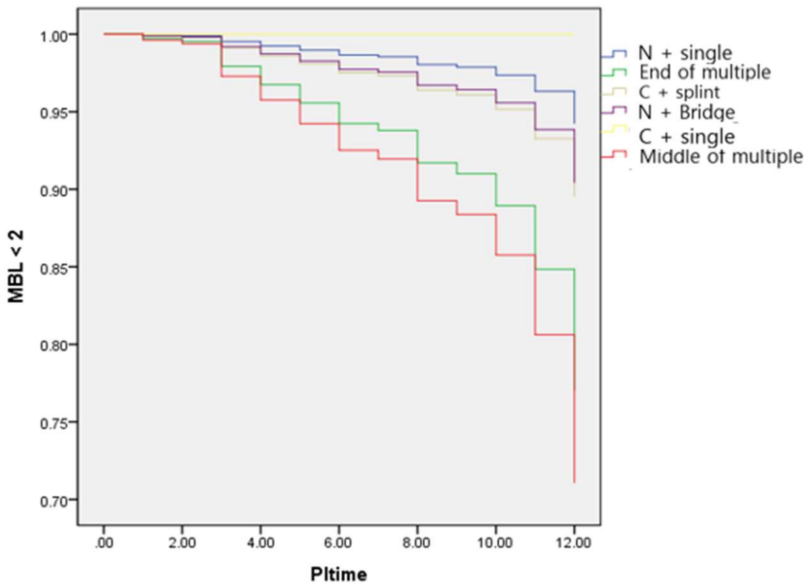

Figure 16. survival function of Contiguousness and prosthetics

When comparing the proximal structure, there was no statistical significance in the mesial area. However, in the distal area, when the adjacent structure was a tooth, the risk was 6.23 and 5.89 times higher for Isp and missing cases, respectively (Table 11, Figure 17).

Table 11. Cox Proportional Hazard model for proximal structure

	beta	SE	Wald	p	Exp(B)	95.0% CI
T(tooth)			6.162	.187		
Ise(seperated)	-10.660	393.402	.001	.978	0.000	.000
Isp(splinted)	1.829	.754	5.889	.015	6.230	1.422-27.297
M(missing)	1.774	.757	5.495	.019	5.893	1.337-25.964
C(cantilever)	1.409	1.225	1.323	.250	4.093	0.371-45.179

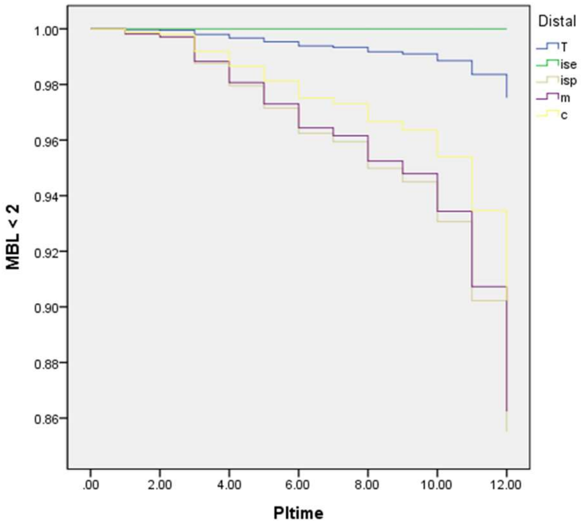

Figure 17. survival function of proximal structure

Ⅳ. Discussion

1. Survival rate

In terms of survival rates, the total implant was 98.8%, and IT implants demonstrated a 99.0% rate, with 16 units being removed. Conversely, 4 units of IU implants were removed, translating to a 98.8% survival rate. There was no significant statistical difference between the two implant types and other variables in terms of survival rates. The reasons for removing implants varied and included bone integration failures, post−operative infections, and post−operative instability within the first two years. Other reasons encompassed fractures of the implant accompanied by loosened screws, the inability to retrieve a broken screw resulting in the implant's disuse, and issues arising from peri−implantitis.

