TO
THE CHAIRMAN OF THE
ACADEMIC COMMITTEE
APPOINTED BY ORDER
№ P 109-599/23.12.2020
OF THE RECTOR OF MEDICAL
UNIVERSITY OF VARNA

With reference to your Record №1 of 05.01.2020

I hereby enclose: A REVIEW
under a procedure for awarding a **Doctorate** degree
in the higher education domain of 7. Healthcare and Sports, Professional field of 7.2. Dental Medicine – PhD programme in Orthopedic Dentistry
to the candidate **Preslav Plamenov Penchev, MD**

Reviewer : Professor Georgi Rangelov Todorov, DMD
Habilitated in the professional field of 7.2. Dental Medicine,
Medical University of Plovdiv

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The review is in accordance with the requirements of the Advancement of the Bulgarian Academic Pool Act, art. 5, para.2; Rules of Advancement of the Academic Pool of the Medical University of Varna, in compliance with art. 24, para. 6 and art. 30, para. 3 of the Implementation Rules of ABAPA

Review

By Professor Georgi Rangelov Todorov, DMD

RE: Dissertation thesis by Preslav Plamenov Penchev, MD, a self-study candidate in the PhD programme in Orthopedic Dentistry enrolled with Order № P-109-162/24.04.2019г.

Theme: Metal Investment Casts Using SLA 3D Printed Prototypes

I. Procedure introduction

This Review has been made on the grounds of Order № P 109-599/23.12.2020 of the Rector of Medical University of Varna in compliance with the Advancement of the Bulgarian Academic Pool Act, art. 5, para.2; Rules of Advancement of the Academic Pool of the Medical University of Varna, in compliance with art. 24, para. 6 and art. 30, para. 3 of the Implementation Rules of ABAPA pursuant to Record No 1/05.01.2020 of the Academic Committee

1. Biographical information

Preslav Penchev, MD was born on 31.04.1991 in Ruse, Bulgaria.

In 2010 he finished the Baba Tonka Secondary School of Mathematics, in Ruse.

In 2016 he was graduated with a Master's degree in Dental Medicine from the Professor Paraskev Stoyanov Medical University of Varna.

Since 2016 he has been occupied as an assistant university professor at the Medical University of Varna, the Faculty of Dental Medicine.

At the Clinic of Prosthetic Dentistry he teaches practicals in Propedeutics of Prosthetic Dentistry.

With Order No P 109-162/24.04.2019 he has been enrolled as a self-study PhD student in the Orthopedic Dentistry.

II. Dissertation thesis

1. **Topicality of the researched theme**

The technology of layer-by-layer fabrication of dental prosthetics is a modern trend in contemporary dental medicine. This method employs a 3D model obtained through applying the material layer-by-layer, allowing the creation of intricate parts, producing multiple items at a time which is impossible to achieve through the conventional technology.

P. Penchev, MD explores and presents the theoretical and the practical side of the 3D SLA prototype printing .

The innovative solutions suggested by the candidate determine very accurately the topicality and appropriateness of the dissertation theme, in my opinion. In this work, the possibilities for fabrication of investments casts with 3D printed prototypes are explored. The original exploration done by the candidate suggest ways of improving the stages of casting through modern technology.

Proof of the topicality of the thesis shall be given in the following art. 2. Bibliographical reference.

2. **Bibliographical reference and overview**

The bibliographical reference in the dissertation thesis contains 180 authors, thereof 26 in languages using the Cyrillic alphabet.

The strongest point proving the topicality and contemporary voice of the theme is the literary overview itself:

- 66% of the publications date from 2010 (and onwards);
- 2% publications date from 2020;
- In 37 publications (in languages of Latin alphabet) Bulgarian authors are present;

The literary overview comprises 35 pages. The candidate P.Penchev, MD competently explores the modern additive technology, stereolithography, selective laser melting (SLM); the casting technology and materials, waxes, investment materials, gating systems are given in precise details. Up to page 18, an exhaustive overview of the contemporary additive technology is given, and onward to page 44 the technology of metal casting, classical materials and methods are explored in detail.

The literary overview ends without analysing the particulars of protocol and approach of additive technology, excluding the five sentences on page 43. **In no way this is considered a weakness, on the contrary, it is yet another proof** of the newness, modernness and innovation of the studied technology and of the topicality and interest of the dissertation theme.

