OPINION

by Prof. Georgi Rangelov Todorov, DMD, DMedSc

ON: dissertation paper of Yavor Vasilev Gagov, DMD, on the topic **Adhesion of dental ceramics to Ti6Al4V alloys manufactured using CAD/CAM technologies** for the acquisition of educational and scientific degree of "Doctor".

1. Relevance of the problem

Yavor Vasilev Gagov, DMD, discusses the properties and adhesion of dental ceramics to Ti6Al4V alloy manufactured using modern CAD/CAM technologies for milling and selective laser melting.

Obtaining good adhesion strength ensures durability of the metal ceramic prosthetic restoration. Currently, there are no sufficient data on the application of titanium and its alloys, in particular the alloys manufactured using selective laser melting and the subsequent importance for ceramics adhesion.

In the practical aspect, Gagov, DMD, discusses and proposes laboratory protocols for the most advanced CAD/CAM technologies for milling and laser melting of titanium alloys. The stages of these protocols facilitate a specific morphology and roughness which ensures an effect on the adhesion strength between the ceramics and the titanium substructure.

I do reckon that the protocols and practical guidance presented by Yavor Gagov, DMD, define the relevance of and need for this dissertation paper.

2. References and literature review

The references include 185 authors, of whom 28 authors use the Cyrillic alphabet, 18% of the sources have been published after 2017 (i.e. in the last five years).

The literature review consists of 44 pages which demonstrates excellent cognizance and knowledge of the topic.

Gagov, DMD, discusses ceramic prosthetic restorations, the use of titanium and titanium alloys in dental medicine, titanium casting protocols, lost-wax casting, modern CAD/CAM technologies, types of dental ceramics and their corresponding adhesion to titanium alloys.

The literature review ends with conclusions which put forward the need for adequate adhesion and the ways to act on the surface of the titanium substructure. The conclusions comment on the issues of titanium alloys and why the modern CAD/CAM technologies for milling and selective laser melting are preferred. The paper looks at the surface features which enable higher adhesion strength between porcelain and titanium and titanium alloys.

In the proficiently presented and detailed literature review, I found a wealth of information and analysis by the doctoral candidate Gagov, DMD, on the presence of

good adhesion, application of milling and selective laser melting, need for experimental research, and presentation of a laboratory protocol for the use of titanium alloys.

3. Objective and problems

The doctoral candidate aims to:

study the adhesion between dental ceramics and Ti6Al4V alloy manufactured using CAD/CAM technologies.

Solutions have been provided for four problems and a total of five subproblems (under problem 1 and 2)

- study the properties of Ti6Al4V alloy manufactured using modern CAD/CAM technologies;
- conduct an experimental study of the adhesion strength with various types of surface processing and to study the mechanisms of coating destruction;
- determine porcelain strength using the finite element method;
- develop a laboratory protocol for the manufacturing of metal ceramic restorations made of Ti6Al4V alloy.

4. Author's own research, results, analysis and conclusions

I received the dissertation paper on my email, along with copies of the author's summary, minutes of the Departmental Council meetings, records of candidate's minimum requirements compliance, records of candidate's entitlement to defense, accompanying orders, certificates, academic transcripts, declarations, a total of, if I have counted correctly, 14 documents.

After stating the objective and problems in chapter two of the dissertation (pages 46 to 64), Gagov, DMD, describes his own materials and methods.

I express my positive assessment and approval of this approach toward arranging a dissertation paper, author's own materials and methods (in chapter two) and the subsequent results, analysis and conclusions (chapter three, four, five and six, respectively), without statistical processing of results.

4.1. Materials and methods

Fig. 2-1 (page 46) shows the entire workflow of the research work:

- production of sized Ti6Al4V plates, a total of 32 pieces and the 7 (groups) tests conducted.

I consider this approach toward systematization in table 2-1 to be an original scientific contribution by Yavor Gagov, DMD.

The materials and methods of author's own research have been presented very accurately and specifically. Then follows (page 46 to 64) the greater picture, the included studies, study procedures:

- geometrical features;

- density;
- surface morphology and roughness;
- microhardness testing;
- adhesion strength;
- elastic modulus;

- finite element method of strength analysis;
- boundary conditions.

