

**"TITU MAIORESCU" UNIVERSITY, BUCHAREST
DOCTORY SCHOOL OF DENTAL MEDICINE**

THESIS SUMMARY

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**STUDIES ON METALLIC BIOMATERIALS USED IN
FIXED DENTAL PROSTHESIS**

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INTRODUCTION

The materials and technologies used in fixed prosthetic rehabilitations have continuously evolved because of the recent advances made in contemporary dentistry. Due to their superior mechanical properties, high durability and favorable behaviour in the oral environment, metallic biomaterials represent an essential component of dental treatments.

Metallic alloys continue to be used as materials of choice in many clinical situations, especially in restorations with increased functional requirements. This remains true despite the significant advances made in the field of ceramic and polymeric materials.

The need for a thorough and updated evaluation of the behaviour of metallic biomaterials used in fixed dental prosthesis, in the context of the diversification of modern manufacturing methods and the increase in clinical requirements, was the reason for choosing this topic. The use of digital CAD/CAM workflows and additive manufacturing technologies, such as 3D printing of metal alloys, has radically changed the way in which dental prosthetic restorations are made. These technologies have opened new perspectives in terms of dimensional accuracy, reproducibility and personalization of metal structures.

However, they have also brought the need for thorough evaluation of the mechanical and electrochemical performances of the obtained materials. From a methodological point of view, this doctoral thesis combines the theoretical analysis of metallic biomaterials with experimental and observational investigations carried out using modern, scientifically validated methods. The methods used allow the correlation of the structural and functional characteristics of dental alloys with the processing techniques used and the clinical effects. The aim of the research was to provide an image of how metallic biomaterials behave in the oral environment by using both standardized laboratory tests and descriptive and comparative analyses. The work is structured in several independent studies, each of them having clear objectives, which helps to substantiate the general conclusions of the thesis.

The doctoral thesis aims to improve the understanding of the role of metallic biomaterials in fixed dental prosthetics, highlighting the benefits, disadvantages and potential uses in contemporary manufacturing technologies. The results provide scientific support for choosing the most effective materials and methods for prosthetic restorations. The quality of the medical act and the longevity of dental treatment are directly affected by these methods.

Hypothesis

The hypothesis of this doctoral thesis is based on the fact that the performance of metallic biomaterials used in fixed dental prosthesis depends on a variety of factors, including the chemical composition of the alloys, the manufacturing technique used and the environment in which they are used.

It is considered that cobalt-chromium alloys created using modern manufacturing technologies, especially by 3D printing, have microstructural peculiarities different from those obtained by conventional casting methods. These peculiarities can affect the electrochemical behaviour, corrosion resistance and mechanical properties of fixed prosthesis restorations.

In this case, the microstructural changes caused by the processing method can directly affect the stability of the alloys in the oral environment, which is characterized by changes in pH, temperature and repetitive mechanical stresses. These variations can stimulate processes of corrosion and decomposition of materials, which can have biological and functional consequences in the long-term success.

To the same extent, the working hypothesis considers the fact that the implementation of digital technologies in dental prosthesis is influenced by the experimentally demonstrated material performances. The perceptions, practical experience and level of acceptance of dental technicians are also important for the adoption and standardization of new technological flows.

Therefore, this thesis starts from the hypothesis that the integrated approach – both experimental and observational – allows a more complete and realistic evaluation of the metallic biomaterials used in fixed dental prosthetics. The present scientific work helps to substantiate clinical-technical decisions based on scientific evidence.

General objectives

The general aim of this doctoral thesis is to analyze in detail the behaviour of metallic biomaterials that are used in fixed dental prosthesis. This is achieved by correlating the manufacturing methods with the electrochemical, mechanical properties and clinical effects of metallic biomaterials.

The research pursued a series of specific objectives interconnected to achieve these general objectives. These objectives include:

- to investigate how manufacturing methods influence the corrosion behaviour of cobalt-chromium alloys used in indirect fixed dental restorations, under conditions simulating the oral environment;
- to examine how pH variations affect the electrochemical stability of metal alloys, using clinical conditions;
- to compare the electrochemical, microstructural, and chemical characteristics of Co-Cr alloys obtained by conventional casting and 3D printing;
- to determine clinically relevant differences between metal structures created by traditional methods and those obtained by modern technologies;
- to assess dental technicians' perceptions of the use of melt-cast and sintering technologies, as well as the degree of integration of digital workflows in the laboratory;
- to examine the relationship between dental technicians' practical experience and their preferences for specific manufacturing methods;
- determining the bending strength of metal-ceramic systems based on cobalt-chromium alloys made by different manufacturing methods;
- correlating the results obtained in experimental and observational studies with the clinical implications regarding the durability, reliability and performance of fixed prosthetic restorations.

