Changes in the fractal dimension on peri-implant bone after surgical treatment of peri-implantitis: a retrospective study

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Directed by Professor Ik-Sang Moon

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감사의 글

부족한 저에게 너무나 많은 분들이, 관심어린 사랑과 이해 그리고 도움과 함께하는 진정한 마음을 주셨습니다. 모든 분들께 감사의 마음을 전합니다. 먼저 부족한 저를 제자로 받아들여, 하나에서 열까지 가르침을 주시고 인내와 사랑으로 지도해 주신 존경하는 문익상 지도교수님 정말 감사드립니다. 평생 교수님의 가르침을 가슴에 새기며 교수님의 제자로써 부끄럽지 않도록 노력하겠습니다.

더불어 실질적인 논문 설계와 진행에 관하여 사랑으로 지도해 주신 이동원 교수님. 교수님의 세심한 배려와 관심 속에서 그나마 논문이 완성되었음을 새기며 감사의 마음을 드립니다. 부족한 논문임에도 불구하고, 깊은 관심으로 심도있게 심사를 해주신 박광호 교수님께도 깊은 감사를 드립니다. 또한 긴 의국생활 내내 많은 도움을 준 손선보 선생님에게도 이 자리를 빌어 고마운 마음을 전합니다.

지난 4년이라는 시간동안 항상 함께하면서 의지가 되어 준 청운이에게 특히 고마웠다는 말을 하고 싶습니다. 그리고 바쁜 와중에도 여러모로 많은 도움을 준 재용, 소란, 해석오빠, 찬호에게도 항상 고맙고 미안한 마음을 전합니다.

언제나 사랑과 믿음으로 지켜봐주시고 응원해주시는 부모님, 착하고 듬직한 사랑하는 상수, 부족한 저를 사랑으로 받아주시는 시부모님께도 감사를 드립니다. 끝으로 저를 있는 그대로 사랑해주고 항상 묵묵히 옆에서 지켜주고 힘이 되어주는 사랑하는 남편에게 고마운 마음과 함께 이 논문을 바칩니다.

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어연호

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ABSTRACT

Changes in the fractal dimension on peri-implant bone after surgical treatment of peri-implantitis: a retrospective study

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The aim of this study was to evaluate bony changes could be caused by surgical therapy for treatment of peri-implantitis around dental implants by fractal dimension analysis. Twenty subjects (12 males and 8 females; age range: 49 to 85 years; mean age: 63.2 years, 35 Implants) were selected from patients who were diagnosed with peri-implantitis at the Department of Periodontology, Gangnam Severance Dental Hospital between August 2007 and October 2012. Five different surface characteristics of implants were included in this study.

Depending on clinical and radiographic outcomes of surgical treatment, subjects were assigned to two groups, treatment success and failure group.

Fractal dimension was measured by comparing radiographs taken before and 3 months after the surgical treatment. The ROIs were set to a width of 100 pixels and a height of 200 pixels at the mesial and distal aspect of implant, and a fractal analysis was performed using the box-counting method of Image J 1.42 software. ROIs were created in same position. Wilcoxon signed-rank was used to analyze the differences in before and after surgery.

There was a statistically significant difference in fractal dimensional changes after 3 months on both groups. In treatment success group, the median fractal dimension was 1.4878 before surgery and it increased to 1.5182 after 3 months surgery (p=0.001). This result could suggest increased mineralization of peri-implant bone structure around the implant as a result of bone remodeling. In treatment failure group, the median fractal dimension was 1.4675 before surgery and it decreased to 1.4334 after 3 months surgery (P=0.001).

There was a correlation between increased peri-implant bone volume and density changes and successive outcome of surgical treatment for treating peri-implantitis as result of bone remodeling. As fractal dimension analysis could detect small trabecular mineralization changes, it could be used for early detection of trabecular bone changes in clinical situation.

