P-BR-131

Impact of posterior maxilla bone quality on short plateau implants success

Vladislav Demenko¹, Igor Linetskiy², Vitalij Nesvit³, Larysa Linetska⁴, Oleg Yefremov¹

¹ Department of Aircraft Strength, National Aerospace University, Kharkiv, Ukraine
² Department of Oral and Maxillofacial Surgery, 1st Faculty of Medicine, Charles University in Prague, Prague, Czech Republic
³ Department of Theoretical Mechanics, Machinery and Robotics, National Aerospace University, Kharkiv, Ukraine
⁴ Department of Rehabilitation Medicine, National Academy of Postgraduate Medical Education, Kharkiv, Ukraine

BASIC RESEARCH

Abstract

It was repeatedly proven that implant design, bone quality and quantity significantly influence the functional load transfer. Posterior maxilla usually offers low available bone quality and quantity, so short implants are often used in edentulism treatment. Bone strains are major stimuli of bone turnover, but their high magnitudes result in implant failure. Numerical simulation is usually applied to correlate bone and implant parameters with bone strain spectrum and evaluate implant prognosis.

The aim of the study was to evaluate the impact of short plateau implants and posterior maxilla bone quality on strain level in adjacent bone to predict implant success.

Four Bicon short implants with 4.5 (N), 6.0 (W) mm diameter and 5.0 (S), 8.0 (L) mm length were selected for this numerical analysis. Their 3D models were inserted in 24 posterior maxilla segment models with types III and IV bone, 1.5 (A), 1.0 (B) and 0.5 (C) mm crestal cortical bone thickness. These models were designed in Solidworks 2016 software. Bone and implant materials were assumed as linearly elastic and isotropic. Young modulus of cortical bone was 13.7 GPa, cancellous bone – 1.37/0.69 GPa (type III/IV). Numerical analysis of bone-implant models was carried out in FE software Solidworks Simulation. A total number of 3D FEs was up to 3,590,000. 120.92 N mean maximal oblique load (molar area) was applied to the center of 7 Series Low 0° abutment. First principal strain (FPS) distributions were analyzed according to the concept of “minimum effective strain pathological” (MESp) by Frost. Maximal FPSs were correlated with 3000 microstrain MESp to evaluate implant prognosis.

350...7500 microstrain maximal FPSs were found in the cortical-cancellous bone interface in the vicinity of the first fin. Critical FPSs (>3000 microstrain) were observed for N implants in IV,B/C,S/L, III,B/C,S, III,C,L scenarios. For W implants, critical FPSs were found only in IV,B/C,S scenarios. Favorable FPSs (350...3000 microstrain) were calculated in vicinity of W implants for all scenarios excluding IV,B/C,S. For N implants, favorable FPSs were observed for III,A,S/L, III,B,L. Implant diameter increase (4.5 vs. 6.0 mm) have led to 64/54/52, 78/68/70, 32/36/39, 50/53/55% FPS reduction for 1.5/1.0/0.5 mm cortical bone and III,S, III,L, IV,S, IV,L scenarios. FPS magnitudes were found sensitive to bone quality: FPS reduction in type III bone relative to type IV was -14/22/36, -95/16/39, 40/44/50, 13/44/59% for 1.5/1.0/0.5 mm and N,S, N,L, W,S, W,L scenarios.

Bone strains were influenced by implant dimensions, cortical bone thickness and bone quality. 4.5×5.0 mm implant was recommended only for types III/IV bone and 1.5 mm cortical bone thickness, while 4.5×8.0 mm implant - for types III/IV bone and 1.5/1.0 mm cortical bone thickness. 6.0 mm diameter implants caused positive bone turnover for all but one scenario (6.0×5.0 mm implant, type IV bone, 0.5 mm cortical bone). Clinicians should consider these findings in planning of short plateau implants.

Background and Aim

Short implants are highly successful in the maxillary molar region with insufficient bone height and poor bone quality^{1,2,3}. Bicon screwless implant system with plateau root-formed body provides 30% more surface area when compared with same-sized threaded implants. Bone healing pathway leading to Bicon implant osseointegration is based on healing chambers, which develop due to the interplay between implant design and drilling dimensions. This results in intramembranous-like woven bone formation at large void spaces occupied by the blood clot immediately after implantation⁴.

Bone strains are well-recognized stimuli of bone turnover. According to Frost mechanostat theory⁵, strains exceeding MESp (3000 μ strain) will cause bone failure. In order to provide peri-implant bone mass increase, strains should be kept above the MESm threshold (1000-1500 μ strain). Treatment success could be achieved by selecting appropriate implant dimensions by correlating safe strain spectrum with available bone quantity. Therefore, the problem of adequate implant selection and successful prognosis is still essential in implant dentistry, especially for poor bone quality. Finite element (FE) method is contemporary instrument to provide adequate analysis of bone-implant interaction.

