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치의학박사학위논문

**Effect of Resorbable Blasting Media
Surface Treatment on Removal
Torque of Orthodontic Mini-implants:
Mechanical and Histological Analysis**

교정용 미니 임플란트의
흡수성 분사 처리가 제거토크에 미치는
영향 및 조직학적 평가

2014 년 2 월

서울대학교 대학원

치의과학과 치과교정학 전공

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-ABSTRACT-

Effect of Resorbable Blasting Media Surface Treatment on Removal Torque of Orthodontic Mini-implants: Mechanical and Histological Analysis

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Objective: The purpose of this study was to evaluate the effect of resorbable blasting media (RBM) treatment on the stability of the orthodontic mini-implant (OMI), using the removal torque, the histomorphometric, the histologic, and the fluorescent evaluation for healing processes of both surfaces.

Materials and Methods: Ninety six titanium OMIs with 6.0 mm length and 1.6 mm diameter, which consisted of machined group (with the machined surface) and RBM group (treated with CaP and HNO₃), were implanted to the tibia of rabbits. Average roughness (Ra), mean square roughness (Rq), and maximum height of the roughness (Rz) of OMIs were analyzed by Optical Profilometer (Wyko NT 8000, Veeco, Tucson, AZ, USA). Maximum removal torque (MRT) and removal angular momentum (RAM) of 16 OMIs of both groups were measured at 2 and 4 weeks after implantation. Bone-to-implant contact (BIC) and bone area (BA) of 16 OMIs of both groups were analyzed at 4 weeks after implantation. Fluorescent dyes were

injected at 1 day, 2 weeks and 4 weeks after implantation and two groups were compared with a fluorescence microscope.

Results: Ra, Rq and Rz of RBM group were higher than machined group. MRT and RAM at 2 weeks of RBM group were significantly higher than machined group. Although there was no statistically significant difference in BIC, BA of RBM group was significantly higher than machined group. Machined group showed more active bone resorption and new bone formation at 2 weeks.

Conclusions: The machined surface OMI may fail at the initial stage by the active bone remodeling. And the bone apposition on RBM surface treatment can support the initial stability of the OMI although it does not increase the stability over time

Key words: Mini-implant, surface treatment, RBM, removal torque, histomorphometric analysis

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교정용 미니 임플란트의 흡수성 분사 처리가 제거토크에 미치는 영향 및 조직학적 평가

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I. INTRODUCTION

Recently, mini-implants have been clinically used as an orthodontic device for an absolute anchorage which can provide a various application of the orthodontic force to the teeth because of its small size.^{1,2,3} However, a small diameter orthodontic mini-implants (OMIs) can be easily loosened by low removal torque⁴ and a short length OMI showed a lower success rate.⁵ There is a limitation in increasing the success rate by changing the diameter and the length of the OMIs because it must be placed between roots without touching it.⁶ Therefore, to increase the success rate, shape,⁷ threads,⁴ soft tissue contact surface,⁸ and insertion method⁹ of the OMIs have been studied.

In the osseointegration of dental implants, the implant surface properties have been reported to be one of critical factors.¹⁰ Surface characteristics of implants such as surface composition, surface structure, surface energy, oxide thickness, and topography may play an important role in formation and maintenance of bone at implant surface.¹¹

Recent studies have shown that an increase in surface roughness could enhance the bone to implant contact (BIC). The roughness appears to be a factor that maximizes new bone formation.¹² There are some types of surface treatment methods to increase the implant roughness such as acid etching of an implant surface,¹³ application of a titanium plasma spray,¹⁴ incorporation of hydroxyapatite,¹⁵ blasting with different substances,¹⁶ and laser ablation.¹⁷

Recently, resorbable blasting media (RBM) such as hydroxyapatite or calcium phosphate have been adopted as sand-blasting medium to increase the surface roughness of dental implants.¹⁸ Researchers demonstrated that RBM surface treated implants have a maximum removal torque (MRT) and BIC than machined implants, and appeared to have the most benefit on early bone formation and initial stability.^{19, 20, 21}

The purpose of this study was to evaluate the effect of RBM treatment on the stability of the OMIs, using the removal torque, the histomorphometric, the histologic, and the fluorescent evaluation for healing processes of both surfaces.