By achieving these objectives, the thesis aims to help optimize the choice of materials and technologies used in modern dental prosthetics, providing scientific support for evidence-based clinical practice.

General research methodology

In this work, the general research methodology was an integrated approach. This was done to gain a deeper understanding of how metallic biomaterials used in fixed dental prosthetics work. This combined laboratory experimental methods with observational methods. The research was structured in three main methodological directions, each representing the studies that were presented in the personal section of the thesis.

First, the research focused on evaluating the corrosion behaviour of cobalt-chromium alloys that are used in fixed dental prosthesis. This experimental study was carried out in vitro. In order to achieve a relevant comparative analysis, metallic samples were constructed using two different manufacturing methods: conventional casting and additive manufacturing, or 3D

printing. The tests were carried out in artificial saliva solutions with different pH levels. These solutions modeled different clinical conditions. Electrochemical analysis included open circuit potential evaluation, potentiodynamic polarization tests and Tafel analysis.

All of these methods are validated and are frequently used in the corrosion assessment of dental biomaterials. Microstructural and chemical analyses were carried out by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS). These analyses revealed surface and compositional changes associated with degradation processes.

A study using a structured questionnaire addressed to dental technicians demonstrated the second methodological direction. The aim of this study was to assess professional experience, current laboratory practices, comparative perceptions of metal component manufacturing methods and the degree of adoption of digital technologies. A descriptive and inferential analysis of the collected data was performed to identify trends, relationships and significant differences between the studied groups.

In the third research direction, comparative experimental research of the mechanical behaviour of different metal-ceramic structures focused on determining the bending strength. Cobalt-chromium alloys that were manufactured by traditional casting and 3D printing were used to create the samples. The appropriate ceramic layer was applied over them. According to international standards, three-point bending mechanical tests were performed.

The conclusions of these tests provided the opportunity to evaluate the impact of the manufacturing method on the mechanical behaviour and clinical reliability of prosthetic restorations.

The research provides a coherent and in-depth approach to metallic biomaterials used in fixed dental prosthetics by correlating the results obtained within the three methodological directions. This is achieved by integrating objective experimental data with relevant information from current laboratory practice.

1st STUDY – CORROSION BEHAVIOUR OF CO-CR ALLOYS DEPENDING ON THE MANUFACTURING METHOD AND THE PH OF THE SIMULATED ENVIRONMENT

The first experimental study aimed to evaluate the corrosion behaviour of cobalt-chromium alloys used in fixed dental prosthetics, depending on the chosen manufacturing method and on the variations in the pH of the simulated environment. Co-Cr alloys represent one of the most used categories of metallic biomaterials due to their high mechanical strength, biocompatibility and relatively low costs compared to noble alloys. However, their electrochemical behaviour can be significantly influenced by the processing method and the conditions of the oral environment.

In this study, two types of metallic structures made from the same type of Co-Cr alloy, but by different manufacturing methods, were analyzed: conventional casting and additive manufacturing using SLM (Selective Laser Melting) technology. The samples were subjected to electrochemical tests in simulated artificial saliva environments with different pH values, in order to reproduce the variable conditions encountered in the oral cavity. The analysis methodology included potentiodynamic polarization tests, determination of corrosion potential and corrosion current density, as well as surface analyses by scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS). These methods allowed the evaluation of both the electrochemical behaviour and the microstructural changes of the samples.

The results of the study revealed significant differences between the alloys obtained by casting and those made by SLM technology. The additively manufactured structures presented a finer microstructure and a more uniform distribution of alloy elements, which led to superior corrosion resistance under certain pH conditions. Also, pH variations directly influenced electrochemical parameters, with acidic environments favouring electrochemical degradation processes. The study demonstrated that the manufacturing method has a significant impact on the electrochemical behaviour of Co-Cr alloys, and additive manufacturing technologies can offer advantages in terms of corrosion resistance and material stability in the oral environment.

