Short implants and bone loss – evaluation of bone turnover

Igor Linetskiy1, Vladislav Demenko2, Larysa Linetska3, Vitalij Nesviti4, Oleg Yefremov2

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

Abstract

Short implants are indispensable in posterior mandible with insufficient bone height. Implant design, bone quality and degree of bone loss predetermine acceptable failure load transfer to adjacent bone. Adequate bone strains are key stimuli of bone turnover, but their extreme magnitudes lead to implant failure. Computer simulation allows to correlate bone and implant parameters with bone strain spectrum and to evaluate implant perspectives. The aim of the study was to evaluate the impact of plateau implants and bone quality on strain levels in adjacent bone at several levels of bone loss to assess implant prognosis.

Cortical and cancellous bone first principal strains (FPSs) were selected to evaluate bone turnover around fully and partially osseointegrated 4.5-Ø, 5.0-Ø and 6.0-Ø (Ø) 5.0 mm diameter implant. FE models were placed crestally in corresponding posterior maxilla segment models with type III bone and 1.0 mm cortical crestal and sinus bone layers. The models were designed in Solidworks 2016 software. All materials were assumed as linearly elastic and isotropic. Elasticity modulus of cortical bone was 13.7 GPa, cancellous bone – 1.27 GPa. Bone-implant assemblies were analyzed in FE software Solidworks Simulation. A total number of 4-node 3D FEA were up to 5,450,000. 125 mm maximal cortical oblique load (maximal was applied to the center of the 7 Series Line 9° abutment. Maximal FPSs were correlated with 2000-microstrain minimum effective strain pathological (MESp) to evaluate the perspective of bone turnover around the implants.

Maximal FPSs for osseointegrated implants (1800 ± 3270 microstrain) were found in the cancellous bone at the first fit edge. For implants with bone loss, they were found at the same location and were significantly dependent on bone loss level (2140 ± 3600, 2200 ± 4100, 2800 ± 4500, 3500 ± 4200 ± 7000 microstrain for 0.2, 0.4, 0.6, 0.8, 1.0 mm bone loss. Comparing to the osseointegrated implants, the following FPS increase on five bone loss levels was determined: for N implants it was 10, 25, 50, 80 and 114%; for M implants – 12, 32, 62, 92, 131% for W implants – 19, 28, 56, 94 and 133%. Bone loss was found to be significantly influenced by implant diameter and bone loss level. 4.5 mm diameter implant is not recommended for type II bone because it provides bone failure risk up to 3000 microstrain threshold even for the fully osseointegrated implant. 6.0 mm diameter implant caused positive bone turnover balance up to 0.6 mm type III bone loss, with 5.0 mm only up to 0.2 mm bone loss. Clinicians should consider these findings in treatment with short plateau implants.

Methods and Materials

The novel method6 was applied to evaluate strain fields surrounding fully and partially osseointegrated (5.0 mm outer diameter, 4.5 mm inner diameter, 5.0 mm height) diameter implants placed in crestal and sinus bone layers in the posterior maxilla segment (Fig. 1) and 1.0 mm cortical and sinus bone layers. The models were designed in Solidworks 2016 software. Implant and bone were assumed linearly elastic, isotropic and homogeneous. The size of models was 300×111 mm (length × height × width). Implant and abutments were considered as a continuous unit and assumed to be made of titanium alloy with the modulus of elasticity and Poisson's ratio of 114 GPa and 0.34. Representative parameters of bone (both cortical and cancellous) was assumed to be 0.34. Elasticity modulus of cortical bone was 13.7 GPa, cancellous bone – 1.27 GPa. Bone-implant contact was assumed to be 100%.

FE model was created by 3D solid elements of an implant and bone structure. FE meshing of maxillary bone segment with 1.0 mm crestal and sinus bone layers (Fig. 2). The models were simulated in Solidworks Simulation software. All materials were assumed as linearly elastic and isotropic. Elasticity modulus of cortical bone was 13.7 GPa, cancellous bone – 1.27 GPa. Bone-implant assemblies were analyzed in FE software Solidworks Simulation. A total number of 4-node 3D FEA were up to 5,450,000. The maximal load was applied to the center of the 7 Series Line 9° abutment. Maximal FPSs were correlated with 2000-microstrain minimum effective strain pathological (MESp) to evaluate the perspective of bone turnover around the implants. Maximal FPSs for osseointegrated implants (1800 ± 3270 microstrain) were found in the cancellous bone at the first fit edge. For implants with bone loss, they were found at the same location and were significantly dependent on bone loss level (2140 ± 3600, 2200 ± 4100, 2800 ± 4500, 3500 ± 4200 ± 7000 microstrain for 0.2, 0.4, 0.6, 0.8, 1.0 mm bone loss. Comparing to the osseointegrated implants, the following FPS increase on five bone loss levels was determined: for N implants it was 10, 25, 50, 80 and 114%; for M implants – 12, 32, 62, 92, 131% for W implants – 19, 28, 56, 94 and 133%. Bone loss was found to be significantly influenced by implant diameter and bone loss level. 4.5 mm diameter implant is not recommended for type II bone because it provides bone failure risk up to 3000 microstrain threshold even for the fully osseointegrated implant. 6.0 mm diameter implant caused positive bone turnover balance up to 0.6 mm type III bone loss, with 5.0 mm only up to 0.2 mm bone loss. Clinicians should consider these findings in treatment with short plateau implants.

Results

Maximal FPSs for osseointegrated implants (1800 ± 3270 microstrain) were found in the cancellous bone at the first fit edge under the result of FPS distribution study in the plane of critical bone-implant interface (Fig. 4). For implants with bone loss, they were observed at the same location and were significantly dependent on bone loss level (2140 ± 3600, 2200 ± 4100, 2800 ± 4500, 3500 ± 4200 ± 7000 microstrain for 0.2, 0.4, 0.6, 0.8 and 1.0 mm bone loss. Comparing to the osseointegrated implants, the following FPS increase on five bone loss levels was determined: for N implants it was 10, 25, 50, 80 and 114%; for M implants – 12, 32, 62, 92, 131% for W implants – 19, 28, 56, 94 and 133%.

Conclusion

Bone turnover was found to be significantly influenced by implant diameter and bone loss level. 4.5 mm diameter implant is not recommended for type II bone because it provides bone failure risk up to 3000 microstrain threshold even for the fully osseointegrated implant. 6.0 mm diameter implant caused positive bone turnover balance up to 0.6 mm type III bone loss, with 5.0 mm only up to 0.2 mm bone loss. Clinicians should consider these findings in treatment with short plateau implants.

References

Presented at Lisbon 2019