Experiments have been presented in 2.2.1 to 2.3.8, a large volume covering 32 samples, 7 groups of tests, 11 figures and 4 tables, properly oriented approach (samples, types of tests), aptly and amply visualized and illustrated.

4.2. Properties of the Ti6Al4V alloy manufactured using milling and selective laser melting.

The following have been studied:
- geometrical features;
- density;
- followed by analysis of results;
- surface morphology and roughness;
- analysis of results.

The paper includes 11 figures, a very detailed images of the titanium alloy samples manufactured using milling, selective laser melting.

Each group of features (density, roughness, hardness, elasticity) ends with an analysis of results (pages 68, 76 and 80) and subsequent conclusions. A total of 15 conclusions have been presented concerning density, surface morphology, roughness and the importance of sandblasting, microhardness testing, influence of subsequent heat processing.

4.3. Experimental study of adhesion strength between dental ceramics and Ti6Al4V alloy

The following have been studied:
- adhesion strength;
- mechanism of coating destruction.

The study has examined the adhesion strength and mechanism of destruction of ceramics bonded to Ti6Al4V alloy processed in three ways: sandblasting, application of bonding agent and combined processing. The adhesive destruction (metal and oxidized layer) and cohesive destruction (through the oxidized layer) have been measured during milling and selective laser melting, respectively, as presented in fig. 4-18 and fig. 4-19. Eight conclusions (discussion) have been made based on the obtained results. A confirmation is reached that, in terms of clinical practice, cohesive fracture is more favorable, and that in the alloy manufactured using selective laser melting the differences are not that big.

4.4. Determination of adhesion strength between porcelain and Ti6Al4V alloys using the finite element method.

Using the finite element method, employing two models of samples divided into two groups, with a total of 4 samples. Determination of stresses in samples without bonding agent and in samples with underlayer of bonding agent, followed by analysis of results.

In the analysis of results, it is hard to account for the conditions at the metal/ceramics and metal/bonding agent interfaces which have an impact on the mechanical and chemical component of the adhesion.

In the samples manufactured using laser, it is not possible to account for the morphology and roughness which increases the mechanical adhesion of the bond to the metal and results in the porcelain being chipped off the bond.

4.5. Laboratory protocol for the manufacturing of metal ceramic restorations from Ti6Al4V alloy

The paper proposes a comprehensive laboratory protocol based on the obtained adhesion strength results. A very detailed step by step description has been provided of the conventional and digital protocol. The digital laboratory protocol is discussed and presented in tables 6-2 and 6-3 (about titanium alloy manufactured using milling and the allow manufactured using selective laser melting).

The dissertation contains author's own research presented on 93 pages, in 58 figures, 14 tables and 13 charts. Four directions for future work have been presented. A significant volume of research has been conducted – if I have counted correctly, there are a total of 48 experimental setups.

I consider this volume of tests and their interpretation, the subsequent analyses, the total of 14 contributions presented, the brilliantly made conclusions, an evidence that the doctoral candidate possesses in-depth knowledge of the topic.

5. Author's summary

Author's summary meets the requirements, it has been properly structured, has been presented on 48 pages, it is completely consistent with the contents of the dissertation paper. Three publications related to topic of the dissertation have been presented.

6. Conclusion

The dissertation paper of Yavor Vasilev Gagov, DMD, titled **Adhesion of dental ceramics to Ti6Al4V alloys manufactured using CAD/CAM technologies** is an analytical, detailed, focused work which has summarized the contemporary trends, materials and equipment in the field of prosthetic dentistry.

I reckon that the large volume of tests, the aptly presented experimental setups, the properly made analysis and subsequent conclusions, the presented academic papers on the

topic are an irrefutable proof that Gagov, DMD, possesses excellent knowledge of the topic.

I hereby express my positive assessment of the dissertation paper of Yavor Vasilev Gagov, DMD, titled "Adhesion of dental ceramics to Ti6Al4V alloys manufactured using CAD/CAM technologies".

I will vote **"YES"** to confer the educational and scientific degree of "Doctor" to Yavor Vasilev Gagov, DMD.

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city of Plovdiv

OPINION HAS BEEN PREPARED BY:
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