Key words: fractal dimension, dental implant, peri-implantitis

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I. INTRODUCTION

Recent studies indicate that peri-implantitis is one of the most common complications around dental implants (Claffey et al., 2008) and increasing number of implants placed in everyday clinical practice, the prevalence of peri-implantitis is also increasing. In a recent review of two cross-sectional study (Fransson et al., 2005; Fransson et al., 2008; Roos-Jansaker et al., 2006), peri-implantitis was found in 28% and 56% of subjects and in 12% and 43% of implant sites (Zitzmann and Berglundh, 2008).

The therapies of peri-implantitis have been based on the evidence available for the treatment of periodontitis. In several studies, non-surgical therapy was not found to be effective and surgical therapy has been advocated as a treatment of peri-implantitis (Claffey et al., 2008; Klinge and Meyle, 2012; Renvert et al., 2008). Following the peri-implant inflammation was resolved as a result of surgical treatment, remodeling of peri-implant bone was expected in the similar result to increase of periodontal bone volume and density after open flap debridement in periodontitis (Schwartz et al., 1997).

Several attempts, such as resective and regenerative treatment in conjunction with various methods of additional surface decontamination have been made to determine a treatment protocol that could successfully achieve bone fill within the peri-implant defect and re-osseointegration on the previously contaminated surface. Experimental studies (Persson et al., 1999; Persson et al., 2004; Schwarz et al., 2006; Wetzel et al., 1999; You et al., 2007) have verified that peri-implant defects may heal with newly formed bone fill, and re-osseointegration is possible to obtain but to be difficult to achieve. The clinical study (Lee et al., 1999) reported to possibility to obtain re-osseointegration but there were few clinical studies regarding to re-osseointegration on account of ethical reasons. Therefore, approaches of the evaluation of treatment outcomes in human were focused on the changes of peri-implant bone level by means of periapical radiographs in clinical situation. Periapical radiographs are most commonly used in routine dental examination. It has high resolution and high specificity (Kornman, 1987), so it might contain significant amounts of information on bone quality, but it has low sensitivity (Akesson et al., 1992) and limited diagnostic value for detection of small changes in the alveolar bone (Lang and Hill, 1977).

Fractal dimension analysis is a one of the method of quantitatively measuring complex bony trabecular pattern by using periapical radiographs and considered to provide a diagnostic tool to objectively characterize trabecular bone structure. There are many useful research applications that correlating trabecular bone structure by using fractal analysis. This could be used to diagnose or monitor pathological conditions, such as osteoporosis (Law et al., 1996; Ruttimann et al., 1992; Southard et al., 1996) or pathological bone lesions (Havlin et al., 1995; Heymans et al., 2000) in medicine. In dentistry, it has been performed for evaluation of periodontally compromised patients (Landini, 1991, 1997; Shrout et al., 1998; Updike and Nowzari, 2008), root canal therapy (Chen et al., 2005; Yu et al., 2009), caries (Gonzalez-Gonzalez, 1997; Umemori et al., 2010) and others (Demirbas et al., 2008; Morinushi et al., 1998).

There have been a publication using radiograph for evaluating the fractal dimensional changes in peri-implant bone after surgical treatment of peri-implantitis in animals (Kim and Kim, 2010), but no clinical study existed. Therefore, the aim of this retrospective study was to evaluate peri-implant bone changes caused by surgical treatment for peri-implantitis by using fractal dimension analysis.

II. MATERIALS AND METHODS

1. Patient selection

This study was approved by the Institutional Review Board of Yonsei University (IRB No. # 3-2012-0208). Patients were informed in detail about the study procedures.

Patients who were diagnosed with peri-implantitis and received surgical treatment were recruited between August 2007 and October 2012 to the Department of Periodontology, Gangnam Severance Hospital, and were selected as subjects for this study. In total, 20 patients (12 males and 8 females, 35 implants) participated in the study, with a mean age of 63.2 years and a range of 49 to 85 years.

They were assigned to two groups according to criteria of treatment success and failure, as mentioned in the 8th section.

All the patients were in good general health. None of the patients had known systemic diseases that would affect bone metabolism, cancers with bone metastasis and they were not using specific drugs of hormones which are known to have adverse effects on bone metabolism.

