Biological evaluation of precipitation hardened anodic oxidation orthodontic miniscrew in the beagle dog

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Biological evaluation of precipitation hardened anodic oxidation orthodontic miniscrew in the beagle dog

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This certifies that the dissertation of

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Table of contents

List of tables

List of figures

ABSTRACT

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This study presented was designed to analyze osseointegration potential and biological stability of orthodontic miniscrews with precipitation hardened anodic oxidized (PHAO) surface when compared with machined surface(MS) miniscrew. A total of 48 miniscrews were placed into the buccal alveolar bone of the mandible in 6 male beagle dogs. Comparison was made between precipitation hardened anodic oxidized surface miniscrew and machined

surface miniscrews (Biomaterials Korea, Seoul, Korea). Maximum insertion torque (MIT) was measured using torque sensor (Mark-10, MGT 50, US) and initial mobility (Periotest, Simens, Germany) was recorded during installation. The force applied groups were reciprocally loaded by Ni-Ti coil spring (250~300 gm) at 3 and 12 weeks of loading period. Bone volume(BV) and bone implant contact(BIC) were also measured in histological section for each loading period. The obtained results were as follows:

Machined surface(MS) miniscrews showed a higher MIT value of 21.68 Ncm compared with precipitation hardened anodic oxidized (PHAO) miniscrews by 21.53 Ncm, which showed no statistical difference ($P>0.05$). And the initial mobility depending on the types of miniscrew was not statistically different between surface types($P>0.05$).

At 3 weeks of loading the BIC of PHAO showed higher values of 65.4% than the values of MS miniscrews 52.9% respectively, and decreased by 61.7% and 44.5% respectively at 12 weeks of loading. And there was statistical difference between experimental groups at both loading period($P<0.05$).

At 3 weeks of loading, the BV was higher in PHAO(46.4 %) than MS miniscrews(36. 3%) showing statistical difference ($P<0.05$). At 12 weeks of loading, the BV of PHAO was

50.1% and MS miniscrews was 46.5%, but there was no statistical difference between two groups (P>0.05).

These results showed that the BIC and BV of PHAO has a higher osseointegration potential than machined surface miniscrews at 3 and 12 weeks loading period. The PHAO's initial stability might be superior to the MS miniscrews. However, the further investigation is required to compare with SLA and other surface modification miniscrews using the measuring the insertion and removal torque, mobility, success rate and so on.

Key words: anodic oxidation, miniscrew, insertion torque, bone implant contact, bone volume.

Biological evaluation of precipitation hardened anodic oxidation orthodontic miniscrew in the beagle dog

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I. INTRODUCTION

Obtaining an appropriate anchorage is one of the most important factors to show dental treatment results. Clinical applications of orthodontic miniscrews have been actively expanded because of their comparative flexibility in selecting location of placement, simple procedure, orthodontic effects occurring immediately after placement, and low cost. Introduction of miniscrews anchorage has become a major breakthrough in orthodontic treatments (Park and Kwon, 2004; Park, 2006a).

The clinical success rate of orthodontic miniscrews has been reported to be more than 90% which is a remarkable improvement over the years, and the dislocation rate reaches 10-15% (Costa et al, 1998; Cheng et al, 2004; Tseng et al, 2006; Kim et al, 2008). The success rate of miniscrew is still lower than that of bone implants and accordingly, prognosis may be unfavorable. According to the study on stability of orthodontic miniscrews conducted by Liou et al (2004), orthodontic miniscrews are stable enough as an anchorage for orthodontic tooth movement, but not absolutely stable enough during orthodontic treatments compared with endossous dental implants.

With regard to the factors associated with stability of orthodontic miniscrews, Lim et al(2009) suggested surgeon factor (number of miniscrews as a clinical experience), patient factors (gender, age, maxilla or mandible, location of placement, tissue mobility in the placed area), miniscrews factors (length, diameter, shape), and reported no significant relations of the above factors with initial stability of miniscrews and accordingly, the initial stability could not be anticipated or secured (Lim et al, 2009). Cheng et al (2004) reported miniscrews placed into the non-keratinized mucous membrane of the mandibular posterior molars area showed high failure rate. Miyawaki et al (2003) reported that stability of miniscrews is affected by age of patient, sex, skeletal shape, fascicular condition, periodontitis, presence of impaired temporomandibular joint, mandibular plane angle, location of placement and presence of inflammation. Buchter et al (2005) and Joes et al (2005) reported that duration and strength of loading can affect on the stability of miniscrews.

Being different from implants used after osseointegration, orthodontic miniscrews sustain initial loads based on the stability from the mechanical sustainability between the miniscrews and bone (Umemori et al, 1999)and consequently, initial stability of miniscrews is very important for early loading of orthodontic force in orthodontic treatments. Initial stability of orthodontic miniscrews is an important factor which can affect on the success of miniscrews procedure (Huja et al, 2005) and accordingly, development of orthodontic miniscrews was initially focused on stability in placement and convenience of procedure, but bone adhesion ability and stability have become more interested in. In an attempt to enhance initial stability of miniscrews, cone-shaped miniscrews were developed to enhance initial fixation by inducing pressure on the cortical bone layer (Motoyosi et al, 2006; Cha et al, 2008), and mechanical improvements such as adding screw threads were also tried.

