

The use of metal alloys in the manufacture of fixed prosthetic restorations

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ABSTRACT

The techniques and classical methods used to make fixed prosthetic restorations may involve recycled metal alloys from previous castings. The article presents an assessment of the procedures that dental technicians apply, the principles and criteria that are at the base of their choices and decisions when they use metal alloys in fixed prosthetic restorations.

Objective. The article aims at the identification of the practices used by dental technicians in Romania when manufacturing non-noble metal alloys prosthetic suprastructures.

Material and method. The data collection methodology is an attribute of both quantitative and qualitative research.

Results. Over 50% of the dental laboratories are using classical methods of processing metal alloys, 82% of dental technicians use non-noble alloys (Cr-Ni, Cr-Co). 60.7% apply the recycling technique by reusing alloys and 46.4% of them are reusing the materials.

Defining factors for choosing recycling process are determined on "personal appreciation based on experience in the field" and "financial-economic" criteria.

Discussions. Scientific studies investigating the negative effects of recycling processes used for fixed prosthetic suprastructures emphasize on microstructural and chemical changes, consequences on the mechanical strength of the materials. They underline the strength in acidic environment, significant long-term toxic contribution in relation to the acidic environment of the oral cavity.

Conclusions. The predominant use of classical laboratory methods favours the over - reuse of alloys left overs from previous melts as well as materials. The effects of these techniques are drastic and the cautious use is fundamental.

Keywords: metal alloys, fixed dental restoration, recycling, crucible

INTRODUCTION

The development of materials science and the evolution of the types of materials used in dental coronary reconstructions have brought technical advancements in the world of dentistry and over time, more specifically, in the field of implant-prosthetic rehabilitation. The first testimonies to the application of coronary reconstructions were recorded as dating back more than four millennia and

were made of gold [1]. Whether they were a representation of an individual's identity or an attempt to repair dental coronary structures, these experiences marked the beginnings of a scientific evolution in dentistry. Nowadays, the choice of the type of metal alloy used for the manufacture of fixed prosthetic restorations is made based on well-determined criteria, such as those related to biocompatibility, biomechanics, corrosion resistance and

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aesthetic appearance. These principles facilitate the assessment of the type of material the prosthetics are made from and they include a multitude of choices: metal alloys, ceramics (zirconium), BioHpp polymers, etc.

For metal suprastructures, among the most used forms of prosthetic rehabilitations, noble metals (e.g. Au, Pd, etc.) or base metals (e.g. Cr-Co, Cr-Ni, etc.) are used. The most common alloy is the one based on Cr-Co or Cr-Ni due to their mechanical and physical characteristics but most importantly, due to the low cost of the materials [2]. But despite the principles appearing simple enough, the alloying of the metals that will be incorporated in future dental suprastructures is a challenge for most dental technicians and for the dentists using it. The dentists are the ones establishing the treatment plan after conducting clinical and paraclinical investigations: anamnesis, metal allergy tests [3], blood tests, radiological investigations, etc.

The structures of prosthetics with a metal base are made by alloying metals, either through the conventional method of melting them using oxy-gas, induction or with the help of additive and digital design methods by sintering or milling [4].

The melting of metal alloys is a principal stage because the melting interval must be the optimal one, as recommended by the manufacturer, given that the casting process requires a relatively long time. The alloying of several metal compounds makes each individual metal have a different melting point than the other alloyed metal. The melting interval is essential for the non-alteration of the mechanical and chemical properties of the obtained alloy, but most importantly so as not to affect the patient's health. The fact that a long melting interval can create oxides and therefore lead to contamination of the prosthetic structure [5].

To the same extent, the materials used for melting and casting the prosthetic metal structure are essential. The crucibles must also comply with certain standards, the quality of the alloys must be superior, the operations performed for melting and casting the metal alloy must comply exactly with the manufacturer's indications [6]. In essence, it is essential that clear and concise protocols are followed. It is not by chance that certain aspects of the process of making metal prosthetics suprastructures were stipulated. Scientific studies have researched the incidence of procedures used in dental laboratories on various cases of cytotoxicity [7,8], galvanism, alloy contamination and subsequently release of metal ions into the body [9] etc. and concluded that the techniques used can bring important changes at the cellular level [10].