2. Marginal bone loss and peri-implantitis

2.1. Implant position

The study's results highlighted several potential factors influencing marginal bone loss around the implant. Implants placed in the maxillary anterior area exhibited less bone loss than those in the upper premolars, molars, and lower molars. Notably, the upper molars displayed a significant relative bone reduction with a difference of −0.05mm/year in the mesial and −0.03mm/year in the distal areas than Maxillary anterior teeth. As Peñarrocha M emphasized, implants situated in the maxilla exhibited a pronounced bone loss post-loading.[19] Furthermore, echoing Noda's research, which spanned a 10-year implant survival rate comparison, smoking was identified as a precursor to early implant failure. In contrast, late failures predominantly involved maxillary and posterior implants.[20] In another study, the most pronounced marginal bone loss was observed in implants in the maxilla of older patients.[21] It's widely understood that the increase in the cancellous compartment from age-related osteoporosis, and the subsequent decline in bone mass density, might affect the bone surrounding the implant.[22]

2.2. Age and implant length

In this research, we evaluated various age demographics and implant length: under 40, those in their 40s, 50s, 60s, and those over 70. In the mesial regions, age groups 40s through 60s showed significant marginal bone loss compared to the under 40 group. And the implant with a length of 10 mm exhibited a significant difference of −0.02mm/year compared to implants longer than 10 mm. However, the distal areas didn't exhibit a similar significant variation.

While our classification differs from that of other studies, Seong−Mo Koo noted that there wasn't a discernible difference between individuals under 60 and those 60 or older.[23] Moreover, Negri M and colleagues, after categorizing age groups as below 50, between 50 and 60, and above 60, found no notable correlation with age.

Regarding the length of the implants, Monje A's conclusions suggest that short dental implants (less than 10mm) exhibit comparable peri−implant marginal bone loss (MBL) to standard−length implants (10mm or more) when used to support fixed prostheses.[24] However, some studies, like those by Raikar S, indicate a heightened failure rate in implants with diameters smaller than 3.75 mm and lengths exceeding 11.5 mm.[25]

In our study, we centered on the age, length, and position at the time of implant placement for measuring and comparing marginal bone loss. A more detailed exploration might be required in the future to understand the variations in marginal bone loss depending on the age of the implant, under consistent controlled variables.

2.3. Microthreads

While the previously discussed average bone loss between implants showed negligible differences in survival rates, the IU implant with a macrothread presented less bone loss in both the mesial and distal regions than its IT counterpart, which incorporates a microthread. Specifically, the IT implant's relative MBL was higher at mesial 0.026mm/year and distal 0.028mm/year.

In a retrospective study by Niu W, the microthread design in the implant neck was noted to potentially reduce MBL. However, they also emphasized that the randomized controlled trials (RCTs) included in their review were limited and that the observed differences were minimal.[26] Another study, which observed implants with and without microthreads over three years post−prosthesis placement, found that during the first year, implants equipped with microthreads exhibited significantly reduced bone loss.[27] This finding suggested that microthreads were effective in preventing bone loss for a certain period. However, some reports argue that microthreads don't have a significant impact on bone loss. Schrotenboer and colleagues, through a finite element analysis study, stated that microthreads could increase stress in the bone bed under functional loads, suggesting a potential disadvantage.[28] Shin et al., in their clinical study, evaluated three different implant types: implants with microthreads and a rough surface, implants with only a rough surface, and implants with a polished surface. One year after restoration, they observed bone loss rates of 0.18mm, 0.76mm, and 1.32mm for the three implant types, respectively. The implant with microthreads and a rough surface showed significantly less bone loss than the one with a machined surface.[29] Given that the longest follow−up period for the IU implant is six years, there's a need for further research with extended follow−ups to understand the impact of microthreads better.

2.4. Prosthesis and Continuity of implant

According to a report by Ravida et al., when three implants are Contiguously placed and the prosthetics are splinted, cleansing becomes difficult, increasing the risk of peri−implantitis.[12] Hence, our study did not follow the conventional prosthetic classification. Instead, we categorized implants based on their Contiguousness and prosthetic type into four groups and further classified adjacent structures for a detailed investigation.

