

REVIEW
on dissertation work
for acquiring the educational and scientific degree "Doctor (PhD)" in

area of higher education – 7. Healthcare and Sports
professional direction – 7.2. Dental Medicine
doctoral program – „Prosthetic Dental Medicine”

Author: Yavor Vasilev Gagov, master - doctor of dental medicine

Theme: „Adhesion of dental ceramics to Ti6Al4V alloy produced by CAD/CAM technologies”

Reviewer: Professor Jordan Mximov, DSc

1. Actuality of the dissertation work

In the last two to three decades, the materials science has been the fastest growing part of the overall science with applications in every sphere of human activity, including dentistry, where the biocompatibility is a major requirement. The subject of the dissertation is the adhesion in the ceramics - titanium alloy Ti64 pair and more precisely the dependence of the adhesion strength on the surface texture and the method of manufacturing the metal matrix. The ultimate goal is to improve the dental health of patients as a result of created prerequisites for the production of quality prosthetic structures. The studies, justifications and research done in the dissertation go beyond the usual framework of the scientific specialty "Prosthetic Dental Medicine" and affect other areas such as mechanics of materials, numerical methods in the mechanics of rigid deformable bodies, fracture mechanics, optimization. In this aspect, the dissertation has a poly-disciplinary character. In the aspect of all the above, I believe that the actuality of the dissertation is beyond doubt.

2. Does the PhD student know the state of the problem

Judging by the literary sources used, the justification and formulation of the purpose and tasks of the research, I think that the dissertation student knows the researched problem. The list of used literature contains a total of 185 titles (of which 157 are in English and 28 in Bulgarian) - books, monographs, textbooks, scientific articles. Among the latter I notice those published in high level Elsevier journals. It can be assumed that the achievements of the scientific community on the problem are known to the author of the dissertation work. On this basis, the dissertation student defines the main goal and the tasks to be solved to achieve the goal, thereby building on what has been achieved so far.

3. Method of the study

Given the specificity of the treated problem, a combination of natural experiments, numerical methods (such as the used finite element method, version in displacements), phenomenological approach (for example observation of the fracture surface by optical microscopy to explain the destruction mechanism) has been correctly chosen.

4. Brief description of the material on which the contributions are formulated

The dissertation work, structured in a logical sequence on 152 pages, contains notations and abbreviations used, introduction, six chapters (with conclusions after each chapter), general conclusions and directions for future work, contributions, 63 figures and 15 tables.

Chapter 1 ("Literature review" - pp 8-45) at the beginning presented titanium as a metal with good biocompatibility for the production of prosthetic structures, and more specifically the Ti-6Al-4V titanium alloy, which, by the way, is also widely used in the aerospace industry. Then, in a logical sequence, the occurrence of a practical problem is traced, i.e. the need to treat the dental crown and tooth row by means of metal-ceramic and titanium alloy prosthetic structures, the manufacturing technologies of these structures by adding and removing material, and the adhesion process at the interface of the ceramic coating – titanium matrix pair. Based on the conducted literature survey and the final conclusions, the dissertation student formulates the purpose of the dissertation work and identifies four tasks, the solutions of which will achieve the defined goal: 1) study the properties of Ti-6Al-4V alloy obtained by two methods; 2) experimental determination of the adhesion strength between the porcelain coating and the titanium 64 matrix based on the method regulated by the standard; 3) determination of adhesion strength by FEM; and 4) laboratory protocol for metal-ceramic fabrication.

Chapter 2 ("Materials and Methods" - pp 46-63) presents the materials and methods for solving the defined four tasks. A flowchart of the study is shown at the beginning of the chapter - something I welcome.

Chapter 3 (pp 64-85) shows and analyzes the results of a study of some physical and mechanical properties, as well as some geometrical characteristics of surface integrity, of titanium 64 alloy samples obtained by milling from rolled steel and by selective laser melting.

Chapter 4 (pp 86-112) shows the results from the experimental determination of the adhesion strength (according to the EN ISO 9693:2019 standard) between a porcelain coating and a titanium 64 matrix (with and without a bonding agent), as the metal matrix being made by the mentioned two manners. A phenomenological approach has been used to establish the destruction mechanism, which makes an excellent impression. An analysis of the obtained results has been carried out.