If there is an incorrect application of technical procedures or repeated rescaling of metal alloys, al-

teration of the structure and microstructure of alloys occurs, which leads to a dental suprastructure susceptible to structural and/or physical damage.

Some of the transformations that occur can be mentioned:

- From a microstructural point of view, modifications can be observed that affect mechanical-physical properties [11] such as changes in the dendritic structures compared to those commonly present in the matrix [12];
- Changes in the chemical composition [11];
- Noticeable differences can be observed at the level of porosity from the new alloy [13];
- Residual inclusions, etc.
- Contamination by oxides [5];
- Cytotoxic effects on the human body [14].

Research objectives

The scientific literature contains extensive references to the effects that the techniques applied in dental laboratories have on the general health of patients who are fitted with metal structure prosthetics.

The main objective of this research is to identify the practices used by dental technicians in Romania when producing the prosthetics suprastructure on base metal alloys, as well as the way in which they are processed (if classical or digital methods are used). Moreover, the research aims to reveal how widespread is the practice of recycling metal alloys and / or materials used in the process of making metal prosthetic suprastructures, as well as identifying the factors that influence the choices of dental technicians.

Research methodology

In order to achieve the research objectives, the data collection methodology involved the use of mixed research methods, specific both to quantitative research (statistical survey based on an anonymous questionnaire with nine questions) and methods specific to qualitative research (telephone interviews).

When referring to the qualitative method of data collection, the structured interview technique was mainly used due to the fact that it involves a set of predetermined questions for all respondents [15]. This method had as a main objective a better and nuanced understanding of the factors that determine the behaviour and motivations of the dental technicians that have an active status in the Romanian dental market.

Regarding the quantitative approach, the questionnaire was disseminated in the main municipalities in Romania in order to ensure a regional uniformity (Bucharest, Ploiesti, Constanta, Timisoara,

Cluj and Brasov). The questions in the questionnaires were formulated with the purpose to refer concisely to the procedure related to the achievement of fixed prosthetic restorations. Respondents were questioned about: a) the type of metal alloys used for the prosthetic structures; b) the method used to melt the metal alloy; c) reuse/recycling of metal alloys left over from other melts; d) the percentage of metal alloy recycled and the frequency of recycling; e) the interval at which the crucible is changed; f) the criteria for dental technicians in determining the number of remelting; g) the reasons for not using the metal alloy recycling procedure, as well as the considerations related to changes/alterations to the final product as a result of recycling of metal alloys.

The sample, made up of representatives of dental laboratories, was prepared based on the electronic records found on the google.ro platform, and the data collection was done through Google Forms, following the distribution of the questionnaire. All the phone numbers related to the dental laboratories found for each city on the google.com platform were called, totalling a total of 350 questionnaires. After the centralisation of the data received, 241 responses were validated, which were subsequently processed and interpreted from a statistical point of view.

The main information resulting from the collection, centralization and interpretation of the data, will be presented below as well as the conclusions which can be drawn on the practices used in the dental laboratory regarding the recycling of metal alloys.

Results and discussions

The data collected indicates that the alloys predominantly used in producing metal-based prosthetics are in a significant proportion (82%) base alloys, such as Cr-Co or Cr-Ni, compared to the use of noble metals ones (18%). Over half of the dental laboratories use the classical methods of processing metal alloys (by induction and oxy-gas – 71.4%), while the rest of dental laboratories are using the digital ones.

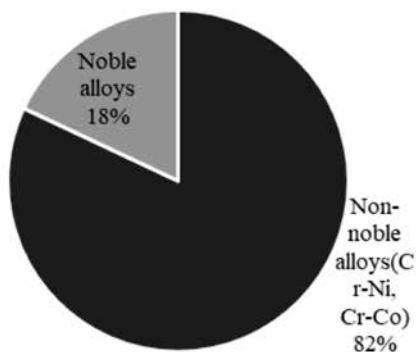


FIGURE 1. Answers to the question „What alloys do you use for fixed prosthetic restorations with metal structure?”