In this study, we aimed for a granular examination of the different implant environments. The correlation between Contiguously placed and non−

Contiguously placed implants was also explored. It was observed that implants that were non-contiguous on both the mesial and distal sides showed relatively lesser bone loss. Furthermore, when compared to single prosthetics, multiple prosthetics on both the mesial and distal sides showed significantly more bone loss. Especially notable was that implants situated between multiple prosthetics or at their ends both exhibited relative bone loss. Interestingly, even when implants were Contiguously placed, if they were restored with single prosthetics, they showed lesser bone loss than other splinted or multiple implants.

Additionally, our study defined peri-implantitis as a marginal bone loss of more than 2mm post prosthetic delivery. Multiple prosthetics posed a risk 6.17 times higher than single prosthetics. Multiple implants were statistically 2.66 times riskier than splints. Individual implants also showed risks, with those in the middle and end of multiples being 5.75 and 4.39 times riskier, respectively, compared to non-Contiguous single prosthetics. There was no statistical difference with two splints compared to single. This indicates that considering not just the splinting but also the number and position of splinted implants is crucial.

Reports by Mendonça JA stated no difference in marginal bone loss between splint and non-splinted groups but noted that nonsplint groups with lengths under 10mm caused more failures in males' posterior areas.[30] Vigolo P mentioned a 0.1mm difference in bone loss between the groups, which is clinically insignificant.[31]

According to a 2019 study by Solá–Ruíz MF, there was no statistical difference between two implant–supported splint crowns and 3– or 4– unit implant–supported fixed partial dentures after three years of loading, similar to our study.[14] Ravida reported various figures on implant survival rates and peri–implantitis frequency, speculating that the challenge in cleansing splinted crowns might be the reason for higher peri–implantitis rates.[12]

Yi et al. found similar results, reporting a 4.66–fold higher prevalence of peri–implantitis in implants splinted to both mesial and distal adjacent implants compared to single restorations. They also highlighted that implant abutments with an emergence profile of ≥30 degrees had higher peri–implantitis rates.[6,7] This factor warrants consideration when dealing with three or more Contiguous implant prosthetics that might not facilitate adequate self–cleansing.

2.5. Proximal structure

In our study, which classified the actual individual implant's mesial and distal compartments, significant bone loss was observed when the proximal structure was an adjacent structure (Isp) with an implant on which the overlying prosthetic was splinted, compared to when a tooth was present in the proximal structure. research by Yi et al. emphasized that overlooking the emergence angle between implants can lead to an excessively large emergence angle, thereby increasing the risk of peri implantitis.[6,7] Therefore, it's vital to consider the appropriate emergence angle of the transmucosal part from the time of surgery, as well as selecting an implant position that promotes a crown shape that is easy to maintain and ensures good hygiene.

In the case of the proximal structure, when compared to tooth, the relative risk of peri-implantitis increased by 6.23 times and 5.89 times in cases where the distal was Isp and missing, respectively. On the mesial side, no statistically significant difference was observed. This suggests that even if the mesial side has an Isp, which may allow for self-cleansing, significant bone loss may occur on the distal side if it is not adequately managed.

Moreover, when there is a tooth at the terminal end, the likelihood of peri-implantitis or marginal bone loss increases compared to when it's missing. These findings are consistent with the other study that a missing tooth often leads to in creased bone loss(11.1%).[32]

A plausible explanation for this is the generation of traumatic occlusal forces due to overbite patterns leading to bone loss when there is no tooth on the distal side. Bertolini MM posited this, and Lee TC further elaborated, stating that the microdamage theory proposes that traumatic occlusal forces have been linked to bone microfractures. This, in turn, leads to bone loss during the healing process, resulting in eventual bone loss. As microdamage accumulates, it results in fracture failures.[33,34]

In addition to such overload, Costa, F. O. and colleagues have noted that groups not receiving regular supportive implant therapy face a risk of peri-implantitis that is 5.92 times higher.[35] Given that poor oral hygiene is known to be a causative factor for peri-implant marginal bone loss, and considering the difficulty in accessing the area that used to be a tooth deficiency (distal) after the implant prosthetic delivery, it underscores the importance of proper oral hygiene education following prosthetic placement.