II. REVIEW OF LITERATURE

Failure rates of orthodontic mini-implants

Most useful intra-oral anchorage device is OMI within easy insertion and removal after treatment and it has 85%-97% success rates. Prosthodontic implants generally have high clinical success rates, though there is variability. Other studies which collectively examined 986 prosthodontic implants of variable diameters, reported cumulative success rates of 98.6% over two years, and 99.3% over three years, respectively.^{22, 23} In comparison, some studies reported about failure rates of OMI ranged in 10% to 30%.²⁴⁻³⁰ In the review of published fourteen clinical studies involving 452 patients and a total of 1519 OMIs of various designs, the mean overall success rate was 83.8% +/- 7.4%, OMIs with lengths shorter than 8 mm and diameters of less than 1.2 mm appeared to compromise success rates even further.²⁵

Mini-implant stability

Some investigators have found that the stability of mini-implant is affected by host factors that age, craniofacial skeletal pattern, side of implantation, and mini implant factors as design, length, dimension³¹⁻³⁴ and surface of mini-implant, and treatment factors that related with angulation of mini-implant to bone³⁵, insertion torque, quality and quantity of the cortical bone.³⁶

Primary stability

Stability immediately after insertion is called primary stability ("Press-fit").³⁷ Martinez and Wilmes said that primary stability expresses the initial stability of a

recently placed implant.^{33, 38} Melsen and Costa referred Primary stability is an important factor for the stability of OMI.³⁹ The essential factors affecting primary stability of the OMI are bone quality,³⁷ implant design,^{7, 32} and insertion modalities.⁹ It is a function of mechanical retention in the bone so it is greatly influenced by the design of the implant shank and the density and amount of the implant bed bone.^{34- 36, 40} Initial stability of the implant is, one of the fundamental criteria for obtaining osseointegration.⁴¹

Secondary stability

Secondary stability is the stability after the placement site has healed. So it is a consequence of bone formation and remodeling on the implant-bone interface and surrounding bone.^{42, 43} The result of the host response to the implant is determined by biologic reactions in addition to mechanical retention. That is achieved through continues bone remodeling around the mini-implant. It is important to improving stability and success rate of implants.⁴⁴ Mechanical retention just after insertion is vanished, because of bone resorption around that implant. Then bone remodeling that is related with secondary stability will increase as time goes on, therefore stability is maintained.⁴⁵

Improving stability of the OMI

Some clinicians described that stability of the OMI is achieved through mechanical retention without osseointegration, which is mechanical interlocking of the OMI thread and cortical bone. However, more recent histomorphometrical reports supported the view that osseointegration does occur. Other study described

that even osseointegration occurs small removal torque value is measured because of a small diameter of OMI surface.⁴ The design and surface characteristics of OMIs are crucial factors for successful osseointegration.⁴⁶ Modifications in the OMI body design and surface of the OMI have been suggested to increase the success rate in the poor quality bone by gaining better anchorage also providing more surface area of load to decrease stress to softer bone types.^{7, 47, 48}

Modifying the OMI surface

Modifying the OMI surface with surface roughening offers good bone anchoring for orthodontic purposes.⁴⁹ Several methods of surface treatment are available, such as hydroxyapatite coating, titanium plasma spray, acid-etching, sand blasting, and RBM. Numerous studies have attempted to use various techniques that sandblasted large-grit and acid-etched (SLA) surface of titanium OMIs in order to improve implant osseointegration. SLA surface treatment is good result for osseointegration.⁴⁹⁻⁵² However, these methods are complicated and expensive methods for roughening the implant surface than the RBM type. RBM surface is roughened using only biocompatible media (calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$) that is fully resorbable.⁵³ The result of RBM surface treatment is clean and textured pure titanium surface. Additionally, RBM does not need strong acids for removing of blasting media remains, which contributes to implant biocompatibility as well. Therefore it does not affect the fatigue strength of the implant surface.^{52, 54} Some results of other studies indicated that RBM treatment of small diameter implant enhances osseointegration is helpful for a new bone formation and it is also associated with a reduction in the healing period.⁵⁴

Methods to evaluate the surface characterization of OMI

A variety of methods are designed for implant surface analysis. In some of the most used analytical tools will be listed and briefly described. The tools are addressing major properties of implant surfaces, ranging from surface topography measurement via elemental analysis of the surface layer to crystalline structural analysis in scanning electron microscope.