The aim of the study was to evaluate the impact of short plateau implants and posterior maxilla bone quality on strain level in adjacent bone to predict implant success.

Methods and Materials

Four 4.5 (N), 6.0 (W) mm diameter and 5.0 (S), 8.0 (L) mm length Bicon short implants were selected for this numerical study. Their 3D models were inserted in 24 posterior maxilla segment models, which were designed in Solidworks 2016 software (Fig. 1), with types III and IV bone (simulated by different cancellous bone elasticity moduli), 1.5 (A), 1.0 (B) and 0.5 (C) mm crestal cortical bone thickness. Their dimensions were selected to simulate the most critical scenario of minimal available bone to fit the specific implant with crestal placement as a necessary compromise, with implant apex supported by sinus cortical bone (see Fig. 1). Bone and implant materials were assumed as linearly elastic, isotropic and homogenous. The size of maxilla segment was 30×9×11 mm (length × height × width).

Implants 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, respectively⁶. The Poisson's ratio of bone tissues (both cortical and cancellous) was assumed to be 0.3⁷. Elasticity modulus of cortical bone was 13.7 GPa⁷ for both bone quality types, for type III bone cancellous bone it was 1.37 GPa and for type IV - 0.69 GPa.

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).

Functional loading of implant was applied at the center of 7 Series Low 0° abutment, in 3D, by 120.9 N mean maximal functional load⁸ 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. All implants were assumed to be completely osseointegrated.

Numerical analysis of bone-implant models was carried out in FE software Solidworks Simulation. A total number of 3D FEs was up to 3,590,000 (Fig. 2). First principal strain (FPS) distributions in bone peri-implant area of 24 bone-implant assemblies were analyzed. Maximal FPSs were correlated with 3000 microstrain MESp⁵ to evaluate implant prognosis.

Fig. 1. Cross-sections of maxillary bone segments with 0.5, 1.0 and 1.5 mm crestal and sinus cortical bone thickness with inserted 4.5×5.0 and 6.0×8.0 mm implants. Oblique functional loading is applied at the center of 7 Series Low 0° abutment upper surface at 7.0 mm distance from the upper bone margin.

Fig. 2. FE meshing of maxillary bone segment with 1.0 mm crestal and sinus cortical bone and 4.5×5.0 mm implant with mapped meshing in the neck area of bone-implant contact. Minimal value of FE size is 0.025 mm.

Results

FPS distributions were investigated in bone-implant interface (Fig. 3). Graphs of FPS dependence on the length of critical bone-implant contact were designed to find FPS maximal magnitudes (Fig. 4). 350...7500 microstrain maximal FPSs were found in the cortical-cancellous bone interface in the vicinity of the first fin. Critical FPSs (>3000 microstrain) were observed for N implants in IV,B/C,S/L, III,B/C,S, III,C,L scenarios. For W implants, critical FPSs were found only in IV,B/C,S scenarios. Favorable FPSs (350...3000 microstrain) were calculated in vicinity of W implants for all scenarios excluding IV,B/C,S. For N implants, favorable FPSs were observed for III,A,S/L, III,B,L. Implant diameter increase (4.5 vs. 6.0 mm) have led to 64/54/52, 78/68/70, 32/36/39, 50/53/55% FPS reduction for 1.5/1.0/0.5 mm cortical bone and III,S, III,L, IV,S, IV,L scenarios. FPS magnitudes were found sensitive to bone quality: FPS reduction in type III bone relative to type IV was -14/22/36, -95/16/39, 40/44/50, 13/44/59% for 1.5/1.0/0.5 mm and N,S, N,L, W,S, W,L scenarios.

Fig. 3. First principal strain distributions in the plane of critical bone-implant interface for selected implants and types III-IV bone segments.

Fig. 4. First principal strain distributions along the critical line of bone-implant interface for studied implants placed into $t_{cort} = 0.5$ mm (two top figures), 1.0 mm (two mid figures), 1.5 mm (two bottom figures) cortical bone and types III ($E_{canc}=1.37$ GPa) and IV ($E_{canc}=0.69$ GPa) cancellous bone.

Conclusion

Bone strains were influenced by implant dimensions, cortical bone thickness and bone quality. 4.5×5.0 mm implant was recommended only for types III/IV bone and 1.5 mm cortical bone thickness, while 4.5×8.0 mm implant - for types III/IV bone and 1.5/1.0 mm cortical bone thickness. 6.0 mm diameter implants caused positive bone turnover for all but one scenario (6.0×5.0 mm implant, type IV bone, 0.5 mm cortical bone). Clinicians should consider these findings in planning of short plateau implants

References

Presented at

EAO
CONGRESS
EUROPEAN ASSOCIATION FOR OSSEointegration
Lisbon
2019