However, when measuring marginal bone loss, the annual bone loss signifies a minimal figure; thus, these statistics are relatively small, requiring careful interpretation in a clinical context. Nonetheless, as emphasized by Muhammad Irshad et al., comprehending the risk factors for peri-implantitis is crucial for clinicians. This insight allows them to thoroughly counsel high-risk patients and underscore the necessity for diligent personal and professional upkeep of the implants.[36] Consequently, it becomes imperative to scrutinize relative bone loss or peri-implant factors with significant attention.

2.6. Marginal bone loss rate

In this study, the annual marginal bone loss for the peri-implantitis risk group was -0.34mm/year, which was significantly greater than the -0.02mm/year observed in the non-risk group.

Galindo-Moreno has previously indicated that a bone loss of -0.44mm during the first 6 months after prosthetic placement is an indication of peri-implant bone loss progression.[2] He further emphasized that, beyond the traditional definitions of peri-implantitis, marginal bone loss (MBL) rates also provide crucial information on the biological events encountered by clinicians. In this study, over a span of 15 years, the marginal bone loss in patients with peri-implantitis was -0.34mm/year. While this figure is less than the previously mentioned -0.44mm, we hope that it can serve as a marker for peri-implantitis during the regular annual check-ups, highlighting potential implant bone loss in patients.

This study has several limitations. As mentioned earlier, the two implants used were introduced clinically at different times, making a direct comparison between them impossible. Therefore, the comparison of bone loss between the two implants was evaluated only up to the longest follow-up period of 6 years for the IU implant. Further research is also needed, considering factors like the type of amalgamation, prosthetic fractures and mechanical failures, as well as patient history factors like smoking and diabetes.

V. Conclusion

1. IT implants with microthreads exhibited a higher incidence of marginal bone loss compared to IU implants with macrothreads.

2. In position, the upper premolars, molars, and lower molars showed more bone loss compared to the upper anterior teeth on mesial side. On the distal side, the upper molars had a relatively higher marginal bone loss.

3. In prostheses, marginal bone loss was greater in multiple prosthetics compared to single prosthetics, and the risk of peri-implantitis was also relatively higher. The risk of peri-implantitis in multiple prosthetics was also higher than in splint prosthetics.

4. Considering individual implants, the risk of peri-implantitis was relatively higher when there was an splinted implant(Isp) or missing tooth at the distal side compared to when there was a tooth.

5. The Marginal bone change rate for peri-implantitis is −0.34mm/year.

Ⅵ. Reference

1. Derks J, Schaller D, Håkansson J, Wennström JL, Tomasi C, Berglundh T. Peri-implantitis – onset and pattern of progression. J Clin Periodontol. 2016 Apr;43(4):383-8. doi: 10.1111/jcpe.12535. Epub 2016 Mar 29. PMID: 26900869.

2. Galindo-Moreno P, León-Cano A, Ortega-Oller I, Monje A, O Valle F, Catena A. Marginal bone loss as success criterion in implant dentistry: beyond 2 mm. Clin Oral Implants Res. 2015 Apr;26(4):e28-e34. doi: 10.1111/clr.12324. Epub 2014 Jan 3. PMID: 24383987.

3. Lazzara, R.J.; Porter, S.S. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. Int. J. Periodontics Restorative Dent. 2006, 26, 9–17.

4. Mishra, S.K.; Gaddale, R.; Sonnahalli, N.K.; Chowdhary, R. Platform-switching concept in dental implants: A systematic review and meta-analysis of randomized controlled trials with a minimum follow-up of 3 years. Int. J. Oral Maxillofac. Implant. 2021, 36, e97–e109.

5. Al−Thobity AM, Kutkut A, Almas K. Microthreaded Implants and Crestal Bone Loss: A Systematic Review. J Oral Implantol. 2017;43(2):157−166. doi:10.1563/aaid−joi−D−16−00170

6. Ng KT, Fan M, Leung MC, Fokas G, Mattheos N. Peri−implant inflammation and marginal bone level changes around dental implants in relation to proximity with and bone level of adjacent teeth. Aust Dent J. 2018;63(4):467−477. doi:10.1111/adj.12650

