DENTAL IMPLANT-ABUTMENT CONNECTION TOPOLOGY – FEA INVESTIGATIONS

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Abstract: Regarding the abutment-implant connection of screw shaped dental implants, the recent studies generally compare the conical and planar ones. The current research aims at improving the abutment-implant connection, from the topological point of view, in order to lower the stresses in the implant body and lower the abutment displacement. The reference shape upon all investigated connections were built is the conical internal one. Therefore, the following connection shapes were studied: external conical, internal conical, concave, convex, concave-convex and convex-concave.

Key words: FEA, dental, implant, abutment, connection

1. INTRODUCTION

The first abutment-implant connections of, the two piece screw shaped dental implants were planar, which led to high abutment displacements during functioning. The introduction of the internal conical connection provided a better sealing and stress distribution between abutment and implant body, as well as the self-guiding of the abutment. As shown in (Wierszycki et al., 2006), the implant-abutment contact surface plays an important role in the implant's lifecycle, influencing directly its behaviour to fatigue loading. The current study investigates alternative connection shapes to the conical one, from the topological point of view, in order to improve stress distribution and values in the implant body and to lower the abutment displacement under load.

2. MATERIALS AND METHODS

The analyses are run in ABQUS, according to the ISO 14801:2007 testing layout, but in static case, with an approach of 4mm/step of the loading device (Fig. 1). The implant model used has a 4,5mm diameter, 10 mm length and bullet shape. The thread was omitted, in order to simplify the model (Kong et al., 2009). As this is a topological investigation, no dimensional analysis is conducted, the connection's shape being the only variable of the study. All connections – conical external (ex.co), concave (cc), convex (cv), concave-convex (cc-cv) and convex-concave (cv-cc) (Fig. 3 and Fig. 7) – are built around an internal conical one (int.co), which was considered the reference shape for all analysed models. The selection of the alternative connections was made on the premises that in order to decrease the stresses in the implant, and implicitly in the bone, the implant-abutment contact surface has to be increased (Bendsoe & Sigmund, 2004). The other criteria on which the above mentioned shapes were chosen are manufacturing costs, production capabilities and implant-abutment sealing.

The research was conducted in two phases. First, the internal and external conical connections were compared to the concave and convex ones. Next, based on the outcome of the analysis, the authors attempted to further improve the results.

The parts used in the tests are presented in Fig. 1. The materials applied to the parts are presented in Tab. 1. (Leyens & Peters, 2003).

Fig. 1. Assembly model and loading schematics

Part No.	Material	Material type	E [Mpa]	Rm [Mpa]	v [-]	Rp0,2 [Mpa]	A [%]
1,2,3	Ti6Al4V	Elastic Plastic	113800	1138	0.342	1069	14
5	Steel	Elastic	210000	-	0,3	-	-

Tab. 1. Material properties of the parts used in the analyses

The loading device (4) and specimen holder (6) are considered to be analytical rigid bodies (0 deformations). The friction coefficient used between the parts in contact is 0,1 (except for tied contacts).

The testing of each implant model was done as follows: an 820N tightening load was applied on the abutment fixing screw and a 500N test load was applied on the loading device.

The safety factor used in the analyses is 1,2, therefore resulting in an acceptable stress limit of 880MPa for the Ti6Al4V parts.

3. RESULTS

3.1 Phase I

The connection shapes analysed in the first phase of the research are presented in Fig. 3.

Fig. 2. Analysed connections' topology – Phase I

Fig. 3. Stress distribution in the models' fixing screws a) int.co; b) ex.co; c) cc; d) cv

According to Fig. 4 b), the stresses in the external conical connection fixing screw are too high and the influenced area too big, for it to be a viable option for the current research.

Fig. 4. Load-displacement graphic of the analysed models

The load-displacement curve was also generated for the ext.co model, for comparison purposes.

The maximum stresses in the implant bodies, after the loading step, are presented in Fig. 6: 1053,6MPa (int.co)(a), 1070,8MPa (ext.co)(b), 765MPa (cc)(c) and 881MPa (cv)(d).

Fig. 5. Stress distribution in the models' implant bodies
a) int.co; b) ex.co; c) cc; d) cv

3.2 Phase II

Further on, the authors are trying to combine the low stresses resulted from the use of the concave connection, with the high stability of the convex one (Fig. 7), resulting in the concave-convex and convex-concave connection shapes. Also, the abutment fixing screw diameter of the concave connection model is shrunk in the area where the abutment comes in contact with it, in order to observe if the displacement of the abutment is low enough as not to overload the screw.

Fig. 6. Analysed connections' topology – Phase II

Fig. 7. Stress distribution in the models' fixing screws a) int.co; b)cc-cv; c) cv-cc; d) cc (modified)

According to Fig. 8, the stresses in the new concave connection fixing screw are too high and the influenced area is too big for it to be a viable option for the current research. However, the load-displacement curve will be generated for this model also, for comparison purposes.

Fig. 8. Load-displacement graphic of the analysed models

The maximum stresses present in the implant bodies, after the loading step, are presented in Fig.10: 1053,6MPa (int.co)(a), 942,6MPa (cc-cv)(b) and 1069,8MPa (cv-cc)(c).

Fig. 9. Stress distribution in the models' implant bodies
a) int.co; b) cc-cv; c) cv-cc

4. CONCLUSIONS

Fig. 11 shows the load-displacement behaviour of all models analysed in the present research.

Fig. 10. Load-displacement graphic of all analysed models

According to Fig.11, the connections which present the best behaviour, from the stress (value and distribution) and displacement points of view, are presented in Tab.2.

Connection shape	Int.co	Cv	Cc-cv
Max. system displacement [mm]	~0,09	~0,07	~0,08
Max. implant stress [MPa]	~1054	~881	~943
Max. screw stress [MPa]	>880	~660	~733
Manufacturing difficulty	Medium	High	Very high
Implant-abutment sealing	Very good	nav	nav

Key: nav – no available data

Tab. 2. Best concluded connections comparison

From a strictly topological point of view, the research shows that the convex connection is superior, displacements and stresses distribution and value wise, to all other connection shapes analysed in the current study.

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