Effects of Coronal Thread Pitch in Scalloped Implant with 2 Different Connections on Loading Stress using 3 Dimensional Finite Element Analysis

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Purpose of present study is to investigate the effects of thread pitch in coronal portion in scalloped implant with 2 different connections on loading stress using 3 dimensional finite element analysis. Scalloped implant with 4 different thread pitches (0.4mm, 0.5mm, 0.6, and 0.7mm) in the coronal part was modeled with 2 different implant-abutment connections. Platform matching connection had the same implant and abutment diameter so that they were in flush contact at the periphery while platform mismatching connection had smaller abutment diameter than implant so that their connection was made away from periphery of implant-bone interface. Occlusal loading of 100N force was applied vertically and 30 degree obliquely to all 8 models and the maximum von Mises bone stress was identified. Loading stress as highly concentrated in cortical bone. Platform mismatching scalloped implant with small thread pitch (0.4mm) model had consistently lowest maximum von Mises bone stress in vertical and oblique loads. Platform matching model had lowest maximum von Mises bone stress with 0.6mm thread pitch in vertical load and with 0.4mm thread pitch in oblique load. Platform mismatching connection had important roles in reducing maximum von Mises bone stress. Scalloped implant with smaller coronal thread pitch showed trend of reducing maximum von Mises bone stress under load.

Key words: Coronal thread pitch, Connection, Scalloped implant, 3D finite element analysis

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INTRODUCION

Dantal implants have shown to be highly successful treatment modalities for partially[1, 2] and completely edentulous patients[3]. Many different implant materials and designs have been introduced in attempt to improve clinical outcomes since overall success and marginal bone loss are considered closely related to them[4-6].

Scalloped implant was introduced[7] to enhance the esthetic outcome since anterior teeth have high proximal and low mid-facial gingival soft tissue that reflects the underlying scalloping osseous architecture[8]. However, few studies available on first generation scalloped implant design showed that marginal bone loss was significantly greater than conventional flat-top implant[9-11], thus negating the theoretical benefits of scalloped implant and adversely affecting possible clinical outcomes.

There is some evidence in flat-top implants that incorporating micro-thread in coronal portion enhanced the bone-to-implant contact[12] and reduced the marginal bone loss in occlusal load[13, 14]. Choi et al demonstrated in an animal study that scalloped implant with coronal micro-thread had significantly less marginal bone resorption compared to conventional flat-top implant[15]. However, their study lacked effects of coronal micro-thread design in scalloped implant under occlusal load. Furthermore, there is no study available on effects of coronal thread pitch in scalloped implant with relation to implant-abutment connection.

Purpose of present study is to investigate the effects of thread pitch in coronal portion in scalloped implant with 2 different connections on loading stress using 3 dimensional finite element analysis.

MATERIALS AND METHODS

Scalloped implants with 4 different helical threads in the coronal portion were modeled with 2 different connections. Dimension of coronal thread pitches were 0.4mm, 0.5mm, 0.6mm, and 0.7mm (Fig. 1). Two connections used in the present study were referred to as platform matching and platform mismatching. Platform matching connection had the same implant and abutment diameters so that they were in flush contact at the periphery whereas platform mismatching connection had smaller abutment diameter than implant so that abutment-implant contact interface was made away from the implant-bone interface (Fig. 2). Thus, a total of 8 scalloped implant models were investigated in the present study.

In order to make the loading possible, implant-abutment assembly was modeled and top of abutment was sealed with 1mm solid abutment material (Fig. 3). One hundred newton force was applied vertically and at 30 degree oblique angle. Loading locations were same for all 8 models for both vertical and oblique angle. Nonlinear contact with friction was assumed between abutment and