7. Saber A, Chakar C, Mokbel N, Nohra J. Prevalence of Interproximal Contact Loss Between Implant−Supported Fixed Prostheses and Adjacent Teeth and Its impact on Marginal Bone Loss: A Retrospective Study. Int J Oral Maxillofac Implants. 2020;35(3):625−630. doi:10.11607/jomi.7926

8. Achanur M, Aldhuwayhi S, Parihar AS, Bhardwaj A, Das R, Anad KS. Assessment of correlation of periodontitis in teeth adjacent to implant and peri−implantitis. J Family Med Prim Care. 2020 Jan 28;9(1):243−246. doi: 10.4103/jfmpc.jfmpc_726_19. PMID: 32110598; PMCID: PMC7014866.

9. Barros RR, Novaes AB Jr, Muglia VA, Iezzi G, Piattelli A. Influence of interimplant distances and placement depth on peri−implant bone remodeling of adjacent and immediately loaded Morse cone connection implants: a

histomorphometric study in dogs. Clin Oral Implants Res. 2010;21(4):371-378. doi:10.1111/j.1600-0501.2009.01860.

10. Yi Y, Heo SJ, Koak JY, Kim SK. 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. J Adv Prosthodont. 2022;14(4):223-235. doi:10.4047/jap.2022.14.4.223

11. Yi Y, Koo KT, Schwarz F, Ben Amara H, Heo SJ. Association of prosthetic features and peri-implantitis: A cross-sectional study. J Clin Periodontol. 2020;47(3):392-403. doi:10.1111/jcpe.13251

12. Kadkhodazadeh M, Amid R, Moscowchi A, Lakmazaheri E. Short-term and long-term success and survival rates of implants supporting single-unit and multiunit fixed prostheses: A systematic review and meta-analysis [published online ahead of print, 2023 Feb 11]. J Prosthet Dent. 2023;S0022-3913(23)00008-2. doi:10.1016/j.prosdent.2022.12.012

13. de Souza Batista VE, Verri FR, Lemos CAA, et al. Should the restoration of adjacent implants be splinted or nonsplinted? A systematic review and meta-analysis. J Prosthet Dent. 2019;121(1):41-51. doi:10.1016/j.prosdent.2018.03.004

14. Eliasson A, Eriksson T, Johansson A, Wennerberg A. Fixed partial prostheses supported by 2 or 3 implants: a retrospective study up to 18 years. Int J Oral Maxillofac Implants. 2006;21(4):567-574.

15. Saleh MH, Galli M, Siqueira R, Vera M, Wang HL, Ravida A. The Prosthetic-Biologic Connection and Its Influence on Peri-implant Health: An Overview of the Current Evidence. Int J Oral Maxillofac Implants. 2022;37(4):690-699. doi:10.11607/jomi.9523

16. Ravidà A, Tattan M, Askar H, Barootchi S, Tavelli L, Wang HL. Comparison of three different types of implant-supported fixed dental prostheses: A long-term retrospective study of clinical outcomes and cost-effectiveness. Clin Oral Implants Res. 2019;30(4):295-305. doi:10.1111/clr.13415

17. Shah AH, Patel P, Trivedi A, Shah A, Desai N, Talati M. A comparison of marginal bone loss, survival rate, and prosthetic complications in implant-supported splinted and nonsplinted restorations: A systematic review and meta-analysis. J Indian Prosthodont Soc. 2022;22(2):111-121. doi:10.4103/jips.jips_365_21

18. Solá-Ruíz MF, Martí-Martí B, Rech-Ortega C, Fernández-Estevan L, Agustín-Panadero R. Influence on peri-implant bone loss of different fixed partial dentures retained on 2 implants. J Prosthet Dent. 2019;122(3):295-300. doi:10.1016/j.prosdent.2018.09.013

19. Peñarrocha M, Palomar M, Sanchis JM, Guarinos J, Balaguer J. Radiologic study of marginal bone loss around 108 dental implants and its relationship to smoking, implant location, and morphology. Int J Oral Maxillofac Implants. 2004 Nov−Dec;19(6):861−7. PMID: 15623062.