2. Diagnosis

In this study, the diagnosis of peri-implantitis was assessed by evaluating clinical and radiographic parameters in according with the most commonly used: clinical signs of suppuration or sulcus bleeding; probe penetration > 5mm into the peri-implant sulcus; and radiographic evidence of peri-implant radiolucency (Ferreira et al., 2006; Karoussis et al., 2004; Zitzmann and Berglundh, 2008).

The parameters were recorded at four locations around each implant (mesial, buccal, distal and palatal/lingual). The amount of plaque was scored using the modified plaque index (mPI)(Mombelli et al., 1987) and bleeding tendency of the marginal peri-implant tissues was evaluated using a modified sulcus bleeding index (mBI)(Mombelli et al., 1987). PPD(Mombelli et al., 1987) defined as the distance from the mucosal margin to the bottom of the pocket, was recorded by light force.

3. Implants

Five different implant systems were evaluated in this study. Different surface characteristic of the installed implant systems is detailed in Tables 1.

Surface	Name	Company	Number of instated implants
Sandblasted Large grit Acid Etched (SLA)	Implantium	Dentium®, Seoul, Korea	10
Resorbable blast media (RBM)	Megafix	Megagen, Seoul, Korea	7
TiUnite	MK Ⅲ	Nobel Biocare AB, Göteborg, Sweden	3
TiOblast	TiOblast	Astra Tech AB, Mölndal, Sweden	8
Fluoride-modified TiOblast (Osseospeed™)	Osseospeed™	Astra Tech AB, Mölndal, Sweden	7

Table 1. Characteristics of the installed implants.

4. Treatment procedure

Surgical treatment for peri-implantitis should include of the two important procedures; granulation tissue removal and implant surface detoxification.

Under local anesthesia, sulcular incisions were used to prepare full thickness flaps at both vestibular and oral aspects of each implant site. All granulation tissue was completely removed from the defect area by using curettes. Saline soaked cotton pellets were adapted to all exposed implant surface areas for implant surface detoxification, which was followed by a thorough irrigation with sterile saline. To ensure a non-submerged healing, the mucoperiosteal flaps were positioned with interrupted sutures (Schwarz et al., 2010). All treatments were performed by the two experienced periodontists.

5. Postoperative care

Sutures were removed 10 days after surgery. The patients received new oral hygiene instructions, aiming at optimal plaque control. A supragingival professional implant/tooth cleaning and reinforcement of oral hygiene were performed at 1, 3 and 6 months after therapy.

6. Radiographic examination

Radiographs were taken with an extension cone paralleling (XCP) device (Extension Cone Paralleling Kit, Rinn, Elgin, IL, USA.) using the parallel cone technique (70 kV, 8 mA, 0.250 s). A 5.5 mm spherical metal bearing was placed to aid length measurement. All films were developed using the same automatic processor (Periomat, Durr Dental, Bietigheim-Bissingen, Germany.) according to the manufacturer's instructions. Films were digitized using a digital scanner (EPSON GT-12000, EPSON, Nagano, Japan.) at an input resolution of 2400 dpi with 256 gray scale. Periapical radiographs (Kodak Insight, film speed F, Rochester, NY, USA.) were taken before the surgery, and 3 months after surgery.

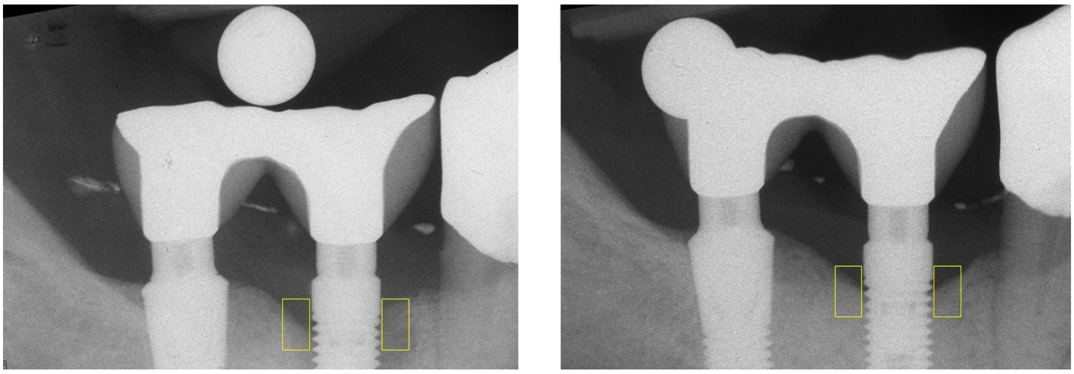
7. Imaging processing (selection of ROI and fractal analysis)