Surface topography

The surface topography could be measured and characterized with or without physical contact between the instrument and sample. The contact measurements use some sort of tip sliding along the surface and the vertical movement is registered along with position in the horizontal plane. The non-contact methods use light and its reflections and register the vertical position via the focus plane. For screw shaped implants the latter is preferred due to difficulties in measurement due to the macro geometry and reaching the bottom and flanks of the threads with the contact stylus.⁵⁵ Further, for contact measurements the size and radius of the tip will determine the resolution level due to the inability to penetrate smaller cavities. Some 50 different parameters could be used for characterization of the surface structure where the parameters could be categorized in amplitude parameters, spacing parameters and hybrid parameters depending on the origin and mathematical treatment of the data.⁵⁶ The evaluation could be performed in 2 dimensions (along a line scan) or 3 dimensions (over a surface).

Scanning Electron Microscope (SEM)

The SEM is a microscopy technique where an electron beam is scanned over the sample surface. The electron beam induces a larger depth of focus than a regular light beam and images at very high resolution can be recorded.⁵⁷ The high energetic electron beam induces elastic scattering of the sample electrons, which gives information both from the surface as well as from the underlying bulk material. The analyzed volume is called the interaction volume and its size depends highly on the energy of the incoming beam. A reduction of the beam energy reduces the interaction volume and the depth of focus. SEM analysis can be utilized on all electric conducting samples which can withstand high pressures.⁵⁷ To obtain topographical information from SEM images; 3D-models have to be created. This is achieved by taking two images at the same spot, but with a separating angle, and then put these two images together. It is highly important that the center of both images is at the same spot otherwise a distorted 3D-model is obtained which gives unreliable data.⁵⁸

Methods for bone-implant interface analysis

The histomorphometric part of the study typically evaluates static parameters such as the amount of bone-to-implant contact (BIC), bone area (BA) within the threads of implant, bone density, amount, and type of cellular content, among others. Less often reported but not less valuable than the static measurements, dynamic histomorphometric parameters such as mineral apposition as fluorescent evaluation have also been utilized. Studies concerning the effect of different

surfaces in bone healing kinetics have been successful in indicating relationships between fluorescent evaluation and static parameters like density.^{59,60} Unfortunately, the literature concerning bone healing dynamics around different implant surfaces is not only sparse but also contradictory.^{59,61} Also, comprehensive studies utilizing both static and dynamic histomorphometric parameters along with biomechanical testing are desirable for better characterizing the evaluation of the bone-biomaterial interface around different implant surfaces. This information would decrease the degree of speculation concerning the mechanisms leading to differences in the results.

Biomechanical methods to test the OMI stability

There are several techniques for measuring implant stability and osseointegration, including clinical measurements of cutting resistance during implant placement and removal torque required after osseointegration. Examples are periotest and resonance frequency analysis, clinical non-invasive tests such percussion radiograph, and dental fine tester have been used to evaluate the implant stability.³⁰ Due to the variations in technique application and inter-observer variabilities, these methods have some difficulties to determine the real stability.⁶⁵⁻⁶⁷ Among these, the removal torque test is widely used to evaluate osseointegration potential.^{8, 68-71} Removal torque test is a research method that is used to evaluate the strength of the implant tissue interface in animal models. The removal torque is used to test the mechanical stability of implants because the removal torque is more related to the resistance to the removal moment than the insertion torque.⁷¹ Kim et al analyzed the energy to remove the OMI to the bone; the angular momentum

(Ncm) was calculated integrating the torque by time. The removal angular momentum (RAM) was the integrated torque from 0 seconds to 4 seconds after MRT. The time of MIT was analyzed to compare the insertion patterns between each group.⁴ Sullivan et al proposed that the osseointegration of titanium implants may be tested clinically by the application of a reverse torque.⁷² In this technique, a counter-clockwise torque is applied to an implant up to a level of 20 Ncm. Osseointegrated implants resisted a reverse torque of this value, while failed implants unscrewed, demonstrating fibrous encapsulation. However it might be an invasive method in the animal study as the technique relies on the direct application of shear stresses at the implant-bone interface. The measured parameter is the peak torque necessary to shear the interface between the implant surface and the surrounding bone. Since removal torque is a measurement of the interfacial strength in shear, it is dependent on both the quality of the bond between the implant and the surrounding tissues, as well as on the geometry of the implant.^{73, 74}

III. MATERIALS AND METHODS

Implants

Ninety six titanium orthodontic mini-implants, 64 for the mechanical study and 32 for the histological study (length 6.0 mm, diameter 1.6 mm, Ti-6Al-4V, Dual-Top[®], Jeil medical corporation, Seoul, Korea), consisted machined group of machined surface and RBM group treated with calcium phosphate and HNO₃ (Figure 1).