20. Noda, K., Arakawa, H., Kimura−Ono, A., Yamazaki, S., Hara, E. S., Sonoyama, W., Maekawa, K., Okura, K., Shintani, A., Matsuka, Y., & Kuboki, T. (2015). A longitudinal retrospective study of the analysis of the risk factors of implant failure by the application of generalized estimating equations. Journal of prosthodontic research, 59(3), 178–184. https://doi.org/10.1016/j.jpor.2015.04.003)

21. Negri M, Galli C, Smerieri A, Macaluso GM, Manfredi E, Ghiacci G, Toffoli A, Bonanini M, Lumetti S. The effect of age, gender, and insertion site on marginal bone loss around endosseous implants: results from a 3−year trial with premium implant system. Biomed Res Int. 2014;2014:369051. doi: 10.1155/2014/369051. Epub 2014 Aug 12. PMID: 25187903; PMCID: PMC4145382

22. Lerebours C, Thomas CD, Clement JG, Buenzli PR, Pivonka P. The relationship between porosity and specific surface in human cortical bone is subject specific. Bone. 2015 Mar;72:109−17. doi: 10.1016/j.bone.2014.11.016. Epub 2014 Nov 26. Erratum in: Bone. 2015 Jun;75:109. PMID: 25433340.

23. Seong-Mo Koo, Dae-Young Kang, Pham-Duong Hieu, Hyun-Seung Shin, Jung-Chul Park. A Retrospective Study on the Factors Affecting the Early Marginal Bone Loss of Tissue-Level Implants. Journal of implantology and applied sciences. 2021, 25, 4.

24. Monje A, Suarez F, Galindo-Moreno P, García-Nogales A, Fu JH, Wang HL. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. Clin Oral Implants Res. 2014 Oct;25(10):1119-24. doi: 10.1111/clr.12236. Epub 2013 Aug 13. PMID: 23937287.

25. Raikar S, Talukdar P, Kumari S, Panda SK, Oommen VM, Prasad A. Factors Affecting the Survival Rate of Dental Implants: A Retrospective Study. J Int Soc Prev Community Dent. 2017 Nov-Dec;7(6):351-355. doi: 10.4103/jispcd.JISPCD_380_17. Epub 2017 Dec 29. PMID: 29387619; PMCID: PMC5774056

26. Niu W, Wang P, Zhu S, Liu Z, Ji P. Marginal bone loss around dental implants with and without microthreads in the neck: A systematic review and meta-analysis. J Prosthet Dent. 2017 Jan;117(1):34-40. doi: 10.1016/j.prosdent.2016.07.003. Epub 2016 Sep 16. PMID: 27646798.

27. Lee, D.W.; Choi, Y.S.; Park, K.H.; Kim, C.S.; Moon, I.S. Effect of microthread on the maintenance of marginal bone level: A 3-year prospective study. Clin. Oral Implants Res. 2007, 18, 465–470.

28. Schrotenboer, J.; Tsao, Y.P.; Kinariwala, V.; Wang, H.L. Effect of microthreads and platform switching on crestal bone stress levels: A finite element analysis. J. Periodontol. 2008, 79, 2166–2172.

29. Shin, Y.K.; Han, C.H.; Heo, S.J.; Kim, S.; Chun, H.J. Radiographic evaluation of marginal bone level around implants with different neck designs after 1 year. Int. J. Oral Maxillofac. Implant. 2006, 21, 789–794.

30. Mendonça JA, Francischone CE, Senna PM, Matos de Oliveira AE, Sotto-Maior BS. A retrospective evaluation of the survival rates of splinted and non-splinted short dental implants in posterior partially edentulous jaws. J Periodontol. 2014 Jun;85(6):787-94. doi: 10.1902/jop.2013.130193. Epub 2013 Oct 30. PMID: 24171498.

31. Vigolo P, Mutinelli S, Zaccaria M, Stellini E. Clinical evaluation of marginal bone level change around multiple adjacent implants restored with splinted and nonsplinted restorations: a 10-year randomized controlled trial. Int J Oral Maxillofac Implants. 2015 Mar-Apr;30(2):411-8. doi: 10.11607/jomi.3837. PMID: 25830402.

