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BASIC RESEARCH

Crestal Versus Subcrestal Short Plateau Implant Placement: Pro Et Contra

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Abstract

Implant prognosis is predetermined by stresses in the bone-implant interface. Plateau implants are considered to be highly successful since they reduce bone stress concentrations. For cases with lack of bone height, crestal placement remains a reasonable alternative. Otherwise, subcrestal placement of short implants is advised since it is considered as a crucial factor in preservation of crestal bone. For such scenario, bone biomechanical state is directly dependent on implant insertion depth.

The aim of the study was to compare the impact of crestal or subcrestal short plateau implant placement in different bone quality conditions on peri-implant bone stresses and to assess implant prognosis under 120.92 N mean maximal oblique functional loading.

5.0×5.0 mm Bicon Integra-CP™ implant was selected for this comparative study. Its 3D models were placed in four posterior maxilla models with types III and IV bone with 1.0 mm cortical bone thickness. Different insertion depths were simulated: the implant neck was in crestal (C) and -1, -2 and -3 mm subcrestal (S1, S2, S3) positions. All materials were assumed to be linear elastic and isotropic. Elastic moduli of cortical, type III/IV cancellous bone and implants were set to 13.7, 1.37/0.69 and 114 GPa, and Poisson's ratio was 0.3 for all materials. Finite element (FE) models were analyzed in Solidworks Simulation software. 4-node 3D FEs were generated with a total number of up to 3,570,000. 120.92 N mean maximal oblique load (molar area) was applied to the center of 7.0 mm abutment. Von Mises equivalent stress (MES) distributions in surrounding bone were studied to determine the areas of bone overload with magnitude >100 MPa in cortical and >5 MPa in cancellous bone.

Maximal MES magnitudes for all scenarios were found at the implant neck. For C scenario, maximal MES magnitudes were found in crestal cortical bone: 21/28 MPa (type III/IV bone). Maximal MES magnitudes in cancellous bone were approximately 5 MPa for both bone types. For S1, S2 and S3 scenarios, since there was no contact between implant and cortical bone, maximal MES magnitudes were located in cancellous bone at the implant neck. For S1 scenarios they were 18…20 MPa, for S2 and S3 scenarios they were 13…14 MPa, for both bone quality types. Another critical MES area was located at the implant root: for C scenario, maximal MES magnitudes were 2 MPa for both bone quality types, for S1 scenario they were 2.5/3.5 MPa, for S2 – 3.5/4.0 MPa and for S3 – 7/10 MPa (for type III/IV bone).

It was found that 5.0×5.0 mm Bicon Integra-CP™ implant in crestal placement generated safe bone MESs and offered favorable clinical prospect. For all subcrestal scenarios, the implant caused exceeding MESs in cancellous bone due to absence of interface between the implant and cortical bone. However, the tested Bicon implant showed low susceptibility to bone quality worsening at studied levels of subcrestal placement. This finding confirms positive clinical experience of Bicon plateau implants.

Background and Aim

Posterior maxilla region with insufficient bone height often provides the challenge for implantologist because primary stability and implant success is difficult to achieve. In such a poor bone quality, the widest applicable implant diameter and crestal implant placement may be the only way to increase tolerance to occlusal forces, to improve initial stability and to provide a favorable stress distribution to the surrounding bone[1]. Unfortunately, crestal placement often leads to significant increase of stress magnitudes in bone-implant interface and result in implant failure.