Since 1990s, studies on the surface treatment of miniscrews to increase bone adhesion, minimize bone absorption around the miniscrews, and enhance compatibility and bonding with the surrounding tissues have been conducted. Oh et al (2006) reported that sandblasted, large-grit and acid-etched (SLA) mini-implants show significantly higher removal torque than smooth mini-implants, and induce more bone bonding to resist against more orthodontic force. Ko et al (2009) reported that anodic oxidation and Ca-P coating could enhance stability but these methods could not be thought to be superior to the conventional SLA methods in spite of enhanced stability and bonding force with surrounding bones. In addition, Habig et al (1990) introduced plasma ion planting method which can deposit thick coating, and was widely used for corrosion and abrasion resistance. Using the ion planting method, they reported enhanced abrasion resistance, color fastness and mechanical features through the experiments of coating TiN on dental metals.

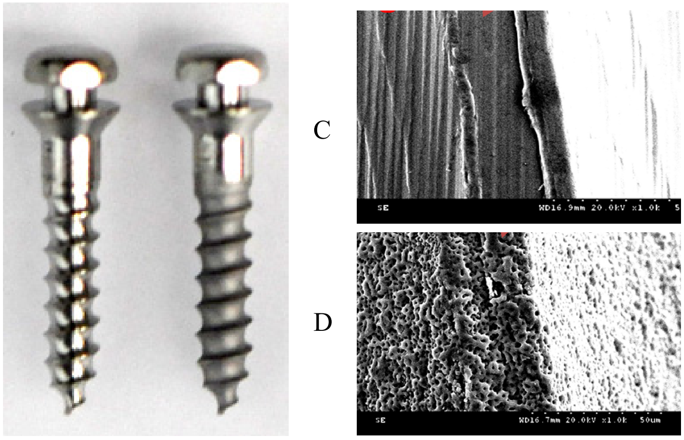
As one of the methods to modify surface of implants, the electrochemical method is comparatively simple and economical, which include anodic or cathodic oxidation film treatments. The method of anodic oxidation requires high voltage with electrolytes to prepare an oxide layer on the surface of implants. Consequently, a rough surface with many pores is formed to enhance bone bonding, and emission of metal ions is restrained to increase surface resistance (Wisbey et al, 1991; Kim et al, 2008). The cathodic HA coating can also be obtained from electrolytes containing calcium-phosphate at high temperature through cathodic deposition, and various thicknesses of coating and crystallinity as well as forms of substrate can be decided (Ban et al, 1998).

Among surface treatment methods, the anodic oxidation method has simpler process than SLA and accordingly, has higher applicability than SLA. The precipitation hardened anodic oxidized (PHAO) method is to form materials promoting reactions with bone cells together with basic anodic oxidation to improve bone adhesion features. In the present study, PHAO orthodontic miniscrews and machined surface(MS) miniscrews were placed into the adult dog to measure maximum insertion torque. And tissue specimen analysis was conducted to assess osseointegration potential by measuring bone implant contact (BIC) and bone volume (BV) of PHAO orthodontic miniscrews and then, to assess initial stability and clinical applicability of PHAO orthodontic miniscrews compared to MS miniscrew.

II. MATERIAL AND METHODS

1. Experimental animals and material

For this study, miniscrews were placed in 6 beagle dogs (age, 1 year; weight, 10-13 kg). Their purchase, selection, management, and experimental procedures were carried out according to prescribed conditions of the institutional review board, the Animal Experiment Committee of Yonsei Hospital, Seoul, Korea. A self-drilling type of miniscrew, 1.5 mm in diameter and 7 mm in length, was used (Diameter of anodic oxidized miniscrews was greater than machined surface miniscrews about 30-40μm). Both 24 machined surface and 24 anodic oxidized surface miniscrews (Biomaterials Korea, Seoul, Korea) were selected; totally 48 screws were used. The roughness of the anodic oxide layers of titanium obtained from electrolyte containing calcium acetate and β-calcium glycerophosphate at 250 V (Fig. 1.).



C

D

A B

Fig. 1.Image of miniscrews tested on this study ; A self-drilling type of miniscrew. A, a machined surface(MS)miniscrew; B, a aprecipitation hardened anodic oxidized(PHAO)miniscrew; C, scanned image of MS; D, scanned image of PHAO ×1000.

2. Methods

A. Implantation and removal of miniscrews

The animals were injected subcutaneously with 0.05 mg/kg of atropine followed by an intravenous injection of rompun, 2 mg/kg, and ketamine, 10 mg/kg, to induce general anesthesia. The anesthesia was maintained with 2% enflurane, and each animal’s temperature was maintained with a heating pad and an electrocardiogram and monitored. When placing the miniscrew, 2% hydrochloric acid lidocaine containing 1:100,000 epinephrine was infiltrated into the placement area. Before placement, gingival incision was made under saline solution irrigation, and complete placement of the screw into the alveolar bone was confirmed. Sites selected were between the roots of the second, fourth premolar for the anodic oxidized miniscrew and the third premolar, first molar for the machined surface miniscrew in the same quadrant mandible. Screw placement was performed manually with 90 angulations to gingival surface in consideration of the buccolingual width of alveolar bone for each experiment. In all miniscrews, an orthodontic force of 250-300 gm was applied with a NiTi coil spring engaged reciprocally from a MS miniscrew to PHAO miniscrew immediately after the placement. Implantation of miniscrews was inferior periosteum to prevent gingival inflammation around the miniscrews (Fig. 2). The orthodontic force was loaded during 3 weeks and 12 weeks for each miniscrews. After 12 weeks, the 3 weeks groups and 12 weeks groups were removed simultaneously.