Image J 1.43u program (Wayne Rasband, National Institutes of Health, USA) was used for all image processing and analyzing. Calibration was performed using the known distance of the spherical metal bearing (5.5mm). Fractal dimension was measured by comparing radiographs taken before the surgery to these taken 3 months after surgery (Figure 1).

The ROIs were set to a width of 100 pixels and a height of 200 pixels (= 1.0mm x 2.0mm) located on the mesial and distal aspect of specific threads of each implant. Radiographs were taken three months after surgery, and ROIs were created in same position.

The protocol used was based on the methods described by White and Rudolph (White and Rudolph, 1999). The ROIs were duplicated and blurred by a Gaussian filter with a diameter of 35 pixels. This step removed all fine-scale and medium-scale structure and retained only large variations in density. The resulting heavily blurred image was then subtracted from the original, and 128 were added to the result at each pixel location. This generates an image with a mean value of 128, regardless of the initial intensity of the image. The aim of this operation was to reflect individual variations in the image such as trabeculae and marrow space. The Image was then made binary, thresholding on a brightness value of

128 and eroded and dilated once to reduce noise. The image of the trabeculae is then inverted to make trabeculae and then skeletonized. Fractal analysis was performed using the box-counting method.



a b

Figure 1. ROIs were selected (a) before the surgery; (b) after 3 months

8. Treatment success and failure criteria

Peri-implantitis treatment success criteria were absence of bleeding on probing and/or suppuration in conjunction to PPD > 5mm (Charalampakis et al., 2011). Radiographically, increased or stable marginal bone levels around dental implants compared with the baseline periapical radiographs were considered to treatment success. Any clinical measurements different from the above thresholds or obvious progressive bone loss radiographically were assigned to treatment failure group (Charalampakis et al., 2011).

9. Statistical analysis

The null hypothesis was that there would be no difference between the fractal dimensional change before and after surgery in each group. The D'Agostino-Pearson test was used to test the normality of the distribution.

As the normality of the distribution was rejected, Wilcoxon signed-rank test was used to analyze the differences in before and after surgery. Computer software (SPSS for Windows, , SPSS Inc, Chicago, USA.) was used to process the data. The values were deemed statistically significant if the p-value was lower than 0.05. The intraobserver agreement reliability was evaluated by Cronbach’s alpha.

III. RESULT

1. Clinical examination

Thirteen of twenty subjects (23 implants) have no specific complications during the observation period. No inflammation was observed in any of the implants of these subjects. All of the implants functioned normally. The peri-implant soft tissues were found to be clinically healthy. They were assigned to treatment success group.

The others, seven subjects (12 implants), suffered clinical symptom, such as pain, suppuration, bleeding on probing and obviously progressive bone loss after surgical treatment during the observation period. They were considered treatment failure, as mentioned above thresholds and classified into treatment failure group.