SEM, scanning interferometer and energy dispersive spectrometer

A topographic evaluation was performed by scanning electron microscopy (JSM-840A, JEOL, Tokyo, Japan) to compare the surface structures between two groups. Two samples of each group were selected randomly and were scanned by Optical Proplier (Wyko NT8000, Veeco, Tucson, AZ, USA) for analyzing the surface roughness such as Ra which is the arithmetic average height of the roughness profile from the midline, Rq which is the root mean square height corresponding to Ra, and Rz which is the maximum peak to valley height in the evaluated area.

Subject preparation

This study was approved by the Seoul National University, Institutional Animal Care and Use Committees (SNU, IACUC 120308-2). Twenty four 3-month old New Zealand White rabbits (mean weight was 3.5 to 4.0 kg) comprised of 16 rabbits for mechanical study and 8 rabbits for histological study.

Surgical procedures

The rabbits were anesthetized with an intravenous injection of Zoletil 50 (7.5 mg/kg) and Rompun 2% (0.15ml/kg). The internal surface of the tibia was further blocked with 0.5 ml of 2% lidocaine. Both tibiae metaphyses were surgically exposed by a scalpel incision to the periosteum and a blunt dissection. One machined and RBM treated OMI were inserted into each tibia using a surgical implant engine (Elcomed SA200C, W&H, Burmoos, Austria) after a pre-drilling (\varnothing 1.0 mm) with the saline irrigation (Figure 2).

Mechanical test for removal torque and removal angular momentum

The orthodontic mini-implants were removed at 2 weeks and 4 weeks after the implantation with the torque recording by the surgical implant engine (Figure 2C), which had rotational speed of 20 rpm. Impdat software (Kea Software GmbH, Poecking, Germany) was used for readout of the recorded torque value. Maximum removal torque (MRT) and removal angular momentum (RAM) which is integrated removal torque during the initial half turn, were evaluated.

Fluorescent bone labeling

Three fluorochromatic dyes (Sigma, St Louis, MO) such as Tetracycline hydrogen chloride (15 mg/kg) at the first day, Calcein (10 mg/kg) at 2 weeks and Alizarin red (30 mg/kg) at 4 weeks after implantation in the day before sacrifice, were injected intramuscularly (Figure 3).

Specimen preparation

Eight rabbits were euthanized for histomorphometric analysis at 4 weeks after implantation. Orthodontic mini-implant specimens with the surrounding tissue were fixed in 4% paraformaldehyde for 48 hours, were dehydrated sequentially in 70%, 90%, 95%, and 100% alcohol, and were embedded in a light-curing resin (Technovit 7200VLC; HeraeusKulzer, Dormagen, Germany). Embedded specimens were sliced and ground into 40 to 50 μm with the Exakt cutting and grinding system (ExaktApparatebau, Nordstedt, Germany) according to the method reported by Donath and Breuner.⁶² Specimens were stained with hematoxylin and eosin (HE).

Histologic and histomorphometric analysis

Each specimen was observed using a fluorescent microscope (Nikon Eclipse TE 200 microscope, Nikon, Toyko, Japan) before staining. The histologic observation was performed using an Olympus BX51 microscope (Olympus Co., Toyko, Japan). The following parameters²³ of the 3 best consecutive screw threads of each screw were measured using image analyzing software (KAPPA, opto-electronics GmbH, Kelines Feld, Germany): (1) the bone-to-implant contact (BIC), the percentage of total bone contact length on the threads of screw and (2) the bone area (BA), the percentage of total bone area within the threads of screw.

Statistical method

Descriptive statistics were utilized to determine the means, standard deviations, ranges and standard error of the individual variables. All the measurements were

statistically evaluated using independent t-test to determine any difference in MRT, RAM, BIC, and BA between machined group and RBM group. A $p < 0.05$ was considered significant.

IV. RESULTS

Topographic evaluation

The scanning electron microscopy analysis demonstrated that surface of the RBM group had rough and irregular pattern, on the other hand the machined specimens showed relatively smooth surface (Figure 4). The RBM surface was reticulated with undermining deformation of metal remaining after the impaction of the resorbable hydroxyapatite material blasted under pressure on the surface of the implant. The surface roughness of the RBM group was significantly rougher than the machined group (Table 1 and Figure 5).

Mechanical analysis

The RBM group showed a significantly higher MRT ($p < 0.01$) and RAM ($p < 0.05$) than machined group at 2 weeks after insertion in the tibia of rabbits (Table 2 and 3). However, at 4 weeks, MRT and RAM of both groups had no significant difference.