3. **Aim and objectives**

The candidate sets the aim to explore the possibilities for fabrication of the metal investment casts using SLA 3D printed prototypes.

For the attainment of the aim, the candidate sets four objectives and seven tasks to include:

- comparative analysis of materials used in metal investment casting where the prototype is eliminated by thermal process;
- comparative analysis of prototype precision in SLA 3D technology;
- exploration of the impact that printed pieces exert on the casting flask, temperature mode and the respective investment material;
- improving the casting conditions through software optimisation of prototypes prior to printing.

4. **Author's original research and development**

Materials and methods

Within 26 pages, the candidate P. Penchev, MD sets forth exhaustively and specifically his own developments in terms of material and technology.

Under objective 1 – Four identical test pieces are fabricated from Pattern Resin, C-cast, CAD/CAM wax and Castable Resin (trade names of different producers).

For the piece made form Pattern Resin, a cylinder silicone mould (20 mm diameter and 20 mm height) is used to fill the material in.

Digital samples of the above dimensions (20 x 20) are generated and cut from C-cast and CAD/CAM wax.

The fourth test piece is 3D SLS printed from Castable Resin.

For this task, a special refractory prop with four beds is made from Sherafina Rapid investment material. The prop with the test pieces undergo a thermal treatment (Fig. 3 and 4), the temperature of 1050^{o} C is sustained for thirty min. and the ash residue is then measured with analytical balances.

Under objective 2 – Digital samples in cubical and cylindrical shape of dimensions 10x10x10 mm are generated. These sample (represented in Fig. 5-A) are classified in three groups (depending on the position of the printing base.

Based on their structure, the printed test pieces fall into six groups (Fig. 5-A and B, page 49 and 50) and exported in .stl file in software (Preform 3.4.4.

Formlabs). Then printing follows (on 3D printer) from resins Castable Resin and Castable wax, of layer thickness of 25 μm; and 10 measurements in the x, y, z planes are done with a digital caliper.

Then follow measurements of the six groups, however varying according to the objectives of the tree task.

Under objective 3 – A key point in task 3 is the weighed quantity of material and temperature mode. Here, identical test pieces are SLS printed from Castable Resin and Castable wax (Fig. 9 and Fig. 10, page. 54). Casting rings of pink wax are made (the piece is at a distance of 5 mm of from the ring wall), a single sprue is applied and two types of investment materials are used; the flask undergo a standard temperature mode (Fig. 61). three different test setups are explored.

Under objective 4 – In files of different extension .stl, six digital prototypes of full crowns (incisors, premolars and molars) are explored, prepared for vacuum casting from cobalt–chromium–molybdenum alloy, followed by software importing in the optimal position. Then digital sprue samples (of 4.5 mm diameter) are generated in a position so that their vector coincides with the biggest diameter of the digital prototype, followed by placing the digital sprue base (Fig. 20). When the digital piece is generated, Transform tool is loaded to allow precise setting of the desired dimensions of the part until an accurate three-dimensional positioning is reached (Fig. 22, Fig. 21 and Fig. 22). Once the positioning of the digital objects relative to the walls of the casting ring is done, an .stl file is generated and the 3D SLS printing with resin Castable wax is done.

Here, in task 2, .stl files imported in non-medical software for 3D processing are used for the positioning of the sprues, and the metal wells, respectively adjusted in size with Transform tool; a casting ring is designed (of dimensions depending on the gating configuration), then it is all exported in an .stl file and 3D printed.

All this is clearly and in detail explained in 26 pages, and without any excessive information the whole picture of the author's authentic research is drawn.

I consider this precise approach and protocol to be a personal contribution of the candidate P. Penchev, MD. If correctly counted, there are total of 72 examinations, and namely this voluminous research work I see as an orginal academic contribution of the candidate.

5. Results and discussion

In chapters Four, Five, Six and Seven (total of 49 pages), the candidate sets forth the results of his exploration illustrated by 43 figures and 29 tables.

Objective 1 The test pieces being burnt off, the ash residue is collected and weighed using an analytical balance. The results are discussed starting from 25ºC, then 100ºC, and further in an interval of 50ºC, and the changes in the test pieces are given in 11 figures.

The material CAD/CAM wax, being composed of wax, burns off leaving an insignificant ash residue, while Pattern Resin, although burning off completely as well, shows a temperature expansion, and C-cast, too, burns off completely but melts at a higher temperature. Castable Resin gives an insignificant ash residue, however when heated no full melting occurs, due to which a modification of the flask heating temperature mode turns out necessary, or alternatively, waxing of the prototype surface, according to the observations of the candidate, P. Penchev.