The placement torque was the highest (in newtons per square centimeter) when the miniscrew was placed completely into the bone. The highest insertion torque was measured during a quarter initial turn by using a torque sensor (MGT50, Mark-10 Co, New York, NY). Screw initial mobility was measured twice on each miniscrew by using a Periotest® (Simens AG, Bensheim, Germany) after insertion. The sleeve of the handpiece of the periotest was positioned with 1 to 2 mm from the screw head perpendicularly. The average of 2 measurements for a miniscrew was recorded as the mobility value.

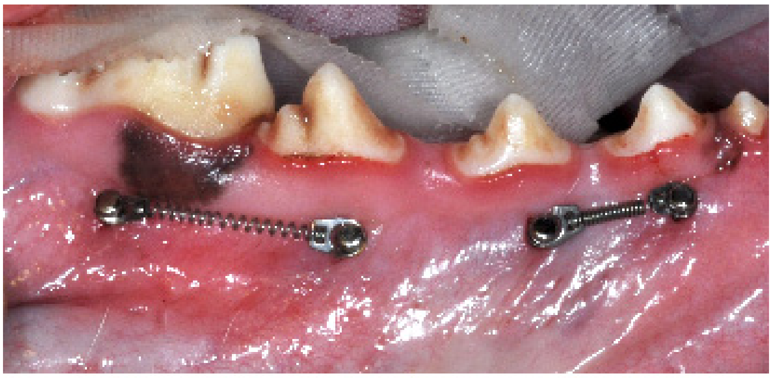


Fig. 2. Implantation sites of orthodontic miniscrews. An orthodontic force was loaded reciprocally between an anodic oxidized miniscrew and a machined surface miniscrew. The force-applied groups were reciprocally loaded by Ni-Ti coil spring (250-300 gm.).

B. Separation of miniscrews from specimen

12 weeks after miniscrew implantation, the beagle dogs were sacrificed, and 2.0 cm x 2.0 cm bone fragments with miniscrews were collected. The bone fragments were decalcified in Calci Clear-Rapid™ (National Diagnostics, Atlanta, USA) and fixed with 10% formalin and neutral PH 7.4 after 4 weeks decalcification. Demineralized fragments were cut in half using the blade parallel to the miniscrew axis.

C. Making the tissue slide

The tissue block was fixed in the formalin solution for one month. After tissue fixation, we dehydrated the specimen with high density alcohol during 14 days, embedded with polymethylmethacrylate and cured in a vacuum. We decalcified specimen with 100-110 μm thickness using the hard tissue grinding system and conducted H-E stain.

D. Histological analysis

We used Photographs of histological sections under optical microscpe by 100 magnification and saved as BMP file. Bone-implant contact(BIC) and bone volume(BV) in the ROI were measured with Image-Pro Version 3.0 (Cybernetics Media,U.S.A.) within the range of 800 μm miniscrew-bone interface (Fig. 3).

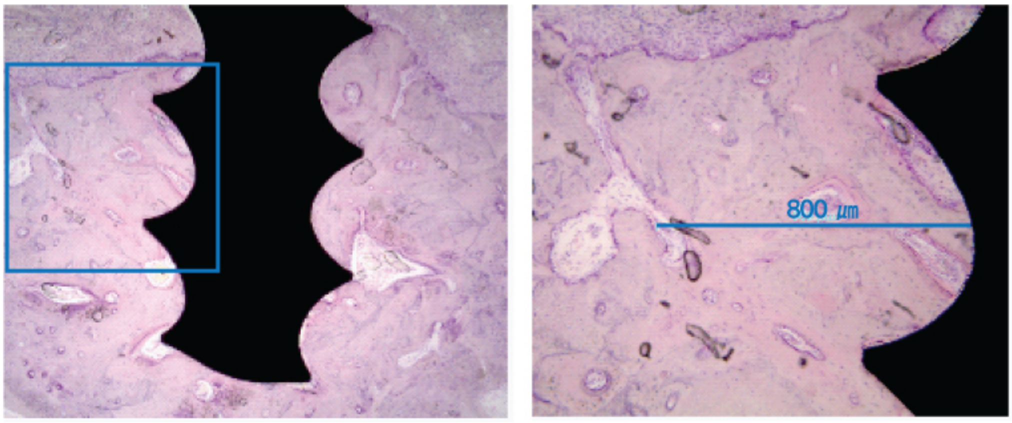


Fig. 3. Histologic analysis for bone-implant contact and bone volume. Bone implant contact (BIC) and bone volume (BV) was measured within the range of 800 μm from miniscrew-bone interface (Left. ×50, Right ×100).

E. Statistical analysis

For statistical analysis, the SPSS 15.0 program (SPSS Inc., Illinois, USA) was used. Results of the quantitative analysis were expressed as median and 95% confidence interval (CI) for the median. In the analyzing of insertion torque and mobility of PHAO and MS miniscrew, we used independent *t*-test. The Mann-Whitney U test was used to identify significant differences between the BIC, BV of PHAO and those of MS miniscrews. *P*-values less than 0.05 were regarded as statistically significant.

III. RESULTS

1. Success rate of miniscrew

The overall success rate was 100% for both types of miniscrew (48 of 48) without failure.

2. Measurement of insertion torque and mobility

Machined surface(MS) miniscrews showed a higher MIT value of 21.68 N cm compared with precipitation hardened anodic oxidized (PHAO) miniscrews by 21.53N cm. But, there was no significant difference (P>0.05) (Fig. 4, Table 1).