Histomorphometric analysis

At 4 weeks after insertion, there was no significant difference in BIC of the machined and RBM group (Table 4). However, the RBM group had significantly higher bone area than machined group ($p < 0.05$)

Histologic findings

In the light microscopic view, new bone was found in both the machined and RBM groups on the lower part of the cortical bone which was contacted to the

OMI. The bone formation was found on the surface of the OMI to the marrow side (Figure 6 A, C). The cortical bone in the RBM group was more than in the machined group (Figure 6 B, D). However, bone remodeling was found in the machined group. On the fluorescent microscopy image, there was more deposition of calcein (2 weeks after implantation) than tetracycline (immediately after implantation) and alizarin red (4 weeks after implantation) in both groups (Figure 6 E, F).

V. DISCUSSION

The bone adaptation on implant surface is important to maintain the stability of dental implants.⁷⁷ It has been reported that the surface treatment can enhance the bone adaptation.²² Previous studies reported that initial removal torque of the implant with surface treatment such as SLA, RBM and anodizing were higher than the implant without surface treatment.⁷⁵⁻⁷⁹ In the present study, at 2 weeks after the implantation, the RBM group showed significantly higher removal torque than the machined group (Table 2). However, there was no statistically significant difference between the two groups at 4 weeks. Even though the machined group had low initial stability, these findings suggest that the stability of machined OMIs might increase during the bone healing process. There was no change in the removal torque of the RBM group during last 2 weeks. Previous studies showed similar results about the removal torque of RBM treated dental implants.^{80, 81}

Histologically, the machined group showed more new bone formation than RBM group at 4 weeks (Figure 6 A, C). The RBM group demonstrated more intact lamella bone than machined group (Figure 6 B, D). In both groups, the calcein could be seen more than other fluorescent dyes; tetracycline and alizarin red (Figure 6 E, F). Calcein area in the machined group was broader than RBM group. These suggested that active bone remodeling has occurred around 2 weeks after implantation and bone remodeling has occurred more in the machined group than in RBM group. Therefore, it could be suggested that the removal torque at 2 weeks after implantation in the machined group was lower than in RBM group because an active bone remodeling such as bone resorption might be initiated during the 2 weeks after implantation in the machined group. The new bone formation might

enhance the stability of the machined group by 4 weeks after implantation. Therefore, the removal torque of the machined group had increased in 4 weeks after implantation and it became not significantly different from that of RBM group.

The result of the present study indicated that the surface treatment such as RBM could attain higher initial stability of OMI, however, no enhancement of bone remodeling could be expected by time.³¹ Although the increased surface area of RBM treated OMIs could be considered to improve the stability of mini-implant by accelerating the bone remodeling. The results of this study showed that the effect of the RBM treatment seemed to reduce the resorption of the lamella bone. This might mean that the RBM surface treatment could induce the bone osseointegration to the OMI surface without the extensive bone resorption and the active bone remodeling.

Brunette reported that the implant surface roughness can affect cell function, matrix deposition and mineralization.⁸² Also, the bone growth into the reticulated structure on the implant surface could have the mechanical interlocking between the implant and the bone, to improve bone-implant interface.^{83, 84} In present study, the Ra of RBM group was 1.54 μm which is close to the optimal surface roughness (Ra 1.0 to 2.0 μm) for the retention in the bone that was demonstrated by Wennerberg and Albrektsson.⁸⁵ The RBM group in present study might have initial bone induction on the OMI surface contacting the bone without broad bone resorption at the initial stage. In the present study, RBM group, there was less new bone remodeling and new bone formation at bone contact on the OMI. This might

suggest that RBM surface treatment might not enhance widespread new bone formation although it could provide a good stability of OMI from the initial stage.

In the histomorphometric analysis, BIC results of both groups were similar to each other. However, machined group had lower BA than RBM group because the new bone formation has the bone cone structures and it replaces the woven bone with the new lamella bone. It might suggest that the machined surface could have a potential to induce bone remodeling. But it might have a reduced initial stability. This was supported by the fluorescent analyzing results which showed that there was active bone formation at 2 weeks after the implantation in the machined group and the old lamella bone was smaller to RBM group because the bone resorption might occur to replace the lamella bone. This was in agreement with Grassi et al who suggested that stability of the OMI with the machined surface might decrease suddenly at the first stage when the woven bone formation followed the bone resorption.⁸⁶

This might suggest that the machined OMIs may have higher possibility of failure especially in the thin bone, because there might be a broad bone resorption around the OMIs at the initial stage. However, the stability of the machined surface implant could be enhanced by the active bone remodeling and the bone apposition if the OMI would survive the initial bone resorption and the remodeling stage. The RBM surface treatment could improve the initial stability of the mini-implant although it might not enhance the stability with time. This effect of the RBM surface treatment was similar to that of SAE (sandblasted and acid-etched) surface treatment results in Mo's study.⁸⁷

The further studies about histological changes around the OMI at each stage during long healing are recommended to help understanding the stability of the OMI.