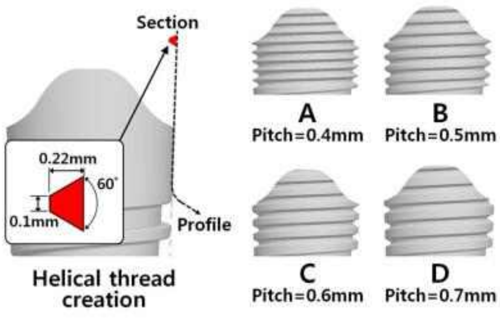
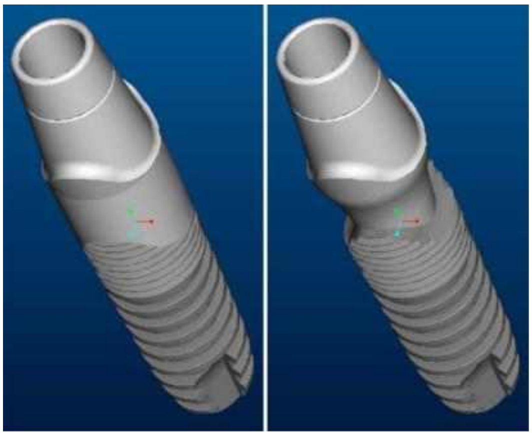


Fig. 1. Coronal thread pitch



A B

Fig. 2. Platform matching and platform mismatching connection models with 0.4mm coronal thread pitch. A: Platform matching connection, B: Platform mismatching connection.

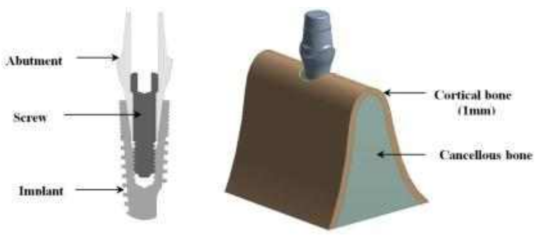


Fig. 3. Implant and bone model. Platform mismatching connection model.

implant and at abutment and screw. The contact area was assumed to transfer only pressure and tangential frictional forces. Material properties from literatures for bone, implant components and friction coefficient of 0.5 were used in the present investigation[16-18](Table I).

A cross-section CT scan image of maxillary anterior region was digitized and used as basis for the shape of solid bone model construction. Commercially available software were used to build 3 dimensional bone and implant models (Pro/ ENGINEER, PTC, MA), (CATIA, Dassult Systemes, MA) and to calculate the von Mises stress in cortical and cancellous bone as well as in the implants (ANSYS 12, Canonsburg, PA). Cortical bone thickness was assumed to be 1mm for the experiment[19]. To simplify the analysis process, cortical and cancellous bone were assumed to be homogeneous, isotropic, and linearly elastic. Implants were assumed to be completely osseointegrated with the bone.

RESULTS

Loading stress was highly concentrated in cortical bone. Oblique loading had considerably higher maximum von Mises stress in cortical bone than vertical loading. Scalloped implant with small coronal thread pitch (0.4mm) had the lowest maximum von

Table I. Material properties

Materials	Young's modulus (GPa)	Poisson's ratio
Titanium grade ELI (abutment)	113.8	0.34
Titanium grade IV (implant)	114.0	0.37
Cortical bone	14.0	0.30
Cancellous bone	1.5	0.30

Table Ⅱ. Maximum von Mises bone stress (MPa) of platform matching connection

Loading direction	Coronal thread pitch			
	0.4mm	0.5mm	0.6mm	0.7mm
Vertical load	20.5	21.9	18.0	23.4
Oblique load	76.1	80.8	78.5	86.3

Table Ⅲ. Maximum von Mises bone stress (MPa) of platform mismatching connection

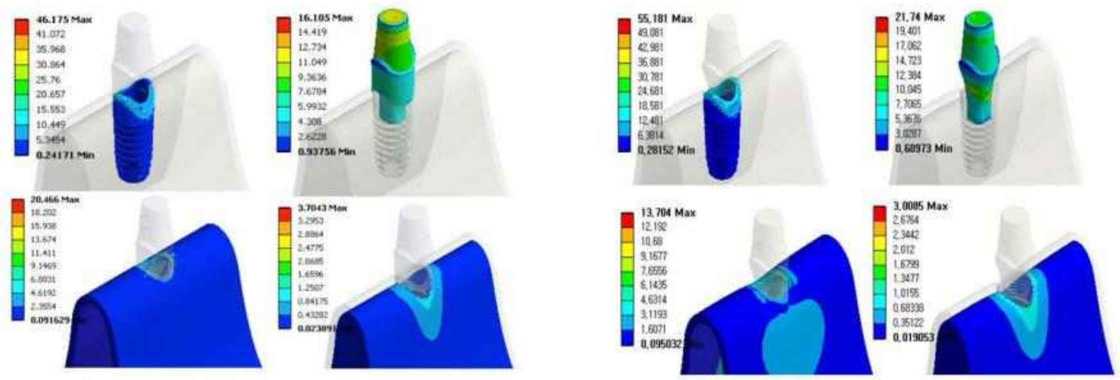
Loading direction	Coronal thread pitch			
	0.4mm	0.5mm	0.6mm	0.7mm
Vertical load	13.7	14.6	18.0	19.7
Oblique load	58.7	66.1	74.8	73.0