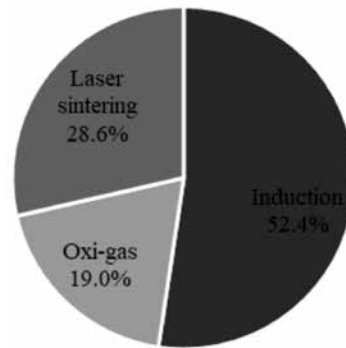


FIGURE 2. The answers to the question „What is the method of alloy processing for prosthetic restorations with metal structure?”

Regarding the recycling/reuse of metal alloys left over from previous melts, a process that can cause negative side effects on the patient according to the literature [5,7,12] (Sakaguchi et. al, 2019; Nandish et. 2020; Čairović et. Al, 2016), data indicates that 60.7% of responding dental technicians, use this technique. Moreover, in 46.4% of the cases, the respondents stated that they do not change the crucible, being situations in which it is replaced only if it undergoes structural changes that do not allow it to support another casting due to cracking, or it is changed after a certain number of melts (being recorded and answers in which it is changed after 50 melts), this contributes to the increase of the alteration of the structure and microstructure of the alloys.

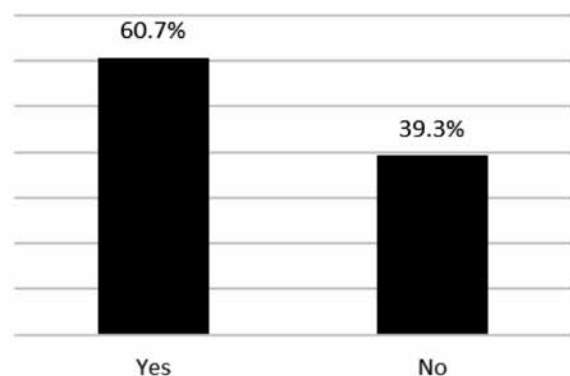


FIGURE 3. The answers to the question „In making metal suprastructures do you reuse/recycle the metal alloys left over from previous melts?”

Regarding the percentage of recycled metal alloy, the data collected indicates that a third of respondents estimate a recycling rate of 25% of the metal alloy left over from previous castings, while 14.3% of them recycle 50% of the remaining alloy. Also, when asked about the maximum number of remelting of alloys left over from previous melts, most of the dental laboratories interviewed remelted 1-3 times the alloy left over from previous meltings (39.3% of the sampled respondents, respectively

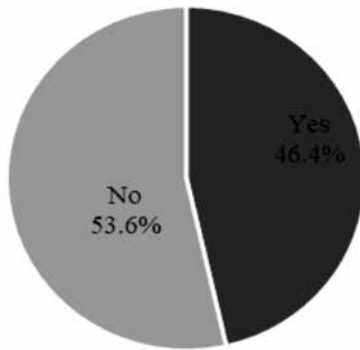


FIGURE 4. Answers to the question „Are you changing the crucible after the process of melting alloys?“

39.3% of the respondents who do not choose to remelt the remaining alloys from the previous melts), but there are also recorded situations where the metal alloys are remelted more than 5 times (7.1% of all respondents, respectively 14.3% of the respondents who said they did not quantify how many times they practice this procedure).