VI. CONCLUSIONS

Orthodontic mini-implants of the RBM group had a significantly higher MRT than machined group at 2 weeks after the implantation. However, there was no significant difference of MRT and BIC. At 4 weeks after the implantation, BA was higher in the RBM group than machined group. Machined group showed more active bone resorption and broader new bone formation than RBM group during 2 weeks after implantation.

These findings mean that the machined surface OMIs are more likely to fail at the initial stage than RBM surface treated OMIs, by the active bone remodeling. And the RBM surface treatment can support the initial stability of the OMI although it might not suddenly increase the stability over time.

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FIGURES AND TABLES

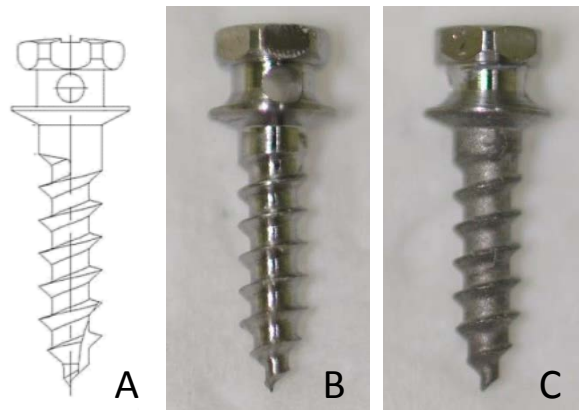


Figure 1. Images of the orthodontic mini-implants.

(A) Design and type of the mini-implant.

(B) Machined group. (C) RBM group.

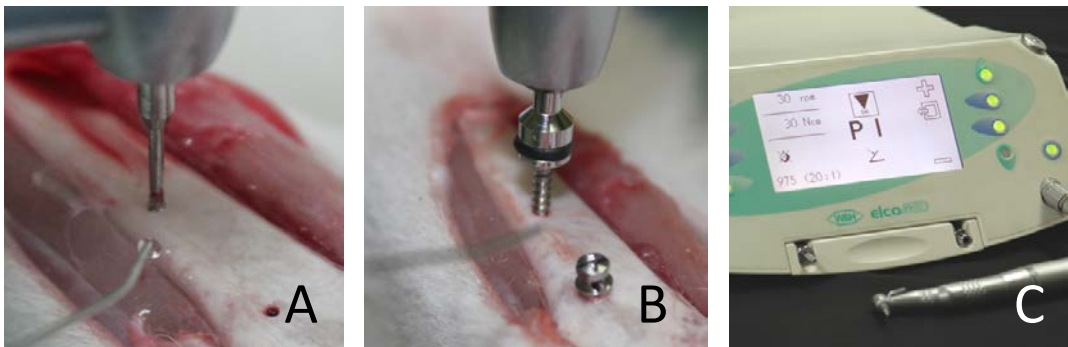


Figure 2. Placement procedure of orthodontic mini-implant and equipment.

(A) Pre-drilling with saline irrigation. (B) Insertion of mini-implant with

surgical engine. (C) Surgical engine which can measure and record the removal torque.

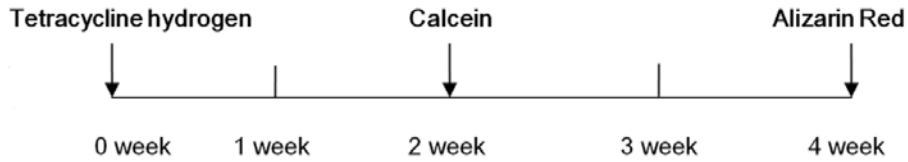


Figure 3. Time table for the flouorochromatic dye.

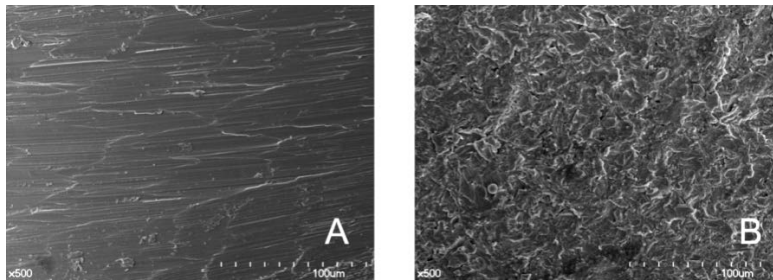


Figure 4. Scanning electron microscopic images of mini-implant surfaces (A) Machined group (x500). (B) RBM group (x500).