Mises bone stress in vertical and oblique loads with platform mismatching connection. When scalloped implant had platform matching connection, 0.6mm coronal thread pitch had lowest maximum von Mises bone stress in oblique load and 0.4mm thread pitch model for lowest maximum stress in oblique load. There was a trend that as the coronal thread pitch increased, maximum von Mises bone stress increased. Moreover, implant-abutment connection played significant roles in reducing von Mises bone stress since platform mismatching connection had consistently lower maximum stress compared to corresponding platform matching connection scalloped implant model. Table Ⅱ and Ⅲ show the maximum von Mises bone stress results in present investigation.

DISCUSSION

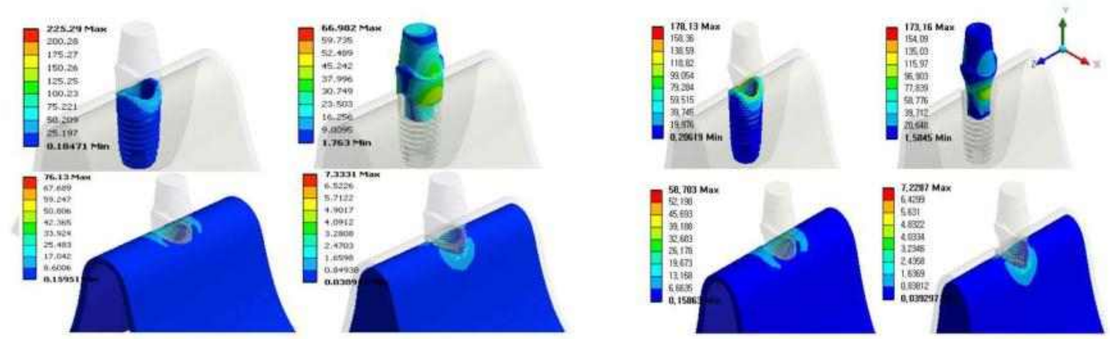
Coronal portion of scalloped implant with smaller thread pitch showed lower maximum von Mises bone stress under load. Platform mismatching connection of scalloped implant demonstrated consistently lower maximum stress in bone compared to corresponding platform matching connection models (Fig. 4,5). Thus, it can be concluded that implant-abutment connection plays important roles in reducing maximum von Mises bone stress. Scalloped implant design with smaller coronal thread is considered more beneficial than bigger thread because occlusal loading stress that is usually more concentrated in cortical bone as shown in present study was decreased with smaller thread pitch. High occlusal stress is one of the major causes for implant bone loss[20,21].

It is still unclear why first generation scalloped implant had more bone loss than conventional flat-top implant, thus no definitive remedy is yet to be provided. However, new scalloped implant design with micro-thread and platform mismatching connection showed promising result in an animal study[16]. Finite element analysis study by Choi et al demonstrated that platform mismatching and micro-



A B

Fig. 4. Vertical loading of 0.4mm thread pitch models. A: Platform matching connection. Implant (top left), abutment (top right), cortical bone (bottom left), cancellous bone (bottom right); B: Platform mismatching connection. Implant (top left), abutment (top right), cortical bone (bottom left), cancellous bone (bottom right).



A B

Fig. 5. Oblique loading of 0.4mm thread pitch models . A: Platform mismatching connection. Implant (top left), abutment (top right), cortical bone (bottom left), cancellous bone (bottom right); B: Platform mismatching connection. Implant (top left), abutment (top right), cortical bone (bottom left), cancellous bone (bottom right).

thread design features in scalloped implant were important for loading stress reduction and distribution[22]. Present study also demonstrated importance of platform mismatching connection in reducing maximum von Mises stress in bone with different thread pitch design in scalloped implant. Based on present experiment, if scalloped implant is to be designed, platform mismatching connection with smaller thread pitch such as micro-thread is more recommended than macro-thread in coronal part of the implant.