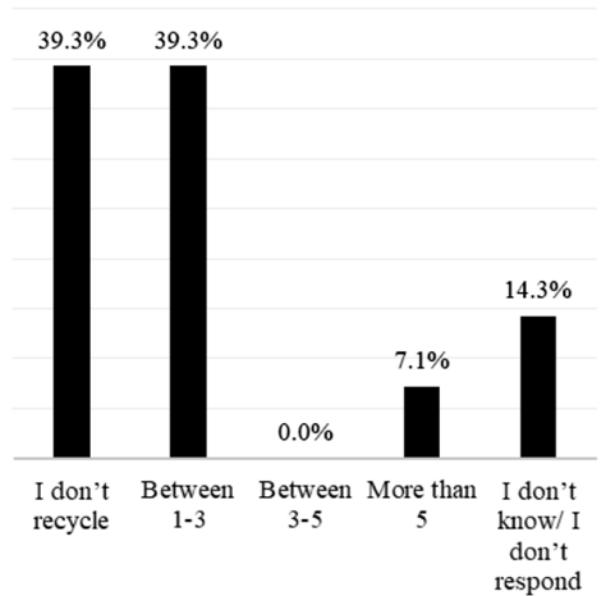


FIGURE 6. The answers to the question „If in current practice you recycle the remaining alloy after the first melting, what is the maximum number of recasting of the alloy?“

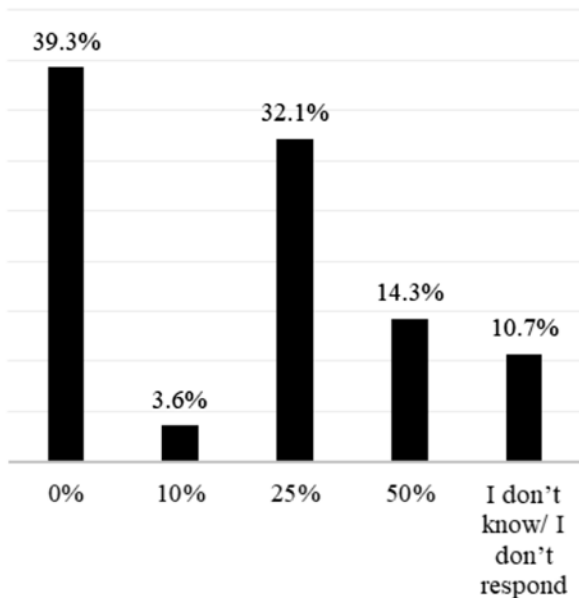


FIGURE 5. The answers to the question „In making metal suprastructures do you reuse/recycle the metal alloys left over from previous castings?“

The answers to question number 7 in the questionnaire reflect what are the motivations of dental technicians regarding the decisions of remelting metal alloys. The multiple answer questions were: a) economic and financial criteria, b) criteria related to the policy of environmental protection, c) the manufacturer’s indications, d) the scientific reviews on the subject of metal alloy recycling, e) personal appreciation based on experience in the field.

According to the data collected, most technicians tend to justify their choice of remelting metal alloys based on *personal experience in the field, economic*

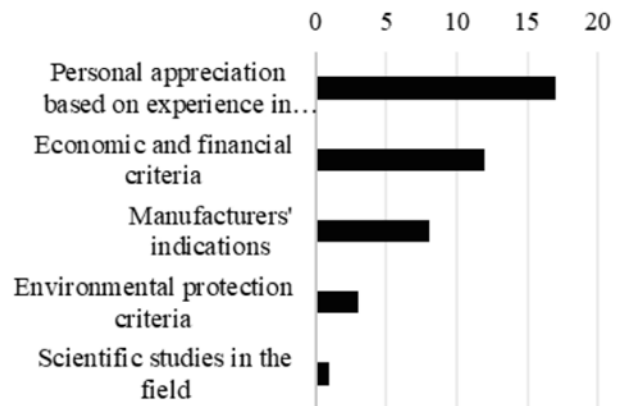


FIGURE 7. The number of answers to the question „What are the criteria taken into account when determining the number of remeltions of metal alloys?“ (multiple answer)