Table 1. Comparison of periotest value(PTV) after insertion and maximum insertion torque between MS and PHAO groups.

Variable	Insertion torque (Ncm)		Initial mobility (PTV)	
	Mean	SD	Mean	SD
MS miniscrew	21.68	3.56	-7.63	0.26
PHAO miniscrew	21.53	6.05	-7.83	0.30

MS, machined surface miniscrew; PHAO, precipitation hardened anodic oxidized surface miniscrew; PTV, Periotest value; SD, standard deviation; PTV with -8 to +9 indicates clinically firm teeth or implant is well osteointegrated, PTV over +10 indicates implant is not or not sufficiently osteointegrated(Schulte and Lukas, 1993).

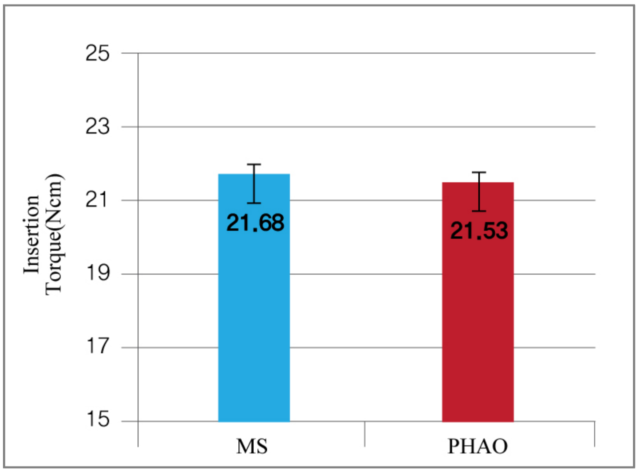


Fig. 4. The insertion torque(Ncm) depending on the types of miniscrew.No significant difference was between surface types by independent *t*-test(*P*>0.05). MS, machined surface miniscrew, PHAO, precipitation hardened anodic oxidized surface miniscrew.

The initial mobility (Ncm) depending on the types of miniscrew, no significant difference was between surface types(*P*>0.05) (Fig. 5, Table 1).

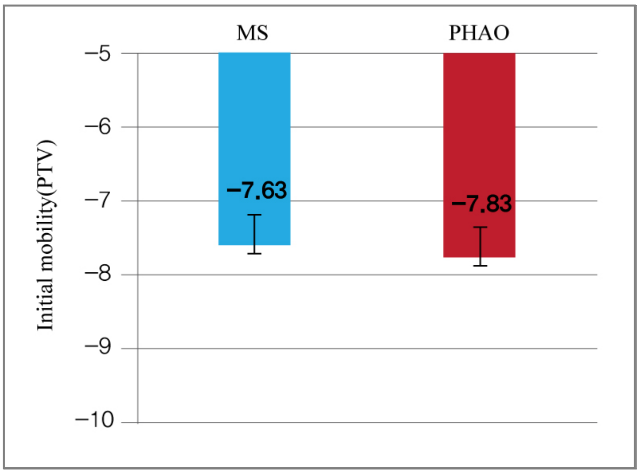


Fig.5. The initial mobility (PTV) depending on the types of miniscrew. No significant difference was between surface types by independent *t*-test(*P*>0.05).

3. Bone implant contact(BIC)

The BIC was decreased in 12 weeks group compared to 3 weeks group at both experimental groups. At 3 weeks of loading the BIC of PHAO showed higher values of 65.4% than the values of MS miniscrews 52.9% respectively, and decreased by 61.7% and 44.5% respectively at 12 weeks of loading. And there was significant difference between experimental groups at both loading period)(P<0.05) (Fig. 6, 7, 8, Table 2).

Table 2. Comparison of bone implant contact(BIC) and the bone volume(BV) between MS and PHAO.

	BIC(%)					BV(%)				
	MS		PHAO		Sig.	MS		PHAO		Sig.
Loading time (wk)	Mean	SE	Mean	SE		Mean	SE	Mean	SE	
3	52.9	3.5	65.4	4.0	*	36.3	3.3	46.4	2.8	*
12	44.5	2.6	61.7	2.2	*	46.5	2.9	50.1	5.3	NS

PHAO, precipitation hardened anodic oxidized surface miniscrew; SE, standard error of mean; NS, not significant; Sig, significance of groups and periods by Mann-Whitney U test.