Subcrestal implant placement in esthetic areas has been a common treatment modality in order to maintain mucosa texture and tonality, as well as to provide sufficient space to achieve an ideal emergence profile[2,3]. Meanwhile, the data from biomechanical analysis have indicated that increased implant placement depth could reduce the strain levels in peri-implant bone[4]. Different types of implant-abutment connections have shown different patterns of bone loss. Compared to external connections and internal screwed flat connection, conical internal connection has exhibited higher stability, improving resistance to micro-movement, reducing bacterial microleakage and preventing the loss of crestal bone[5]. Animal models using implants with morse tapered implant-abutment interface (IAI) have previously indicated a positive impact on bone contact with the neck of the implant when positioned at a subcrestal level[3,6,7]. However, clinical studies utilizing implants with tapered internal IAI inserted at subcrestal levels presented contradictory results with respect to peri-implant bone loss. In a retrospective study, Lee et al. showed that the failure rate for the implants placed at the margin level was significantly greater than implants placed ~2mm subcrestally[8]. Conversely, results from a 36-month prospective split-mouth clinical trial[9] and a 3-month prospective randomized controlled clinical trial[10] indicated no statistically significant differences in crestal bone loss around implants placed at crestal and subcrestal levels. Moreover, results from a prospective 60-month follow-up study showed peri-implant bone loss was significantly greater in subcrestal implants with platform-switched morse taper connection[11].

The aim of the study was to compare the impact of crestal versus subcrestal short plateau implant placement in different bone quality conditions on peri-implant bone stresses and to assess implant prognosis under 120.92 N mean maximal oblique functional loading.

Methods and Materials

Four posterior maxilla segment 3D models were designed in Solidworks 2016 software to simulate different types of 5.0×5.0 mm Bicon Integra-CP™ implant placement: crestal (C) and three subcrestal positions (S1 (1 mm), S2 (2 mm) and S3 (3 mm)) (Fig. 1). Bone segment with 1.0 mm crestal and sinus cortical bone layers and 8 mm cancellous bone core consisted of types III/IV bone simulated by different cancellous bone elasticity moduli. The implant was inserted monocortically in crestal position only, while there was no cortical bone-implant contact in S1 and S2 scenarios. Besides, in S3 position, the implant apex was in contact with sinus cortical bone (Fig. 1). The size of maxilla segment was 30×9×11 mm (length × height × width).

Implant and bone were assumed as linearly elastic and isotropic and all materials volumes were considered homogeneous. Implant and abutments were considered as a continuous unit and were assumed to be made of titanium alloy with the modulus of elasticity and Poisson's ratio of 114 GPa and 0.34, respectively[12].

The Poisson's ratio of bone tissues (both cortical and cancellous) was assumed to be 0.3[13]. Elasticity modulus of cortical bone was 13.7 GPa[13] for both bone quality types, for Type III bone cancellous bone it was 1.37 GPa and for type IV - 0.69 GPa. Ultimate tension strength of cortical and cancellous bone were 100 and 5 MPa[12].

With respect to boundary conditions, disto-mesial surfaces of the bone segment as well as upper cortical shell planes in all models were restrained (see Fig. 1).

Bone-implant assemblies were analyzed in FE software Solidworks Simulation. 4-node 3D FEs were generated with a total number of up to 1,556,000.

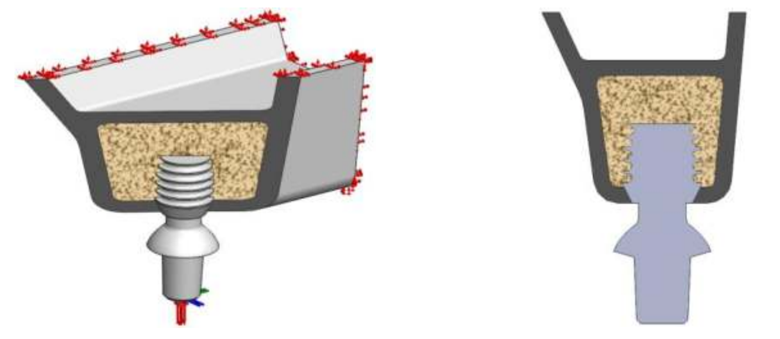
7 Series Low 0° abutment was used for crestal scenario. In order to ensure identical functional loading for other scenarios, abutment length was increased by the subcrestal insertion value to keep the same loading application height. Loading of implant was performed at the center of abutment, in 3D, by 120.9 N mean maximal functional load[14] applied obliquely at the angle of approximately 75° to the abutment top surface. Components of functional loading were determined as 116.3, 17.4 and 23.8 N in axial, lingual and disto-mesial directions. The last two components represent the resultant vector of 29.5 N horizontal functional load acting in the plane of critical bone-implant interface. For all scenarios, the implant was assumed to be completely osseointegrated.