Scalloped implant model with 0.4mm thread pitch had more surface area that was in contact with bone. As the coronal thread pitch increased from 0.4mm to 0.7mm, overall implant surface area decreased 4% while cortical bone contact area decreased 10% (Table Ⅳ). Decrease in surface area explains the maximum von Mises bone stress increase, particularly in cortical bone. Since greater loading stress is concentrated in cortical bone and considered to have negative effects in clinical outcome, implant design that helps to increase the contact area with bone to decrease the stress should be considered positive feature. Thus, scalloped implant with smaller thread pitch in coronal part to increase cortical bone contact needs to be strongly considered for clinical use as well as platform mismatching connection.

Limitation of present study is same for any finite element analysis studies that in vivo condition can never be the same as computer simulated environment. Bone is never homogeneous and isotropic and implant is not 100% osseointegrated in reality. Thus it is unclear if 14MPa difference in maximum von Mises oblique load stress from 0.4mm to 0.7mm thread pitch in scalloped implant in cortical bone would represent clinically significant bone loss difference. Further study is required to understand the differences in scalloped implants. However, it is generally agreed that implant design that transmit less stress to cortical bone is more clinically beneficial since marginal bone resorption caused by overload is unfavorable for overall implant success. By implementing combined platform mismatching connection and small coronal thread in scalloped implant design, maximum von Mises stress in cortical bone was reduced 41% in vertical load and 32% in oblique load based in present study (Fig. 4,5).

Therefore, following conclusions can be made:

1. Platform mismatching connection had important roles in reducing maximum von Mises stress in cortical bone.
2. Scalloped implant with smaller coronal thread pitch showed trend of reducing maximum von Mises stress in cortical bone.

ACKNOWLEDGEMENTS

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REFERENCES

1. Lindquist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prosthesis supported by osseointegrated implants.

Table Ⅳ. Scalloped implant surface area (mm^2)

	Coronal thread pitch			
	0.4mm	0.5mm	0.6mm	0.7mm
Cortical bone	22.35	21.13	20.66	20.03
Bone (total)	195.92	192.32	189.61	187.96