32. Algahtani FN, Hebbal M, Alqarni MM, Alaamer R, Alqahtani A, Almohareb RA, Barakat R, Abdlhafeez MM. Prevalence of bone loss surrounding dental implants as detected in cone beam computed tomography: a cross−sectional study. PeerJ. 2023 Aug 3;11:e15770. doi: 10.7717/peerj.15770. PMID: 37551351; PMCID: PMC10404392.

33. Bertolini MM, Del Bel Cury AA, Pizzoloto L, Acapa IRH, Shibli JA, Bordin D. Does traumatic occlusal forces lead to peri−implant bone loss? A systematic review. Braz Oral Res. 2019 Sep 30;33(suppl 1):e069. doi: 10.1590/1807−3107bor−2019.vol33.0069. PMID: 31576953.

34. Lee TC, O’Brien FJ, Gunnlaugsson T, Parkesh R, Taylor D. Microdamage and bone mechanobiology. Technol Health Care. 2006;14(4−5):359−65.

35. Costa, F. O., Takenaka−Martinez, S., Cota, L. O., Ferreira, S. D., Silva, G. L., & Costa, J. E. (2012). Peri−implant disease in subjects with and without preventive maintenance: a 5−year follow−up. Journal of clinical periodontology, 39(2), 173–181. https://doi.org/10.1111/j.1600−051X.2011.01819.

36. Irshad M. Peri−implantitis; comparison with periodontitis from etiological perspective: A literature review. EC Dent Sci. 2016:1426–32.

국문 요약

보철물 종류 및 임플란트의 연속성 여부가 1792개 내측연결형 임플란트 변연골 흡수에 미친 영향: 최장 15년 다기관 후향관찰 연구

오 지 환

연세대학교 대학원 치의학과

<지도교수 김선재>

연구 목적: 이번 연구의 목적은 marginal bone change 와 임플란트 연속성, 보철 유형 및 인접 또는 근접 구조와 및 임플란트 기본 요소(위치, 길이, 직경 등) 와의 상관 관계를 평가하는 것이다.

재료와 방법: 이 연구에서는 2003년부터 2020년까지 두 기관에 내원한 환자를 대상으로 진행하였으며, 임플란트의 특성과 이들과의 관계에 따라 주변 marginal bone loss(MBL)을 기준으로 임플란트를 분류했다. 특

히 임플란트의 연속한지 혹은 그렇지 않은지 나누고 상부 보철을 4가지로 (single, splint, multiple, bridge) 세분화 하였다. 이 연구에서는 periapical 방사선사진을 사용하여 MBL을 평가하고 peri-implantitis 위험 지표를 설정했다. 통계 분석 방법으로는 Kaplan-Meier 추정, Linear Mixed Model, Generalized Estimating Equation 및 Cox Proportional Hazard 모델이 사용되었다.

결과: 후향적 분석에서는 804 명의 환자에서 총 1,792 개의 임플란트를 평가했으며, 평균 추적 기간은 5.4 년이었다. 임플란트의 생존률은 98.8% 이었으며 측정 변수들과의 상관성은 관찰되지 않았다. Linear Mixed Models 및 Generalized Estimating Equations을 사용하여 위치, 연령, 길이, 연속성, 보철 유형 및 인접 구조와 같은 결정 요인들이 주변 골 손실에 영향을 미치는 것으로 확인되었다. Cox Proportional Hazard model을 통해 상대적으로 multiple보철, 임플란트 연속성 및 인접 구조가 peri-implantitis의 중요한 위험 요소로 확인했다.

결론: microthread를 가지는 IT는 IU 보다 marginal bone loss 양상이 더 진행되었다. 위치에서는 상악 전치부와 비교하였을 때 상악 소구치 및 대구치, 하악 대구치에서 골 손실을 보였다. 보철에서는 Multiple prosthesis가single보다 더 많은 골 손실을 유발하고 peri-implantitis 위험을 증가시켰다. distal 측면에서 Isp(splinted) 또는 missing 부위에서 자연치와 비교하였을 때 peri-implantitis 위험을 증가시켰다. peri-implantitis와 관련된 MBL rate은 −0.34mm/year이었다.

keywords : survival rate, marginal bone loss, peri-implantitis, Contiguousness, marginal bone loss rate