THE INFLUENCE OF THE TECHNOLOGICAL PARAMETERS ON THE CHARACTERISTICS OF CAST DENTAL BRIDGES

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Abstract:
The dental bridges have a non metallic element made up in ceramic or composite that will rehabilitate the morphology and the functions, and a metallic framework, that assure the resistance and the retention of the aesthetic component. The technological algorithm used in order to obtain cast prostheses has the following steps: pouring the casts, the wax patterns, investing and realization of the mold, dental alloy melting and casting, divesting and polishing. The aim of our study was to emphasize the technological steps that can influence the final parameters of the cast prostheses. Twenty-one metallic frameworks for different dental fixed prostheses were cast (crowns, short bridges and the full arch bridges) and evaluated through the macroscopic examination method in order to detect any possible surface defects (pores, fissures, fractures, holes or excesses of alloy). In conclusion, the accuracy of the technological parameters will prevent any errors and will lead to dental cast prostheses with optimal biomechanical and clinical behavior.

Keywords: metallic framework**,** macroscopic examination, technological algorithm

INTRODUCTION

Metallic dental fixed prostheses are used as therapeutic solution for a various range of clinical situations: inlays, onlays, crowns and bridges. The dental alloys frequently used in practice for making of these appliances are the Chrome-Nickel and Chrome-Cobalt-based alloys [1, 3].

Mixed dental bridges have a metal infrastructure which provides resistance and support of the veneering component and an esthetic component that will restore the dental morphology and functions [4, 5]. Metal-ceramic bridges have a series of characteristics that prevail in relation to other prosthetic alternatives, such as optimal mechanical properties due to the metallic infrastructure, dimensional stability and excellent biocompatibility [6-9].

The technological algorithm for obtaining of cast framework includes several steps: the casts, the wax pattern, the investing and making of the mold, melting and casting the alloy, divesting and finishing. Metallic infrastructures must be carefully verified before veneering in order to identify the potential defects.

Defectoscopy is the science dealing with the definition, identification, characterization, and measuring of shape and sizes of defects in the material that may appear during the casting process [10].

The defectoscopic evaluation can be done through destructive and non-destructive methods. The destructive tests (mechanical resistance, physical properties, and quantitative analyses, etc.) require the destruction of the specimen, therefore are not frequently used in the routine defectoscopy.

Non-destructive methods do not destroy the analyzed pieces, using techniques such as optical-visual/macroscopic investigation, microscopic investigation, defectoscopic control by ultrasounds, magnetic powder test, penetrating liquid analysis, X-ray examination, infrared thermography analysis and micro-XCT examination [11-13, 14-22].

According to the particularities of the dental alloys and to the accuracy of the technological parameters, will prevent any errors and will lead to dental cast prostheses with optimal biomechanical and clinical behavior

MATERIALS AND METHOD

In this study we intended to highlight the technological parameters that may influence the characteristics of a metallic framework and the non-destructive defectoscopic evaluation through macroscopic examination.

For this purpose, we made 21 metal frameworks using three different Co-Cr-based alloys (table 1) for metal-ceramic dental fixed prostheses cast (crowns, short bridges and the full arch bridges) and evaluated through the macroscopic examination method in order to detect any possible surface defects (pores, fissures, fractures, holes or excesses of alloy).

Table 1. Co-Cr-based alloys subject to experimental researches

Non-noble alloys	Trade name	Manufacturer	Recommendations for use
Co-Cr-based alloys	Brealloy C+B 270	Bredent	Metal-ceramic fixed restorations
	Heraenium P	Kulzer	
	Wirobond 280	Bego	

The chemical composition and the values for physical and mechanical properties of the Co-Cr-based dental alloys are given in table 2 and 3.

Table 2. Chemical composition [14-16]

Alloy	Chemical composition, [%]										
	Co	Cr	W	Mo	Si	Mn	Ga	Nb	Fe	N	C
Brealloy C+B 270	66	20	6	6	0.9	0.7	-	-	-	-	0.02
Heraenium P	59	25	10	4	1	0.8	-	-	-	0.2	-
Wirobond 280	60.2	25	6.2	4.8	<1	<1	2.9	-	-	-	-

Table 3. Physical properties of Co-Cr-based alloys selected[14-16]

Alloy	Physical properties					
	Melting temp. [°C]	Casting temp. [°C]	Solidification temp. [°C]	Thermal expansion coeff. (TEC 20-500/600°C), [µm/mK]	Density [g/cm³]	E [GPa]
Brealloy C+B 270	1350	1450	1280	14.4	8.4	200
Heraenium P	1400	1550	1305	13.8	8.8	200
Wirobond LFC	1435	1480	1335	15.6	7.9	205

After impressions we made the working casts from hard gypsum and the wax patterns of metal frameworks using inlay blue wax. In order to prevent technological errors, the following conditions for the wax must be fulfilled: the wax must not be overheated, it should be applied in one step, and does not modify its properties after solidification.