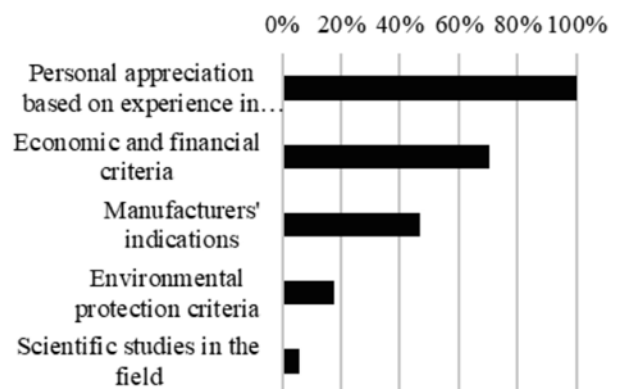


FIGURE 8. The criteria taken into account by respondents who claimed to recycle metal alloy

and financial criteria and manufacturers' indications. Moreover, the data in Figure 8 indicate that in all laboratories where the procedure of recycling alloys left over from previous castings is consciously applied, the main criterion taken into consideration is that of *the experience of the technicians* (100%), followed by *the economic and financial criterion* (70.6%) and the fact that *the manufacturers' indications allow* such procedures (47.1%). In contrast, only 17.6% of respondents who say they practice the procedure of metal remelting do so for reasons of *protecting the environment* and only 5.9% based on scientific studies in the field.

Therefore, the beliefs that urge them to use metal alloy recycling processes are different. Most of the time it is about the economic advantages that this practice brings. However, as we can see from the questionnaire answers, 17.6% of the respondents are aware of the beneficial effects that this practice brings on the environment. Resorting to the ideology of conscious recycling implies an environmentalist movement that comes to bring to attention the situation of limiting the natural resources used in the dental field [16].

As regards respondents who do not use the metal alloy recycling method, the data collection methodology involved the use of an open question to capture the professional reasons why they do not put this procedure into practice. The most common answers to this question tend to support the scientific literature and to mention both aspects of a technical nature („*The remelting of alloys creates inhomogeneity in the molten alloy, so pores are resulting from boiling when melting the alloy in the crucible*”; „*it changes the composition of the alloy*”; „*after more*

than 2-3 repeated castings into the nonprotective atmosphere of inert gas, the alloy changes its mechanical properties”; „*the metal has a coefficient of metals and when melting some metals are burned and no longer have the same quality*”; „*oxides appear and the metal becomes more porous after reuse*”), as well as factors related to the quality of the prosthetic framework and the fact that manufacturers do not specify that the alloys can be remelted.

Additionally, in the answer to the last question addressed to dental technicians, most respondents associated the recycling of metal alloys used in the production of metal based prosthetic restorations with *the microstructural and chemical damage of the finished alloy, contaminations of the final alloy, chemical changes, respectively the increase of the degree of cytotoxicity*. It is worth mentioning that some of these responses were selected including by the representatives of the laboratories using the recycling procedure, despite the fact that they are aware of the risks associated with it. From the data analysis, only a small proportion of those interviewed were not aware of the negative effects that the reuse by remelting of metal alloys implies and some of them did not consider that the remelting procedure generated negative effects on the quality of the prosthetic suprastructures.

The effects of recycling metal alloys used in metal fixed prosthetic suprastructures in dental reconstructions are notable. Numerous studies have included extensive research on the microstructural, chemical consequences on the mechanical strength of materials but especially on the resistance in an acidic environment, and the conclusions are varied, but most of them tilt the balance towards the cau-