Objective 2 Statistical processing of the results is made using specialised software – IBMMSPSS и IBM^{TM}. Further the conclusions are presented:

- The material Castable wax provides conditions for better precision of objects compared to Castable Resin. These two materials are suitable for fabrication of prototypes concerning the criterion Precision of printing;
- Castable Resin has better mechanical strength, however due to the shrinkage, any further polymerisation treatment is unsuitable;
- As a result of the software modifying, the mechanical qualities of the test pieces change but without affecting the printing precision.

Objective 3 The derived results are photographed, coded and interpreted in tables, software processed and analysed to give the following conclusions:

- The temperature expansion of the pieces from Castable Resin and Castable wax considerably exceed that of the investing materials;
- The employed materials sublimate with the rise of temperature, no gas exhaustion is observed, however additional tension is found on the internal flask surface;
- The results show that besides those recommended by Formalabs, other investment materials can be used as well;
- Cracks in the flask wall occur with both materials (Castable wax and Castable Resin);

- For the purpose of reducing the tension on the flask surface following the temperature expansion and massive gas flow, the pieces can be digitally modified into hollow objects with openings;
- Such modification allows for the proper and effective elimination of the prototypes without compromising the integrity of the flasks made from investment materials of compression strength from 5.5 MPa to 11 MPa.

Objective 4 Digitalising of the gating system allows for accurate positioning of the components towards each other:

- 3D printing systems are more resistant to external influence;
- The preparation performed with software means saves time compared to the conventional methods;
- Digitalisation of the whole gating system (funnel, casting ring, etc. elements) ensures optimal casting and reliable results.

The candidate, Preslav Penchev, MD has explored (in 78 test pieces and total of 14 types of testing) which technological methods should be observed in the process of fabricating prosthetic prototypes through SLA 3D printing. Studied are temperature and volume changes observed in the prototypes, problems and specifics are identified and their respective solutions are suggested.

It is very well observed how positioning affects the direction of printing, and the issues of printing precision changes are examined.

The established parametres as a result of the study could be used to facilitate the dental technicians in producing the gating system as a whole – flask, casting ring, sprue base, sprues, prototype elimination, temperature mode, investment material. These outcomes would improve the dental room and dental laboratory technology for 3D printing in metal investment casting.

6. **Dissertation summary**

The dissertation summary fulfills the structural implications for units organisation, comprising 63 pages, 51 figures and 2 tables. Provided are 3 publications of related topics. The contribution of the dissertation thesis are presented as:

- **contributions of original nature**: The macroscopic changes in the test pieces for investment casting with dental alloys are well documented; the high precision of the 3D printing with Castable wax compared to Castable Resin is proven; the polymerisation of Castable Resin is not obligatory, it causes deformity of parts; the weighed quantity of pieces from Castable wax and Castable Resin accounts for the flask wall tension, and therefore the parts need to be digitally designed as hollow objects with an opening.

- **contributions of confirmatory nature**: The material Castable Resin is suitable for prosthetic prototypes in terms of its high precision and ash residue; the study proves that in 3D printing with Castable wax and Castable Resin on Form® 2 printer, precise prototypes are produced, with discrepancy of 25.27μм in Castable Resin and 13.87μм in Castable wax.
- **contributions of original nature**: Suggested is a method for digital design of the whole gating system based on predefined dimensions of the casting ring and their subsequent 3D printing as a monolithic object; suggested is an individual gating plan and 3D printing.

7. Impression

The dissertation thesis 'Metal Investment Casts Using 3D SLA Printed Prototypes' is of practical application, it represents a summary of the modern trends and tendencies in Prosthetic dentistry.

A technological protocol and method are suggested that could be applied in postgraduate training, PhD programmes, and dental laboratory technicians training.

The related scientific publications of the candidate prove beyond any doubt the expertise of Preslav Penche in the topic.

I hereby express my positive opinion of the dissertation thesis 'Metal Investment Casts Using 3D SLA Printed Prototypes'.

I shall give my 'Pro' vote for awarding a Doctorate degree to Preslav Plamenov Penchev, MD.

17.01.2021
Plovdiv

Reviewer:
Professor Georgi Rangelov Todorov, DMD