2. Fractal dimensional change before and after surgery

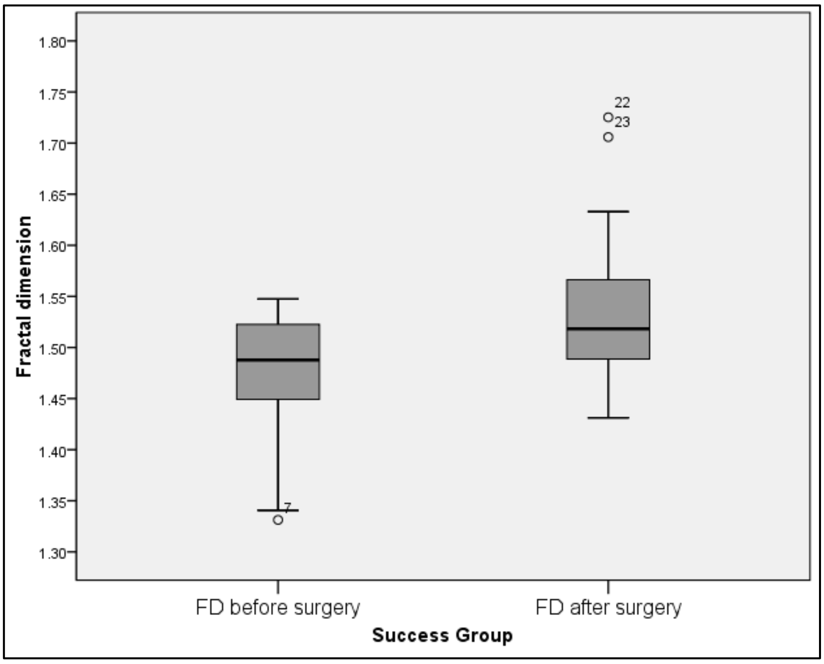
The Cronbach's Alpha value for interobserver reliability was 0.8684. The median fractal dimension was 1.4878 before surgery and it increased to 1.5182 after 3 months surgery in success group (P=0.001). The median fractal dimension was 1.4675 before surgery and it decreased to 1.4334 after 3 months surgery in failure group (P=0.001).

There were statistically significant differences in fractal dimensional changes after surgery in both groups. ($p < 0.05$; Table 2, Figure2)

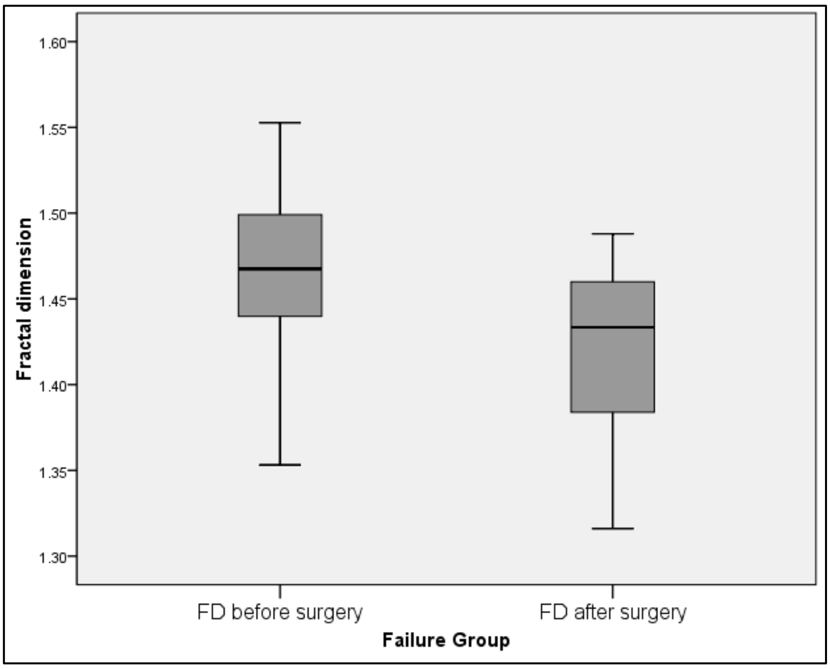
Table 2. Fractal dimensional change (median (95% CI for the median))

	Before surgery	After surgery	p- value
Success	1.4878(1.4452-1.5019)	1.5182(1.5044-1.5701)	p=0.001*
Failure	1.4675(1.4334-1.4998)	1.4334(1.3813-1.4552)	p=0.001*

* statistically significant different



* p=0.001, statistically significant different



* p=0.001, statistically significant different

Figure 2. Fractal dimension alteration

IV. DISCUSSION

New bone formation within the peri-implant defect and re-osseointegration is the ultimate goal of surgical therapy of peri-implantitis. Several clinical (Charalampakis et al., 2011; Claffey et al., 2008; Heitz-Mayfield et al., 2011; Romeo et al., 2007) and experimental (Persson et al., 1999; Persson et al., 2004; Schwarz et al., 2006; Wetzel et al., 1999; You et al., 2007) studies reported that peri-implant bone density and volume was improved as a consequence of treatment success. On the basis of these results, the aim of this study was to evaluate bony density and volume changes caused by surgical therapy for treatment of peri-implantitis by using fractal dimension analysis.