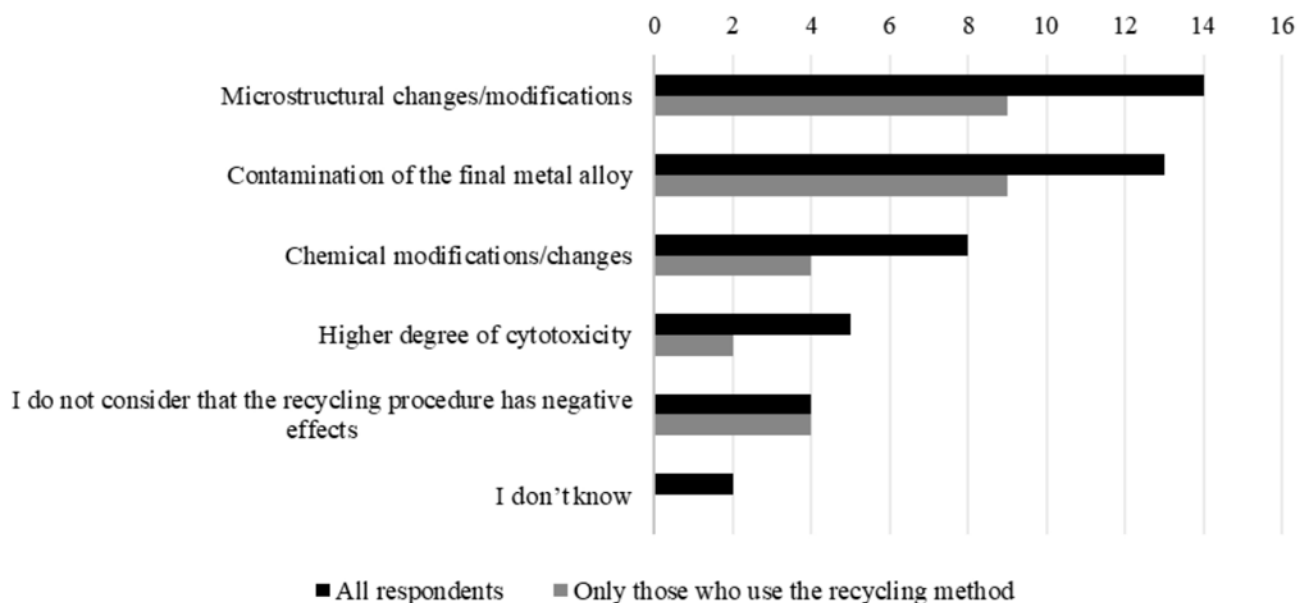


FIGURE 9. Number of answers to the question „Do you consider that the remelting of metal alloys causes important changes to the prosthetic suprastructure such as:” (multiple answer)

tious use of this process. Studies on the cytotoxicity of dental metal alloys emphasize the need to be aware of the significant toxic contribution that these materials have in the long term, in relation to the acidic environment of the oral cavity, the general state of health and the lifestyle of patients. Imirzalioglu P et al. studied the impact of the remelting of noble and non-noble metal alloys on gingival fibroblast cells and identified that in addition to the proven cytotoxicity of Cr-Ni alloys, when remelting with both recycled alloy and new alloy, the cytotoxic effect increased significantly [17]. An in vitro study on fibroblast cells from mice revealed that the cytotoxicity effect of three of the most widely used metal alloys based on Cr-Ni, marked a much higher level of cytotoxicity in remelted alloys mixed with new alloys [18]. But long-term cellular damage is extended from the oral cavity to the entire body, as shown by studies on the reactions that metals such as cobalt, nickel, iron, copper, cadmium [19] generate, etc. Chronic conditions such as cancers and neurodegenerative diseases [20] are the most mentioned adverse effects in the scientific literature.

In respect of microstructural and chemical changes, respondents who no longer apply the classical casting methods for the production of prosthetic suprastructures noticed significant differences, which probably also determined the transition to digital methods such as laser sintering. Agrawal A. et al. have highlighted the negative consequences that recycling dental metal alloys have. In the refer-

ence study, the degree of roughness and mechanical tensile strength of new alloys in relation to those recycled from previous castings was assessed, and the result indicated that there was a significant difference in relation to surface roughness, while tests on tensile strength did not show statistically noticeable differences [21]. The roughness of the finished material generates a major predisposition to the retention of bacterial plaque, which together with the release of metal ions in the presence of saliva acidity [22], enables the appearance of the galvanism process and ultimately cytotoxicity in the tissues [23].

CONCLUSION

As we learned from the quantitative and qualitative interpretation of the questionnaire answers, most of the dental technicians interviewed use classical methods of processing metal alloys, which allows them to be recycled. Economic considerations and personal professional experience are two major factors for determining the number of reuses of materials left over from previous castings, and not the scientific research on the effects of this method on the material itself and on the human body in the medium and long term.

The need to reuse resources in the dental field is vital, but it must be done on a scientific basis and with rigorous procedures so that the „economy” does not affect the patient’s health, which is fundamental to dental services.

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