Von Mises equivalent stress (MES) was selected as the measure of bone failure risk. MES distributions in critical bone-implant interface of 8 bone-implant FE models were studied to calculate maximal MES values. Areas of bone overload with MES magnitude greater than 100 MPa in cortical and 5 MPa in cancellous bone were analyzed.

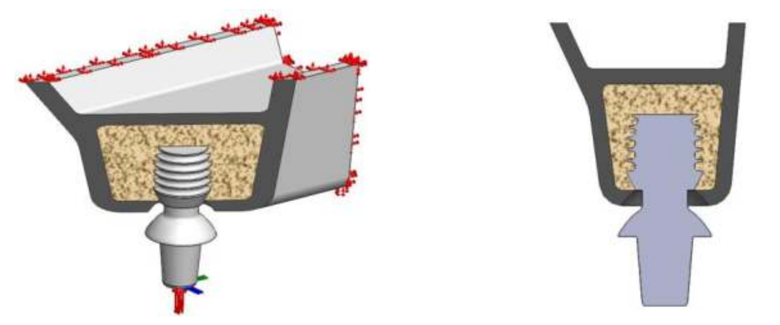
Results

Maximal MES magnitudes for all scenarios were found at the implant neck (Fig. 2, 3). For C scenario, maximal MES magnitudes were found in crestal cortical bone: 21/28 MPa (type III/IV bone). Maximal MES magnitudes in cancellous bone were approximately 5 MPa for both bone types. For S1, S2 and S3 scenarios, since there was no contact between implant and cortical bone, maximal MES magnitudes were located in cancellous bone at the implant neck. For S1 scenarios they were 18…20 MPa, for S2 and S3 scenarios they were 13…14 MPa, for both bone quality types. Another critical MES area was located at the implant root: for C scenario, maximal MES magnitudes were 2 MPa for both bone quality types, for S1 scenario they were 2.5/3.5 MPa, for S2 – 3.5/4.0 MPa and for S3 – 7/10 MPa (for type III/IV bone).

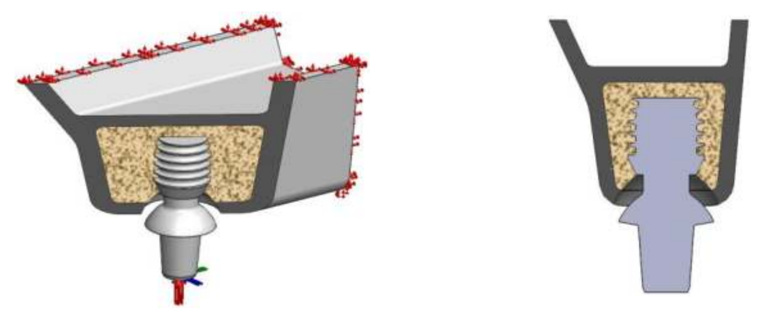
Crestal position (C) of 5.0×5.0 mm implant