As trabecular bone is a better indicator for bone metabolic activity and more useful in monitoring changes, it has been used to evaluate the changes of bone density and volume in many studies by using several clinical methods (Chen and Chen, 1998; Jolley et al., 2006; Southard et al., 1996). One such method, fractal analysis, could be a useful tool to quantify bone changes in clinical situation. Several studies demonstrated that there were strong correlations between generalized mineralization of trabecular bone and increasing fractal dimension (Chen and Chen, 1998; Schou et al., 2003a; Schou et al., 2003b; Southard et al., 1996; Southard et al., 2001). And there are several studies regarding the reliability of fractal dimension measurement from radiographs (Jolley et al., 2006; Shrout et al., 1997a; Shrout et al., 1997b).

Despite the fact that the position and size of ROI may affect fractal dimension(Lee et al., 1999; Schou et al., 2003c), previous experimental and clinical studies merely provide insufficient or even no details respecting reference of position and size of ROI. The remodeling of peri-implant bone was pronounced within 1mm (Garetto et al., 1995). For this reasons, the ROI was set to a width of 1.0mm adjacent to the implant-bone interface. In our studies, almost every peri-implant bone loss was occurred more than 1mm vertically. To include the bone defect sufficiently within ROI, the ROI was set to a height of 2.0 mm. For investigating not only bone density but volume changes of peri-implant bone defects, the ROI was located on the mesial and distal aspect of the implant including bone defects on the basis of Kim et al. (Kim and Kim, 2010).

Subjects were assigned to two groups, treatment success and failure, according as clinical and radiographic criteria. In treatment success group, there were statistically significant differences in fractal dimensional changes after 3 months of surgery ($p < 0.05$). This result demonstrated that increased fractal dimensions after surgery, which could suggest increased mineralization of peri-implant bone around the implant as a result of bone remodeling. Other studies reported the similar results. Wojtowicz et al. (Wojtowicz et al., 2003) showed the increasing complexity of trabecular patterns as the bone grew, and Nair et al. (Nair et al., 2001) and Heo et al.(Heo et al., 2002) reported that the fractal dimension increased during the bone recovery process.

However, in treatment failure group, they showed that decreased fractal dimension after 3 months of surgery ($p < 0.05$). This result suggested that decreased fractal dimension means decreased mineralization of peri-implant bone in consequence of failure of resolution the peri-implant inflammation. Similar results were reported. Fractal dimension was decreased in patients compromised by periodontal disease compared with normal subjects (Cha et al., 2001; Khosrovi et al., 1995). Ruttimann et al. (Ruttimann et al., 1992) reported that fractal dimension diminished with continued mineral loss.

Judging by these results, the tendency to increased bone architecture here measured with fractal dimension analysis would seem to be in agreement with a significant increase of density and volume in the peri-implant bone. And we could consider that there was a correlation between increased peri-implant bone density and successive outcome of surgical treatment for treating peri-implantitis as result of bone remodeling.

The main limitation of this study is the surface characteristics difference of treated implants. Several studies reported that reosseointegration may be influenced by the implant surface characteristics and in smooth surface implant was less than rough surface implant (Persson et al., 2001; Persson et al., 2004; Schwarz et al., 2006; Shibli et al., 2003; Wetzel et al., 1999). But, these studies also reported that similar amount of peri-implant new bone formation was founded in consequences of peri-implant inflammation resolution, regardless of the different surface characteristics. And the level of surface roughness of implants using in our study was comparable, these effects was considered to be minimal. The aim of this clinical study was focused on the meaning of evaluation of peri-implant new bone formation, not re-osseointegration. Therefore, surface characteristics were not considered to be critical factor.