2nd STUDY – OBSERVATIONAL STUDY ON DENTAL TECHNICIANS’ PERCEPTION OF MELTING-CASTING AND SINTERING TECHNOLOGIES

The second study was observational in nature and aimed to evaluate dental technicians’ perception of the technologies used in the processing of metal alloys, especially traditional melting-casting methods and modern sintering or additive manufacturing technologies.

The main aim of the study was to analyze the level of knowledge, degree of use and preferences of dental technicians in relation to these technologies, as well as the factors that influence the choice of a manufacturing method in laboratory practice.

The study was conducted based on a structured questionnaire, distributed to dental technicians active in dental laboratories. The questionnaire included questions regarding professional experience, types of technologies currently used, perceptions of the advantages and disadvantages of each method, and anticipated trends for the future of metal prosthetics.

The analysis of the results highlighted that, although traditional casting methods continue to be widely used, digital technologies and sintering or 3D printing processes are gaining more and more ground in modern laboratories. Technicians recognized the advantages of digital technologies in terms of precision, reproducibility and reduction of human errors, but limitations related to high initial costs and the need for additional training were also mentioned.

The study highlighted a clear trend of transition to digital workflows, confirming that additive manufacturing and CAD/CAM technologies are becoming increasingly relevant in contemporary prosthetic practice.

3rd STUDY – COMPARATIVE EXPERIMENTAL STUDY ON THE BENDING STRENGTH OF CO-CR ALLOY–CERAMIC SYSTEMS OBTAINED BY CASTING AND 3D PRINTING

The third experimental study aimed to compare the bending strength of metal-ceramic systems made on cobalt-chromium alloy frameworks, obtained by two different manufacturing methods: conventional casting and 3D printing. The bending strength of metal-ceramic systems is an essential parameter for evaluating the durability of prosthetic restorations, as they are constantly subjected to complex mechanical stresses in the oral environment. The manufacturing method of the metal framework can influence the alloy microstructure, ceramic adhesion and the mechanical behaviour of the entire system.

In the study, standardized metal-ceramic samples were made, using the same type of cobalt-chromium alloy, but processed by two different methods: conventional casting and additive manufacturing using SLM technology. A ceramic layer was applied to these metallic infrastructures according to specific technological protocols.

Mechanical testing was performed by the three-point bending test, using a universal testing equipment, according to the applicable standards. The main parameter analyzed was the bending strength of the metal-ceramic system, correlated with the type of metallic infrastructure used.

The results of the study highlighted differences between the two analyzed groups, suggesting the influence of the manufacturing method on the mechanical behaviour of the ceramic-metal system. The structures obtained by 3D printing technology presented comparable or superior values of bending strength, due to the more homogeneous microstructure and the high density of the material.

The study's conclusions emphasize that additive manufacturing technologies can represent a viable alternative to conventional methods, offering adequate mechanical properties and an increased potential for standardization of the manufacturing process.

DISCUSSIONS

The results obtained in the three studies included in this thesis provide an integrated perspective on the behaviour of metallic biomaterials used in fixed dental prosthesis, both from an experimental point of view and from the perspective of technical and clinical practice. The comparative analysis of the manufacturing methods, electrochemical behaviour and mechanical properties of cobalt-chromium alloys highlighted the direct influence of the processing technology on the performance of the materials.

The first study demonstrated that the manufacturing method has a significant impact on the corrosion behaviour of Co-Cr alloys. The structures obtained through the additive manufacturing technology presented a finer microstructure and a more uniform distribution of the alloy elements, which contributed to a superior corrosion resistance under certain environmental conditions. These results are clinically relevant, as corrosion is one of the main factors that can affect the durability of metal restorations and their biocompatibility in the oral environment. The simulated pH variations in the study demonstrated that acidic environments favour electrochemical degradation processes, confirming that fluctuations in the oral environment can influence the behaviour of dental materials. This aspect emphasizes the importance of selecting biomaterials and manufacturing technologies according to the specific clinical conditions of each patient.