1 mm subcrestal position (S1) of 5.0×5.0 mm implant



2 mm subcrestal position (S2) of 5.0×5.0 mm implant



3 mm subcrestal position (S3) of 5.0×5.0 mm implant

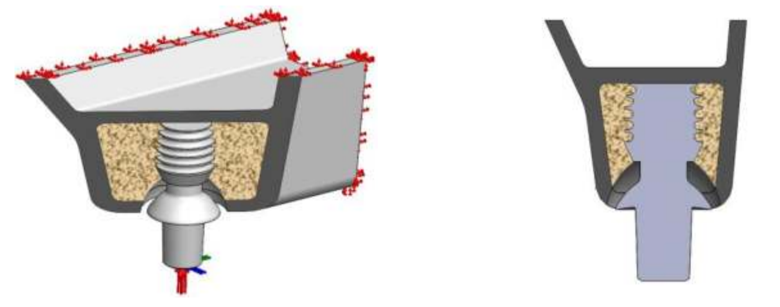
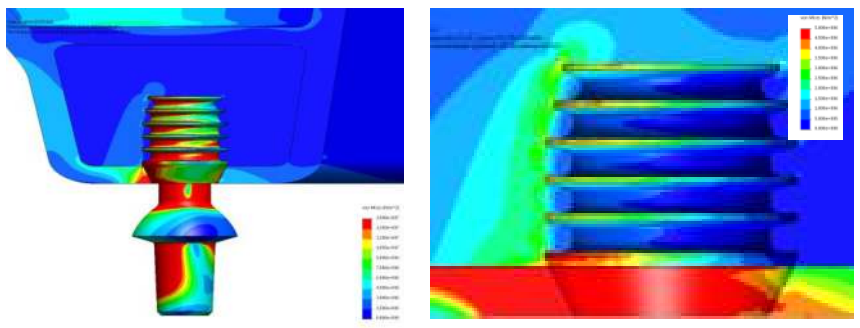
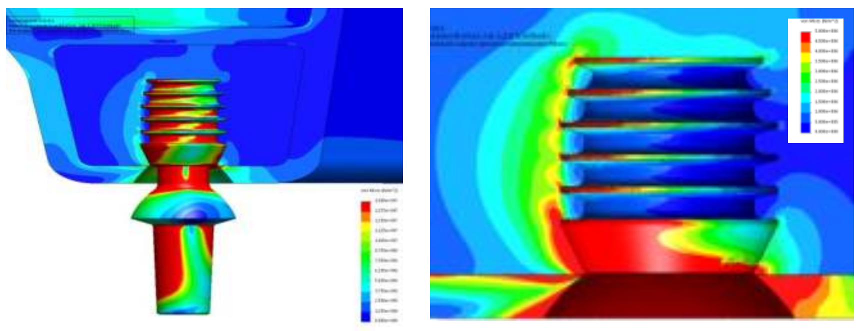


Fig. 1. Maxillary bone segment of 1.0 mm crestal and sinus cortical bone thickness with 5.0×5.0 mm implant placed in crestal and subcrestal (1, 2, 3 mm) positions. Oblique loading is applied to the center of abutment upper surface at 7.0 mm distance from the upper bone margin.

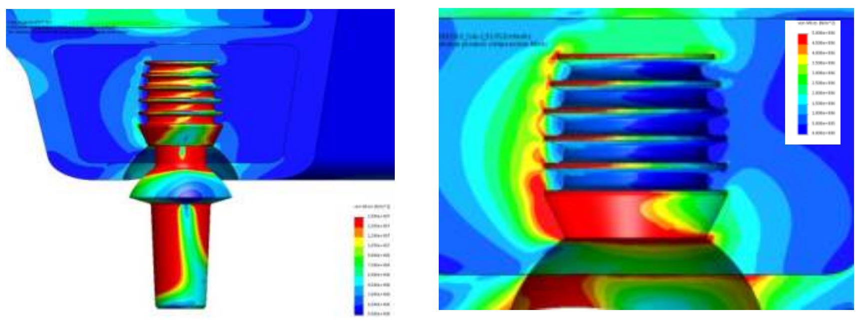
Crestal position (C)



1 mm subcrestal position (S1)



2 mm subcrestal position (S2)



3 mm subcrestal position (S3)