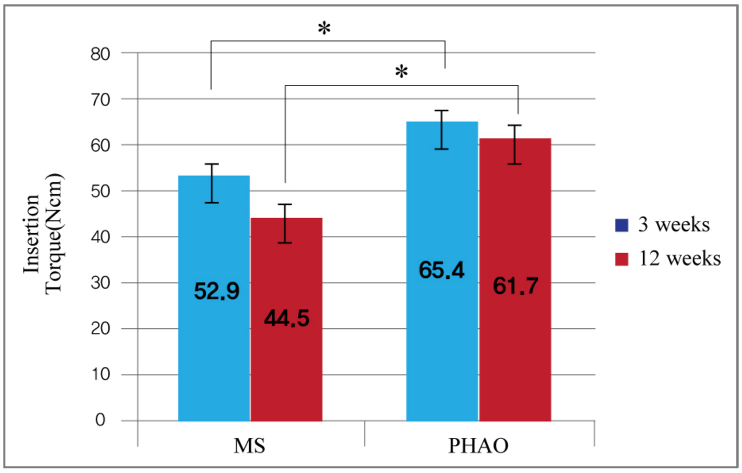
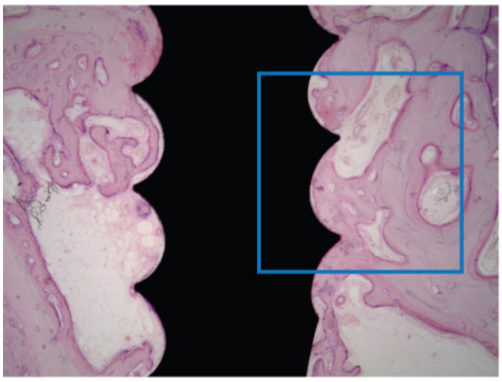
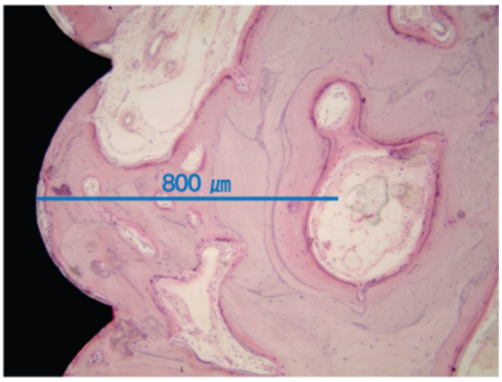


Fig. 6. Bone Implant contact (%) of each screw type for loading periods. Significant difference was between surface types and loading period by Mann-Whitney U test (*P*<0.05).



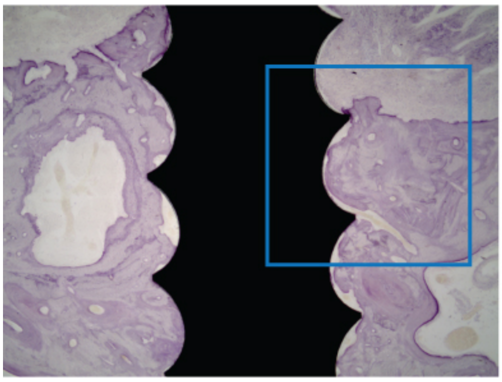


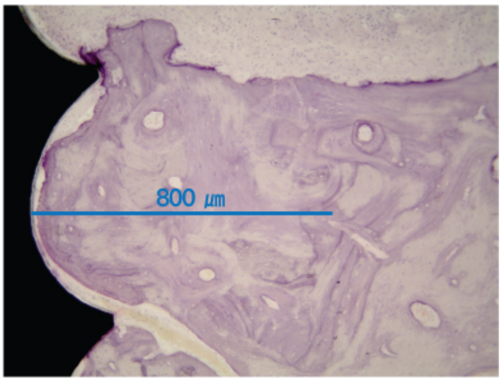
Smooth surface miniscrew

(3 weeks) ×50

Smooth surface miniscrew

(3 weeks) ×100





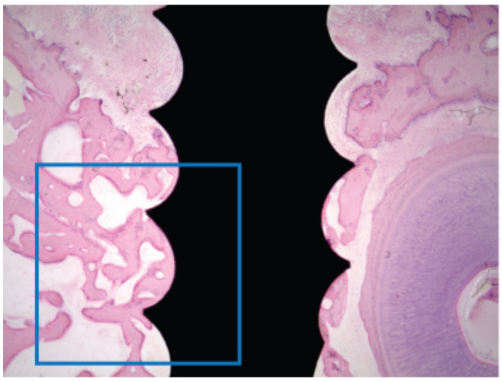
Smooth surface miniscrew

(12 weeks)

Smooth surface miniscrew

(12 weeks)

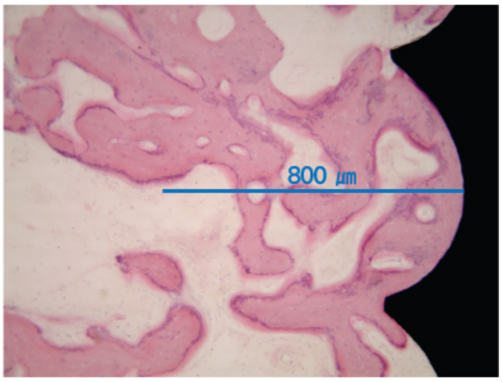
Fig. 7. Comparison of machined surface miniscrew according to loading periods. H-E staining (Left×50, Right ×100). BIC was decreased by loading period, but bone volume was increased.



Precipitation hardened anodic

oxidized miniscrew

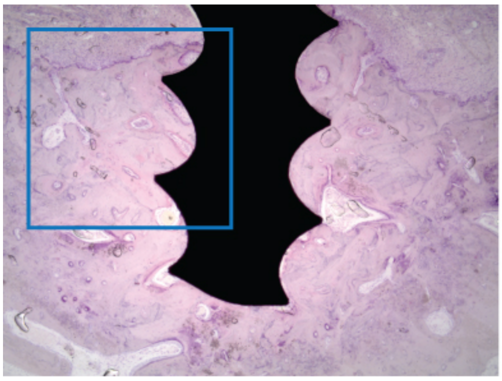
(3 weeks) ×50



Precipitation hardened anodic

oxidized miniscrew

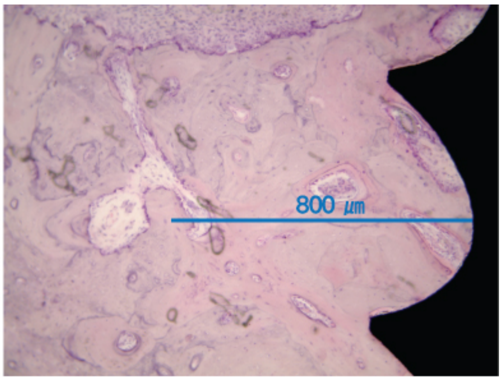
(3 weeks) ×100



Precipitation hardened anodic

oxidized miniscrew

(12 weeks)



Precipitation hardened anodic

oxidized miniscrew

(12 weeks)

Fig. 8. Comparison of precipitation hardened anodic oxidized miniscrew according to loading periods. H-E staining(Left×50, Right×100). BV was increased by loading period.