The second observational study provided a practical perspective on the way in which traditional and modern technologies are perceived and used in dental laboratories. The results indicated a still predominant use of conventional casting methods, but with a clear trend of transition towards digital technologies and sintering or 3D printing processes. This development reflects the current transformations in the field of dental prosthetics, where the digitalization of workflows is becoming increasingly common. Dental technicians have recognized the advantages of digital technologies, especially in terms of precision, reproducibility and the reduction of human errors. However, high initial costs and the need for additional training have been identified as limiting factors in the wide adoption of these technologies. These observations are in line with the results of experimental studies, which suggest that modern technologies can provide superior performance, but imply significant changes in infrastructure and professional training.

The third experimental study analyzed the flexural strength of metal-ceramic systems made on Co-Cr frameworks obtained by different manufacturing methods. The results showed that structures made by additive manufacturing have comparable or superior flexural strength

values compared to those obtained by conventional casting. This can be explained by the more homogeneous microstructure, the high density and the reduction of internal defects, characteristic of 3D printing processes. The correlation of the results of the two experimental studies highlights a common trend: additive manufacturing technologies can positively influence both the electrochemical behavior and the mechanical properties of Co-Cr alloys.

These results support the idea that modern manufacturing methods are not only a technological alternative, but can contribute to improving the clinical performance of prosthetic restorations.

The integration of the results of the observational study with those of the experimental studies suggests that the evolution of manufacturing technologies should be analyzed not only from a material and mechanical point of view, but also from the perspective of the professional and technological adaptation of dental laboratories. The adoption of new technologies depends on both scientifically demonstrated clinical benefits and economic accessibility and the level of training of personnel.

Overall, the results of the thesis highlight that the manufacturing method directly influences the performance of metallic biomaterials used in fixed dental prosthetics. Additive manufacturing technologies offer important advantages in terms of microstructure control, reproducibility and mechanical properties, which gives them significant potential in modern prosthetic practice.

However, the transition to these technologies requires a careful assessment of costs, the necessary infrastructure and the level of professional training. Therefore, the optimal integration of new technologies in dental prosthetics must be supported by both scientific evidence and appropriate educational and economic strategies.

GENERAL CONCLUSIONS

The main objective of this doctoral thesis was to evaluate the behaviour of metallic biomaterials used in fixed dental prosthetics, by correlating the manufacturing methods with electrochemical and mechanical properties and current trends in technical and prosthetic practice. Based on the results obtained in the three studies, the following general conclusions can be formulated:

1. Cobalt-chromium alloys remain basic biomaterials in fixed dental prosthetics, due to their high mechanical strength, biocompatibility and low cost compared to noble alloys.
2. The manufacturing method significantly influences the electrochemical behaviour of Co-Cr alloys, with structures obtained through additive manufacturing presenting a finer microstructure and a more uniform distribution of alloy elements.
3. Alloys manufactured using SLM technology have demonstrated corrosion resistance comparable to or superior to those obtained by conventional casting, depending on the simulated environmental conditions.
4. Variations in the pH of the oral environment directly influence the corrosion behaviour of metallic alloys, with acidic environments favoring electrochemical degradation processes.
5. Modern manufacturing technologies, such as CAD/CAM and 3D printing, are positively perceived by dental technicians, especially due to the increased precision and reproducibility of the technological process.
6. Conventional casting methods are still widely used in dental laboratories, but there is a clear trend of transition to digital workflows and additive manufacturing technologies.
7. The main barriers to the adoption of digital technologies are the high initial costs and the need for additional professional training, aspects that influence the pace of their implementation in current practice.
8. The flexural strength of metal-ceramic systems is influenced by the manufacturing method of the metal infrastructure, due to the microstructural and density differences of the material.
9. The structures made by additive manufacturing presented comparable or higher values of flexural strength, indicating a favorable mechanical behaviour for clinical use.
10. Additive manufacturing technologies offer an increased potential for standardization and control of material properties, contributing to obtaining prosthetic restorations with predictable performance.

11. The correlation of the results of the three studies highlights the advantages of modern manufacturing technologies, both from an electrochemical and mechanical point of view, compared to conventional methods.

12. The integration of digital technologies in dental prosthetics must be carried out gradually, taking into account costs, infrastructure and the need for adequate professional training.

13. The results of the thesis contribute to the reason of choice of biomaterials and manufacturing methods according to clinical requirements, providing scientific support for the optimization of fixed prosthetic treatments.

14. Future research directions should focus on optimizing the composition of alloys, additive processing parameters and evaluating the long-term clinical behaviour of digitally fabricated metal structures.

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