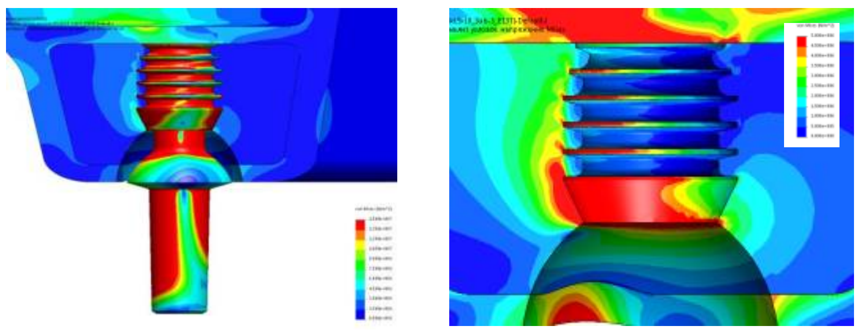
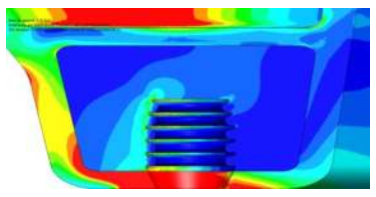


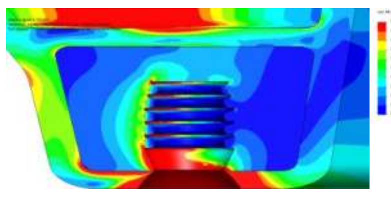
Fig. 2. Ensuring of identical functional loading for crestal and three subcrestal (1, 2, 3 mm) implant insertions by variation of abutment height.

Type III bone

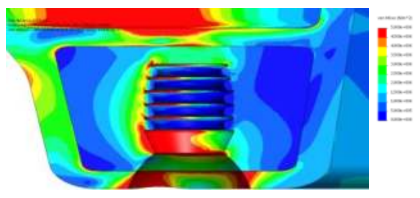
crestal position



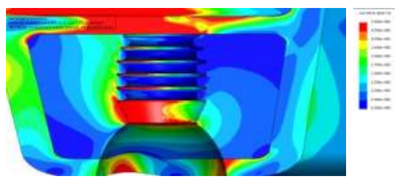
1 mm subcrestal position



2 mm subcrestal position

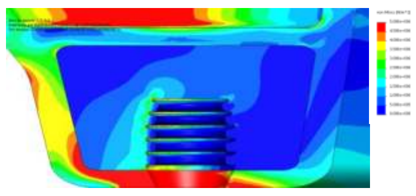


3 mm subcrestal position

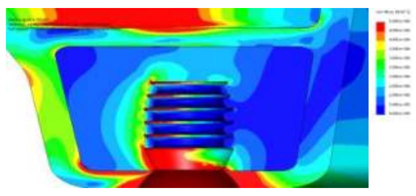


Type IV bone

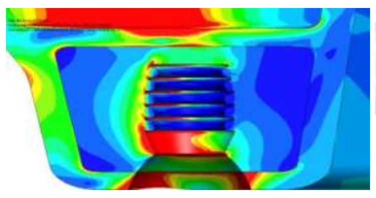
crestal position



1 mm subcrestal position



2 mm subcrestal position



3 mm subcrestal position

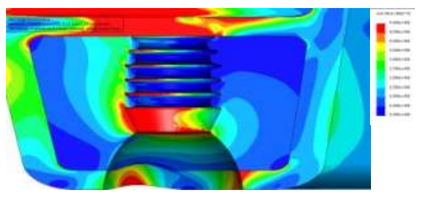


Fig. 3 Typical von Mises stress distribution along the critical bone-implant interface in type III and IV maxillary bone segments for crestal (top left), 1 mm subcrestal (top right), 2 mm subcrestal (bottom left) and 3 mm subcrestal (bottom right) implant placement.

Conclusion

It was found that 5.0×5.0 mm Bicon Integra-CP™ implant in crestal placement generated safe bone MESs and offered favorable clinical prospect. For all subcrestal scenarios, the implant caused exceeding MESs in cancellous bone due to absence of interface between the implant and cortical bone. However, the tested Bicon implant showed low susceptibility to bone quality worsening at studied levels of subcrestal placement. This finding confirms positive clinical experience of Bicon plateau implants.

References

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