Clinical results and marginal bone loss. Clin Oral Implants Res 1996;7:329336.
2. Jemt T, Lekholm U,Adell R. Osseointegration in the treatment of partially edentulous patients: A preliminary study of 876 consecutively placed fixtures. Int J Oral Maxillofac Implants 1989;4:211217.
3. Adell R, Lekholm U, Rockler B, Brnemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387416.
4. Brunski JB. Biomaterials and biomechanics in dental implant design. Int J Oral Maxillofac Implants 1988 Summer;3(2):85-97.
5. Steigenga JT, al-Shammari KF, Nociti FH, Misch CE, Wang HL. Dental implant design and its relationship to long-term implant success. Implant Dent 2003;12 (4):306-17.
6. Albrektsson T, Sennerby L. State of the art in oral implants. J Clin Periodontol 1991 Jul;18(6):474-81.
7. Whrle, PS. Nobel perfect esthetic scalloped implant: Rationale for a new design. Clin Implant Dent Relat Res.2003 5: 64-73.
8. Becker WC, Ochsenbein C, Tibbetts L, Becker BE. Alveolar bone anatomic profiles as measured from dry skulls. Clinical ramifications. J Clin Periodontol 1997 Oct;24(10): 727-31.
9. Nowzari H, Chee W, Yi K, Pak M, Chung WH, Rich S. Scalloped dental implants: a retrospective analysis of radiographic and clinical outcomes of 17 Nobel-Perfect implants in 6 patients. Clin Implant Dent Relat Res 2006;8:1-10.
10. Kan J, Rungcharassaeng K, Lieddelow G, Henry P, Goodacre C. Peri-implant tissue response following immediate provisional restoration of scalloped implants in the esthetic zone: A one-year pilot prospective multi-center study. J Prosthet Dent 2007;97:109-118.
11. Tymstra N, Raghoebar GM, Vissink A, Den Hartog L, Stellingsma K, Meijer HJ. Treatment outcome of two adjacent implant crowns with different implant platform designs in the aesthetic zone: a 1-year randomized clinical trial. J Clin Periodontol 2010;38: 74-85.
12. Abrahamsson I, Berglundh T. Tissue characteristics at microthreaded implants: An experimental study in dogs. Clin Implant Dent Relat Res 2006; 8: 107-113.
13. Lee D, Choi Y, Park K, Kim C, Moon I. Effect of microthread on the maintenance of marginal bone level: a 3-year prospective study. Clin Oral Implants Res 2007;18:465-470.
14. Shin Y, Han C, Heo S, Kim S, Chun H. Radiographic evaluation of marginal bone level around implants with different neck designs after 1 year. The Int J Oral Maxillofac Implants 2006;21:789-794.
15. Choi KS, Lozada JL, Kan JY, Lee SH, Kim CS, Kwon TG. Study of an experimental microthreaded scalloped implant design: proximal bone healing at different interimplant distances in a canine model. Int J Oral Maxillofac Implants 2010;25:195-202.
16. Chun H, Shin H, Han C, Lee S. Influence of implant abutment type on stress distribution in bone under various loading conditions using finite element analysis. Int J Oral Maxillofac Implants 2006;21:195-202.
17. Merz BR, Hunenbart S, Belser UC, Mechanics of the implant-abutment connection: an 8-degree taper compared to a butt joint connection. The Int J Oral Maxillofac Implants 2000;15:789-794.
18. Abkowitz S, Burke JJ, Hiltz RH. Titanium in Industry. New York: Van Nostrand Co Inc, 1955.
19. Katranji A, Misch K, Wang HL. Cortical bone thickness in dentate and edentulous human cadavers. J Periodontol 2007;78:974-8.
20. Misch CE, Suzuki JB, Misch-Dietsh FM, Bidez MW. A positive correlation between occlusal trauma and peri-implant bone loss: literature support. Implant Dent. 2005 Jun;14(2):108-16.
21. Oh TJ, Yoon J, Misch C E, Wang HL. The causes of early implant bone loss: myth or science? J Periodontol 2002;73:322-333.
22. Choi KS, Park SH, Lee JH, Jeon YC, Yun MJ, Jeong CM. Stress distribution of scalloped implant with different microthread and connection configurations using 3 dimensional finite element analysis. Int J Oral Maxillofac Implants (manuscript accepted).

연결부 형태가 다른 두 가지 scallop 임플란트에서 경부 나사선 피치가 응력 분포에 미치는 영향 : 삼차원적유한요소분석

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본 연구는 삼차원적 유한요소분석을 통하여 연결부 형태가 다른 두 가지 scallop 임플란트의 경부 나사선 피치가 응력 분포에 미치는 영향을 간접적으로 확인하고자 하였다. 4가지 경부 나사선 피치 (0.4mm, 0.5mm, 0.6mm, 0.7mm)를 갖는 scallop 임플란트를 두 가지 다른 연결부 형태 (platform matching connection, platform mismatching connection)로 지대주와 연결되는 유한요소모형을 설계하였다. 8개의 모든 모델에 100N의 하중을 수직 및 30도 경사 방향으로 인가하여, 임플란트, 지대주, 그리고 치조골에 가해지는 최대등가응력을 분석하였다. 유한요소분석결과 응력은 치밀골에 집중되었다. 작은 나사 피치가 설계된 platform mismatching connection 모델에서 수직 방향과 경사하중 시 최대등가응력이 가장 낮게 나타났다. 측정되었다. Platform matching connection 모델에서는 경사하중의 경우 0.6mm, 수직하중의 경우 0.4mm 나사 피치에서 가장 낮은 최대등가응력을 보였다. 따라서 scallop 임플란트에서 platform mismatching connection은 최대등가응력을 감소시키는 데 중요한 역할을 하며, 경부 나사 피치가 작을수록 최대등가응력이 감소되는 경향을 보임을 알 수 있었다.

주요어: 경부 나사선 피치, 연결부 형태, scallop 임플란트, 삼차원적유한요소분석

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