In Chapter 5, the adhesion strength was determined by the finite element method, displacement version, and implicit analyzes have been performed using ABAQUS v. 6.12.1. A comparison has been made with the experimentally obtained results. The observed differences are explained by the determinism of the FEM (the area of

integration is mathematically defined), while the characteristics of the surface integrity of the metal matrix have a stochastic nature.

Chapter 6 presents a laboratory protocol for the fabrication of titanium 64-based metal ceramics.

5. Contributions of the dissertation

Regardless of what was written in the dissertation, I have supplemented, summarized and classified the contributions as follows:

A. Scientific and applied contributions

A.1. Creation of new classifications, methods, constructs, models, etc.

- Finite element model and methodology for determining the Young's modulus of a two-component beam model subjected to three-point bending.

A.2. Obtaining and proving new facts

- Surface topography characteristics of Ti6Al4V alloy samples obtained by different methods with and without additional mechanical surface treatment.
- Correlation between the additional mechanical surface treatment of the titanium 64 matrix and the adhesion strength to the porcelain.
- Characteristics of the stressed and strained state in the vicinity of a point at the interface of a two-component (porcelain-titanium 64 matrix) beam with and without a bonding agent.

A.3. Obtaining corroborating facts

- ◆ Correlations between the roughness and micro-hardness on the one hand, and the method of sample preparation (beam type), with and without additional surface machining, on the other hand.
- ◆ The adhesion strength between the porcelain coating and the titanium alloy produced by the two methods showed close values.
- ◆ The destruction mechanism of ceramics is mixed (adhesion-cohesion), with a difference in the layer in which the adhesion or cohesion destruction occurs.

B. Applied contributions

I agree with the two applied contributions as defined in the dissertation and add a third applied contribution: Young's modulus for Ti6Al4V: 180 GPa for milled and 120 GPa for beam type SLS specimens.

6. Publications on the dissertation

The author has published a total of 3 scientific papers on the dissertation, distributed as follows:

- 1) Scientific report presented at scientific conferences in Bulgaria (Varna, 2022);
- 2) Scientific article in a web-based Bulgarian scientific journal;
- 3) Scientific article in a refereed international scientific journal, published by Elsevier, 2022.

The first publication is in Bulgarian, and the remaining two are in English.

Based on the above data, it can be concluded that the results of the dissertation have been publicized and discussed well enough.

7. Authorship of the obtained results

The dissertation has been made under the expert guidance of the scientific supervisor Prof. Tsanka Dikova, DSc. I believe that everything that should have been done personally by the PhD student has been done.

8. Autoreferat

The autoreferat reflects the essence of the dissertation and is made according to the requirements established over the years.

9. Remarks on the dissertation

The dissertation is structured and written very well. I highly appreciate the experimental research done. The latter are extensive and thorough. You can see the engineering approach to solving the problem by the scientific supervisor Prof. Tsanka Dikova, as well as her experience as an author and reviewer in international scientific journals with an impact factor. I have no fundamental remarks.

I would like to point out the following:

- The defined objective of a PhD thesis should be more specific. In this case, the definition of the objective begins with "To investigate ...". Research, in itself, is a process that results in the achievement of a goal, but research itself cannot be a goal.
- Minor inaccuracies such as "three-point experiment of bending" instead of "experiment of three-point bending".
- The wording "For the first time the topography was studied..." is not suitable for describing a contribution. It is obvious that if it is "for the second time" - it will not be a contribution. Moreover, research, in itself, cannot be a contribution; contribution is the result obtained from the research.

10. Other questions

I strongly believe that the educational function of doctoral studies has achieved its goal. The doctoral student has increased his knowledge in the field of the dissertation.

11. Conclusion

I believe that the presented dissertation meets the requirements of the Law for the Development of the Academic Staff in the Republic of Bulgaria. The achieved results give me the reason to propose to the respected scientific jury to award the educational and scientific degree "Doctor" to Yavor Vasilev Gagov, Master - Dentist, in the field of higher education - 7. Health care and sports, professional direction - 7.2. Dental Medicine, doctoral program "Prosthetic Dental Medicine".

12.03.2023 r.

Reviewer:



Gabrovo

Professor Jordan Maximov, DSc