The other limitation in this study, did not give a clear description of the morphology of the peri-implant bone defect. Several studies attempted to evaluate efficacy of the procedures used for surgical treatment of peri-implant bone defects, but the configuration and sizes of the bone defects were not reported in most of the studies (Ericsson et al., 1996; Persson et al., 1996; Schou et al., 2004; Schou et al., 2003a; Schou et al., 2003b). However, these previous studies pointed out that defect morphology plays a major role in the healing process. In particular, it was founded that the deeper the defect the greater was the amount of clinical improvement, while the wider the defect the lower were the attachment and bone gain (Garrett et al., 1988; Tonetti et al., 1993; Tonetti et al., 1996). And the number of residual bony walls may affect the regeneration potential (Goldman and Cohen, 1958). In our studies, bone defect configuration was divided into two shapes, horizontal and intrabony defects. Only seven out of thirty-five were intrabony defects configuration, therefore large number samples is needed in future study.

Despite of these limitations, we found that there was a correlation between increased peri-implant bone density and successive outcome of surgical treatment. And as fractal dimension analysis could detect small trabecular mineralization changes, it could be used for early detection of trabecular bone changes in clinical situation.

V. CONCLUSION

There was a correlation between increased peri-implant bone density changes and successive outcome of surgical treatment for treating peri-implantitis as result of bone remodeling. As fractal dimension analysis could detect small trabecular mineralization changes, it could be used for early detection of trabecular bone changes in clinical situation.

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국문요약

임플란트 주위염의 수술적 치료 후

임플란트 주변 골의 변화에 대한 프랙탈 분석: 후향적 연구

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이 연구의 목적은 임플란트 주위염의 수술적 치료 후 임플란트 주위 골의 골소주의 변화를 프랙탈 차원 분석을 이용하여 측정하는 것이다.

본 연구는 강남 세브란스 병원 치주과에서 임플란트 주위염으로 진단받고 수술적 치료를 시행받은 20명의 환자(35개의 임플란트)를 대상으로 진행되었으며, 서로 다른 표면 처리를 한 다섯 개의 임플란트 시스템이 포함되었다.

수술적 치료 후 환자들은 수술 후 임상적 및 방사선학적 결과에 따라 수술 성공과 실패의 두 그룹으로 나뉘었다.

수술적 치료 전과 치료 3개월 후에 방사선 사진을 촬영하여, 각 임플란트의 근, 원심 부위의 인접 치조골 가장 상부에 100x200 픽셀 크기로 두 사진의 같은 위치에 관심 영역을 설정하여 프랙탈 차원 분석을 시행하였다. Wilcoxon signed-rank test를 이용한 분석 결과 수술 후 성공적 결과를 보인 환자들에서 술 전 프랙탈 차원 값은 중간값 1.4878, 술 후 1.5182으로 통계학적으로 유의성 있게 증가한 양상을 보였으며(P=0.001) 이는 수술 후 임플란트 주위 골의 치유 과정에 의해 임플란트 주위 골의 부피와 밀도가 증가함을 의미한다.

수술의 실패로 간주되는 환자들에서는 술전 프랙탈 차원 값은 1.4675, 술후 1.4334으로 통계학적으로 유의성있게 감소한 양상이 관찰되었다(P=0.001).

본 연구의 결과, 임플란트 주위염의 수술적 치료 후 골의 리모델링으로 인한 임플란트 주위 골의 부피 및 밀도의 증가는 수술 후 성공적인 치료 결과와 밀접한 관련이 있음을 알 수 있었다. 또한, 프랙탈 차원 분석은 적은 양의 골소주의 변화를 감지할 수 있는 방법으로, 정기적으로 촬영한 방사선 사진에서 골 소주의 변화를 조기에 감지할 수 있는 유용한 방법이다.

핵심 단어: 프랙탈 차원 분석, 임플란트, 임플란트 주위염