4. Bone volume(BV)

BV was increased by loading period at both experimental groups. At 3 weeks of loading, the BV was higher in PHAO(46.4 %) than MS miniscrews(36. 3%). And, there was significant difference (P<0.05). At 12 weeks of loading, the BV of PHAO was 50.1% and MS miniscrews was 46.5%, but there was no significant difference between two groups (P>0.05) (Fig. 7, 8,9, Table 2).

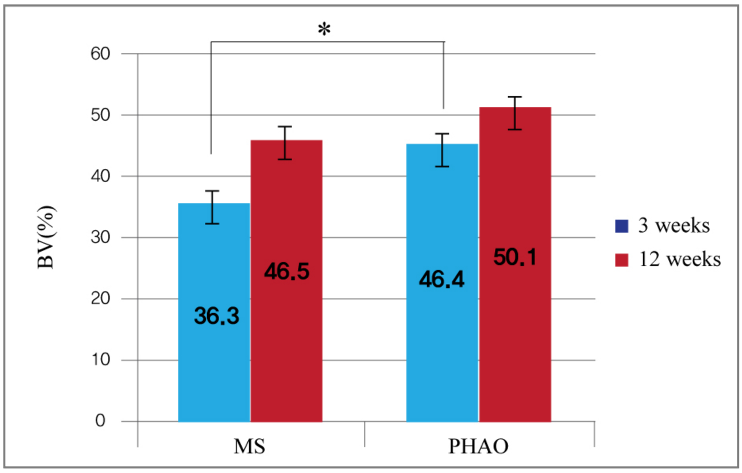


Fig. 9. Bone Volume(%) of each screw type for loading periods. At 3,12 weeks of loading, the BV was higher in PHAO miniscrew than MS miniscrew, and there was no significant difference between two groups at 12 weeks loading (P<0.05).

IV. DISCUSSION

In order to assess biological stability and clinical applicability of PHAO orthodontic miniscrews which is one of the methods of treating surface of miniscrews, miniscrews whose surfaces were not treated were compared through direct measuring methods including MIT, mobility and success rate of miniscrews, and indirect methods using BIC and BV according to the time of applying orthodontic force.

Upon introduction of miniscrews anchorage, miniscrews were initially developed with emphasis on placement stability and easy procedure based on the merits of comparatively flexible placement area, simple procedure and immediate application of orthodontic force right after placement and low cost (Park et al Kwon, 2004; Park, 2006) but gradually, emphasis was moved on to bone bonding ability and stability. Being different from prosthetic implants which are used after bone bonding, orthodontic miniscrews have been understood to be loaded with initial orthodontic forces based on the stability from the mechanical sustainability between the miniscrews and bone (Umemori et al, 1999; Maino BG et al, 2003), The initial stability in orthodontic miniscrews is an important factor affecting success of miniscrews procedure, and the thicker the cortical bone into which miniscrews are placed, the higher pull-out strength is shown (Huja et al, 2005). Park et al (2006) reported that the presence of inflammation around the miniscrews is the most important factor affecting stability of the miniscrews. Albrektsson et al (1981) suggested important factors for ideal bonding of implants with surrounding bones, such as biocompatibility, design, surface quality, condition of host tissues, surgical technique and loading condition.

Among these factors, initial fixation could be enhanced by modifying design of miniscrews, such as cone-shaped miniscrews which could induce pressure force into the cortical bone layer (Cha et al, 2008, Motoyosi et al, 2006,). Cha et al (2008) reported that the cone-shaped miniscrews initiate modifications in the surrounding bones inducing close contacts with bones to reduce mobility, and to be favorable for the initial anchorage. In addition, the cone-shaped miniscrews are advantageous in terms of initial stability compared with the cylindrical structure by virtue of the significantly increased initial MIT. Mechanical improvements such as introducing screw threads were also tried. Upon comparing and measuring MIT, removal torque and BIC after placing self-tapping type miniscrews and self-drilling type miniscrews, Chen (2008) reported that the self-drilling type miniscrews showed higher stability than the latter self-tapping type miniscrews.