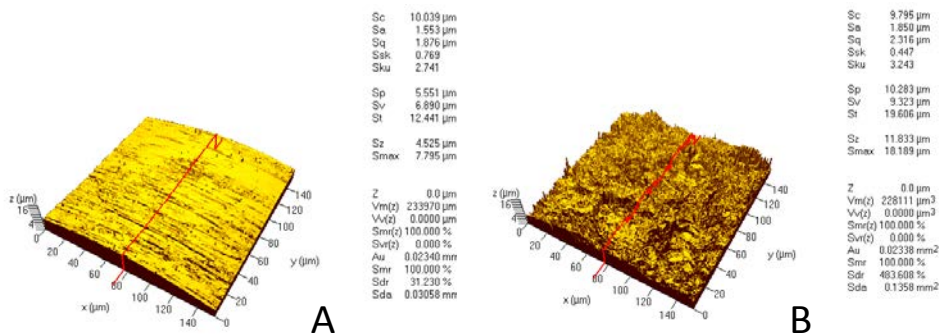


Figure 5. Three dimensional roughness of the mini-implant surfaces. (A) Machined group. (B) RBM group.

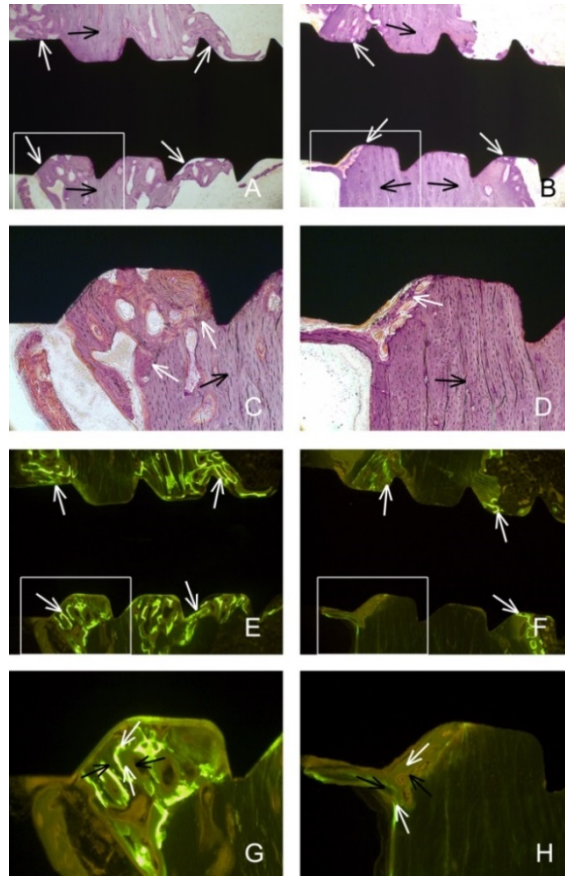


Figure 6. Histologic specimens of machined group (A, C, E and G) and RBM group (B, D, F and H). H-E staining microscopic views are A to D and fluorescence microscopic views are E to H. (A) In machined group, a broad new bone remodeling (white arrows) surrounded a thin cortical bone (black arrows) (x4). (B) In RBM group, a broad cortical bone (black arrows) was between a thin new bone remodeling (white arrows) (x4). (C) A magnified view of white box in figure (A). New bone (white arrows) occupied in broadly resorbed cortical bone (black arrow) (x10). (D) A magnified view of white box in figure (B). Cortical bone (black arrow) was resorbed in a thin surface margin and a small new bone (white arrow) was in there (x10) (E) Fluorescence view of figure (A). Green color (calcein, white arrows) was found broadly in the margin of the mini-implant (x4). (F) Fluorescence view of figure (B). There were few fluorescence colors (white arrows) (x4). (G) and (H) A magnified view of white box in figure (E) and (F). There was a bone remodeling after bone resorption. There was old bone (left black arrow) and new bone at 2 weeks (calcein, upper white arrow), between 2 weeks and 4 weeks (lower white arrow) and at 4 weeks (alizarin red, right black arrow).

Table 1. Surface roughness of machined and RBM orthodontic mini-implants in topographic evaluation.