However, studies on stability of miniscrews were conducted with non-surface treated miniscrews because orthodontic miniscrews were thought to be maintained by a mechanical bonding (Maino et al, 2003). According to studies on comparing the conventional surface-treated implants for dental restoration and non-surface treated implants, the surface-treated experimental group showed high bonding strengths and bone bonding (Lim et al, 2001). Studies on surface treatment of miniscrews such as enhancing bone adhesion, minimizing bone absorption around the implants, and improving compatibility and bonding force with surrounding soft tissues were also actively conducted. Surface treatments of implants such as titanium plasma spray, acid pickling, acid etching, sandblasting have been tried. Based on the results that these treatments could improve bone adhesion of implants, there is a report that sandblasted large grit and acid etched (SLA) implants improved bone adhesion ability (Jeon et al, 2008; Klokkevold et al, 2001). Oh et al (2006) reported that the SLA mini-implants showed higher removal torque, and induced more bone bonding compared with the smooth surface mini-implants, which were statistically significant and consequently, could resist against the stronger orthodontic forces, Kim et al (2008) also reported that SLA mini-implants showed higher removal torque and accordingly, improve stability against large and dynamic orthodontic forces. Meanwhile, through the experiments on coating dental metals with TiN, Habig et al (1990) reported that the plasma ion planting method could increase abrasion resistance, color fastness and mechanical properties thanks to enhanced thickness of coating.

Chemical changes in implants surface accompany deposition of hydroxyapatite and combination of calcium ions, phosphorus and fluorite. SLA treatments can modify shape and energy of the surface, and roughness and shape can be adjusted by acid solution and oxidation. Among many methods changing surface, the electrochemical method is simple and economical. The method of anodic oxidation requires high voltage with electrolytes to prepare an oxide layer on the surface of implants. Consequently, a rough surface (0.60~1.00 μm) with many pores (0.5~2.0 μm of diameter) is formed to enhance bone bonding, and emission of metal ions and free radicals is restrained to increase surface resistance. Elias et al (2008) reported that implants with oxidated surface have higher removal torque than regular implants by 45.6%. Cathodic HA costing can be obtained through cathodic deposition in electrolytes containing calcium-phosphate at high temperature, and this method has advantage of diversely deciding thickness and crystallinity of the coated layer (Ban et al, 1998).

PHAO method is to form materials promoting reactions with bone cells together with basic anodic oxidation to improve bone adhesion features. The anodic oxidation film can have flat, drencher or non-fixed forms (Kim et al, 2009), and the thickness of oxidated coating could range from several nanometers of the natural thickness to tens of nanometers. These treatments of anodic oxidation film are conducted using acidic or non-acidic electrolytes. As acidic electrolytes, sulfuric acid is widely used in addition to hydrogen peroxide and hydrochloric acid and phosphoric acid (Liang et al, 2003), while non-acidic electrolytes may include sodium phosphate of ethylene glycol, isopropyl phosphate, ammonium pentaborate, calcium acetate and calcium glycerophosphate forming TiO_2 oxidated coating on the surface of implants (Zhu et al, 2001).

According to the present study, the success rates of both groups of PHAO miniscrews and non surface treated miniscrews were 100%. The experimental group showed lower mobility and MIT than the control group did, but the difference was not statistically significant. Additionally, the success rate of PHAO miniscrews of the present study was higher than that of SLA screws (Oh et al, 2006; Kim et al, 2008), Ca-P coated and anodic oxidation treated screws (Koh et al. 2009). This is a different result from that of Koh et al (2009) that anodic oxidation and Ca-P coating on the surface of implants can improve the bonding force with the neighboring bones and stability, but cannot be considered to be superior to the conventional SLA method in terms of stability. Accordingly, comparative studies on stability and bone bonding ability of miniscrews treated with anodic oxidation film, and HA, SLA miniscrews will be necessary in the future.

In addition to direct measurement such as MIT, mobility and success rate, BIC and BV were also measured. The reason of conducting these measurements is that upon completion of bone bonding, implants can function as an absolute anchorage for tooth movement, and BIC of the placed implants can be a standard indicating degree of direct adhesion with bones, which can be expressed as the ratio between the measurement using a computer program and the total surface of the miniscrews (Chen et al, 2008). According to the loading experiment on miniscrews conducted by Melsen et al (2000), BIC increased in proportion to the loading period regardless of form of bones or strength of orthodontic force. By comparison, the present study showed decreased BIC in both the experimental and control groups at 3 and 12 weeks of loading period with statistically significant difference (Table 2, Fig. 6). According to the study conducted by Melsen, various BICs ranging from 10% to 58% were shown when immediate loading was applied for 6 months. By comparison, a mean of 65.4% of BIC was shown in the present study, which is the result anticipating good stability in the clinical cases applying mostly immediate load right after placements. Meanwhile, the experimental miniscrews group showed significantly higher BIC compared with the control group at 3 and 12 weeks of loading period ($P<0.05$). This result coincides with that of the study (Lim et al, 2001; Chon et al, 2008) that the surface treatment group showed higher bonding strength and bone bonding than the non-treatment group did.

In terms of BV, the experimental group (46.4%) also showed higher value for the first 3 weeks than the control group (36.3%) did with a statistical significance. This means favorable results with the initial stability (Huja et al, 2005)which is regarded to be important for success of orthodontic miniscrews procedures. In the 12 weeks of loading period, the experimental group (50.1%) also showed higher BV than the control group (46.5%) did without statistically significant difference ($P>0.05$). As time went on, increase in BV was observed in both groups. Accordingly, even though PHAO miniscrews were not considered to obtain ability of bone generation and induction as time went on, many pores and rough surfaces were created thanks to the oxide layer enabling improvement of osseointegration potential and surface resistance, as reported by Wisbey et al (1991). Likewise in the present study, BV of the experimental miniscrews group at 3 and 12 weeks loading periods were higher than those of the control miniscrews group meaning that improvement in osseointegration potential on the surface of miniscrews was possible through the oxidation film treatment.

Therefore, PHAO miniscrews can be considered to show better osseointegration potential than the non-surface-treated miniscrews do, but this does not necessarily mean that PHAO miniscrews show absolutely better initial stability and bone bonding ability than miniscrews with other surface treatments such as SLA, HA, plasma ion covering and Ca-P coating. Consequently, verification on the PHAO method using the criteria such as success rates of other surface treatments of miniscrews, mobility, and insertion and removal torque is necessary.

V. CONCLUSIONS

A total of 48 miniscrews were placed into the buccal alveolar bone of the mandible in 6 male beagle dogs. Comparison was made between precipitation hardened anodic oxidized surface miniscrew and machined surface miniscrews. Maximum insertion torque (MIT) was measured using torque sensor and initial mobility was recorded during installation. The force applied groups were reciprocally loaded by Ni-Ti coil spring (250~300 gm) at 3 and 12 weeks of loading period. Bone volume(BV) and bone implant contact(BIC) were also measured in histological section for each loading period.

The obtained results were as follows:

1. Machined surface(MS) miniscrews showed a higher MIT value of 21.68 Ncm compared with precipitation hardened anodic oxidized (PHAO) miniscrews by 21.53 Ncm, which showed statistical difference (P>0.05). And the initial mobility (Ncm) depending on the types of miniscrew was not statistically different between surface types(P>0.05).

2. At 3 weeks of loading the BIC of PHAO showed higher values of 65.4% than the values of MS miniscrews 52.9% respectively, and decreased by 61.7% and 44.5% respectively at 12 weeks of loading. And there was statistical difference between experimental groups at both loading period(P<0.05).
3. At 3 weeks of loading, the BV was higher in PHAO(46.4 %) than MS miniscrews(36. 3%). And, there was statistical difference (P<0.05). At 12 weeks of loading, the BV of PHAO was 50.1% and MS miniscrews was 46.5%, but there was no statistical difference between two groups (P>0.05).

These results showed that the BIC and BV of PHAO has a higher osseointegration potential than machined surface miniscrews at 3 and 12 weeks loading period. The PHAO's initial stability might be superior to the MS miniscrews. But, the further investigation is required to compare with SLA and other surface modification miniscrews using the measuring the insertion and removal torque, mobility, success rate and so on.

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국 문 요 약

성견에서 석출강화형 양극산화 교정용 미니스크류의 생물학적 평가

교정용 미니스크류의 안정성을 높이고자 많은 디자인과 방법들이 개발되고 있으며, 또한 생물학적으로 골 접촉률과 골 결합능력을 높이기 위해 다양한 표면처리에 관한 연구가 진행 되어지고 있다.

본 연구에서는 석출 강화형 양극 산화법을 적용한 교정용 미니스크류의 식립 후 시기별 안정성과 골 결합능력을 알아보기 위해 석출 강화형 양극 산화법을 적용한 미니스크류와 표면처리를 하지 않은 교정용 미니스크류를 사용하여 식립 토오크 및 동요도와 조직시편 분석을 시행하였다. 성견 6마리의 하악 협측골에 직경 1.45 mm, 길이 7 mm의 non-drilling 형의 원추형(OAS-1507T, Biomaterials Korea Inc., Seoul, Korea) 미니스크류를 각각 24 개씩 48개를 식립하여 즉시 부하를 적용시킨 후 성공률, 동요도 및 식립 토오크를 측정하고3, 12주 후에 동물 희생 후 조직시편분석을 시행하여 각 미니스크류의 골 접촉률과 골 면적비율을 계측, 비교하여 다음과 같은 결과를 얻었다.

1. 미니스크류의 표면처리에 따른 식립 토오크는 실험군과 대조군에서 각각 21.53 Ncm과 21.68 Ncm로 통계적으로 유의한 차이는 관찰되지 않았고($P>0.05$), 식립 시 동요도에서도 통계적으로 유의한 차이는 없었다($P>0.05$).

2. 골접촉률(BIC)은 식립 후 3주에서 대조군은 52.9%, 실험군의 경우 65.4%이었으며, 12주에서는 각각 44.5%, 61.7%로 산화피막 처리를 한 실험군에서 평균 골 접촉률이 높았으며 군 간에 유의한 차이가 있었다($P<0.05$).
3. 골 면적비율(BV)은 두 군 모두에서 시기별 증가양상이 관찰되었으며 ($P<0.05$), 3주에서 대조군, 실험군은 36.3%, 46.4%로 산화피막 처리를 한 실험군이 통계적으로 유의하게 높았으며 ($P<0.05$), 12주에서는 각각 46.5%, 50.1%로 실험군이 높았으나, 군 간에 통계적으로 유의한 차이는 없었다 ($P<0.05$).

본 연구에서 석출 강화형 양극성 산화피막 처리를 한 미니스크류는 표면처리를 하지 않은 미니스크류에 비교해서 성공률, 식립 토오크, 동요도 등에서 유의할 만한 차이를 보이지 않았다. 그러나 골 접촉률, 골 면적비율에 있어서는 유의할 만한 더 높은 골 유착성을 보여 주어 미니스크류의 초기 안정성에 도움이 될 것으로 보이나, 향후 제거 토오크 등의 비교를 통한 물리적인 안정성에 대한 연구 및 SLA, Ca-P coating, HA coating 등과 같은 다른 표면처리법과의 비교 연구가 좀 더 필요할 것이다.

핵심 되는 말: 양극 산화, 미니스크류, 골 접촉률, 골 면적비율