Time	Surface roughness (μm)			
	Machined group (n=3)		RBM group (n=3)	
	Mean	SD	Mean	SD
R _a	0.49	0.06	1.54	0.28
R _q	0.58	0.86	1.88	0.65
R _z	1.57	0.21	5.14	0.54

SD - Standard Deviation

RBM - Resorbable Blasting Media

R_a - arithmetic mean of the departures of the roughness profile from the mean line

R_q - root mean square parameter corresponding to R_a

R_z - maximum peak to valley height in the evaluation area

Table 2. Maximum removal torque of machined and RBM groups at 2 and 4 weeks after the implantation.

Time	MRT (Ncm)						<i>p</i> value*
	Machined group			RBM group			
	n	Mean	SD	n	Mean	SD	
2 weeks	16	5.45	1.35	16	7.06	1.78	0.007 [†]
4 weeks	16	6.41	2.30	16	7.08	3.12	0.530

SD - Standard Deviation

RBM - Resorbable Blasting Media

MRT - Maximum Removal Torque

* Independent t-test; [†]*P* < .01

Table 3. Removal angular momentum of machined and RBM groups at 2 and 4 weeks after the implantation.

Time	RAM (Ncm)						p value*
	Machined group			RBM group			
	n	Mean	SD	n	Mean	SD	
2 weeks	16	6.45	1.67	16	7.90	1.86	0.026 [†]
4 weeks	16	13.62	5.07	16	12.52	2.93	0.489

SD - Standard Deviation

RBM - Resorbable Blasting Media

RAM - Removal Angular Momentum is the integrated removal torque as the time till half turn

* Independent t-test; [†] $P < .05$

Table 4. Histomorphometric analysis of machined and RBM groups in non-calcification specimens.

Measurement	Machined group (n=16)		RBM group (n=16)		p value*
	Mean	SD	Mean	SD	
BIC (%)	71.86	10.84	69.96	11.30	0.631
BA (%)	67.99	10.68	77.30	11.82	0.026 [†]

SD - Standard Deviation

RBM - Resorbable Blasting Media

BIC – Bone - to - Implant Contact

BA - Bone Area

* Independent t-test; [†] $P < .05$

교정용 미니 임플란트의 흡수성 분사 처리가 제거 토크에 미치는 영향 및 조직학적 평가

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오돈투야

연구목적

본 연구는 흡수성 분사 처리가 교정용 미니 임플란트의 안정성에 미치는 영향을 평가하기 위하여 제거 토크, 조직형태학적인 비교 및 형광조직학적 분석을 실시하였다.

연구방법

총 96 개의 교정용 미니 임플란트 (길이 6.0mm, 직경 1.6mm)를 표면처리하지 않은 군 (기계가공군)과, CaP 와 NH_4OH 로 표면을 분사처리한 군(흡수성 분사처리군)으로 나누어 토끼 경골에 식립하였으며, 식립 후 1일, 2주, 4주에 fluorescent dye를 주입하였다. 식립 후 2주 및 4주에 Maximum removal torque (MRT) 및 Removal angular momentum (RAM)을 측정하였다. 식립 후 4 주에 Bone-to-implant contact (BIC) 과 Bone area (BA)를 평가하였다. 또한 각 군의 미니 임플란트의 표면거칠기를 Optical Profilier (Wyko NT 8000, Veeco, Tucson, AZ, USA)로 분석하였다.

결과

1. 흡수성 분사처리군의 표면거칠기는 기계가공군보다 높았다.
2. 식립 후 2 주에 흡수성 분사처리군의 MRT 및 RAM 이 기계가공군보다 유의하게 높았다.
3. 식립 후 2 주에, 기계가공군에서 보다 활발한 골흡수 및 신생골 형성 등의 골리모델링이 나타났다.
4. 식립 후 4 주에, 두 군간에 BIC 에서 유의한 차이가 없었으나, BA 는 흡수성 분사처리군에서 기계가공군보다 유의성있게 높게 나타났다.

결론

기계가공군은 식립 직후, 왕성한 골 리모델링으로 인하여 초기 안정성이 취약할 수가 있지만, 흡수성 분사처리를 할 경우 식립 직후에 광범위한골흡수 등이 없어 안정적인 골 접촉을 유지함으로 인하여 초기 안정성에 더 도움을 줄 수 있다고 보인다.

주요어: 미니 임플란트, 표면처리, 흡수성 분사처리, 제거토크, 조직학적 평가

학 번: 2010-31374