The framework wax pattern must have the following characteristics: to be undersized by 1-1.5 mm in order to provide the equal space for the ceramic component, the thickness of the metal framework must be 0.4-0.5 mm, with a smooth surface without any macro-retentions; to avoid the fracture or detachment of the ceramic component, wax pattern will be modeled with an 90° angle between metal and ceramic (fig.1).

Figure 1. Metal framework wax patterns

The next technological steps are spruing and investing phase. During modeling the wax, some internal stresses accumulate into the pattern, that may generate shape and dimensions modifications leading to poor adaptation of the future metal framework on the working model. Therefore, the elimination of these internal stresses is mandatory before the investing step.

The spruing is another important phase that ensures the optimal flow of the alloy into the mould, the number, location, and dimensions of the sprues being correlated to the amplitude of the framework and the alloy fluidity (fig.2).

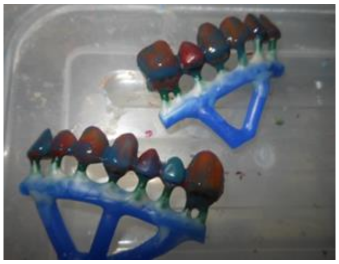

Figure 2. Spruing

The success of casting process is conditioned by the presence of air vents, for gas evacuation. These sprues are 0.5-0.7 mm diameter and have one end on the wax pattern and one end on the top of the mold.

For investing there are used investment materials, specific to each alloy, which has a expansion coefficient equal to the alloy's contraction coefficient. Regardless of their chemical composition, the investment materials come in a two-component system, powder and liquid; the ratio between the two components is indicated by the manufacturer as it differs from one type of investment material to the other. In our study we used Bellavest SH graphite-free investment material containing phosphate and having a fine creamy consistence.

The investment ring size must be selected in order to preserve a 6 mm thickness of the investment material, and at least 1 cm distance between ring walls and the wax. The sprued wax pattern should be placed in the investment ring precisely in the middle of the mold, where is the highest temperature.

The paste was prepared by mixing the powder with the liquid in the proportions indicated by the manufacturer by means of the vacuum mixer to eliminate the air inclusions. The sprued wax patterns were covered in investment material paste, and the pouring was done under vibrations, using a lab vibrator, in order to avoid incorporation of air bubbles into investment material (fig.3).

Figure 3. Wax pattern investing

In order to obtain the mold, the invested wax pattern was placed into an electric oven, where temperature rises slowly up to a value close to the alloy melting point. During heating, the wax melts and flows, the remain wax burns, the mold wall dry out and thermal expansion of the mold starts (fig.4).

Figure 4 Crucible and Mold heating

The following phases are alloy's melting and casting into the mold.

The chemical composition of Co-Cr alloys is approximately similar but it does not determine by itself their physical, mechanical and chemical properties, these being influenced by the technological steps accuracy.

The melting process was carried out in a ceramic crucible for non-noble alloys, using a Ducatron Quattro centrifuge (fig.5). Overheating is forbidden since it modifies the alloy structure and their mechanical and clinical behavior.

Figure 5. Ducatron Quattro-

Centrifugal induction casting machine

After cooling at the room temperature air for 40-50 minutes, the cast pieces are divested, by removing the investment material from their surface (fig.6).

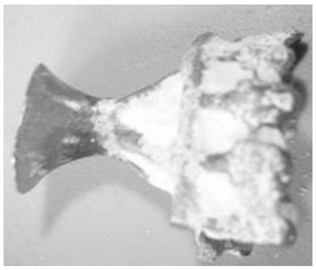

Figure 6. Divestment

There may be very little highly adherent areas of investment material and a continuous film of metal oxide on the framework surface, which should be removed through sandblasting. The processing of the metal framework aims to eliminate the fragments of investment material and oxides from the surface of the metal framework, to flatten and smooth it.

Sandblasting is the process by which the metal framework is subject to the action of a jet of abrasive particles of aluminum trioxide (Al2O3).

Choosing the particle granulation depend on the alloy hardness, for harder alloys as cobalt -chrome, recommended granulations being 120-250 µm. The pressure of the particle jet is another factor that influences the surface quality, and in case of harder alloys it ranges between 3 and 6 bars. The angle of the particles jet 45 degrees, this incidence allowing the reflection of the particles on the metallic surface, preventing their embedding into the metal. The distance optimal to the metal structure is 30-35 millimeters, and sandblasting time about five seconds for each surface (fig.7).

Figure 7. Sandblasting

After sandblasting, the clean metal allows a better survey of the surfaces in order to identify any potential defect.

After sprues removal, next steps are finishing and polishing of the framework (fig.8).

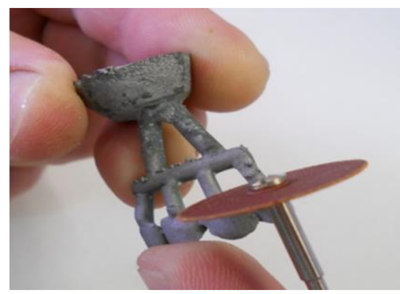

Figure 8. The sprues are cut with a diamond disk

Finishing was performed by means of abrasive materials: carborundum disks, mounted and non-mounted stones, hard mills all of them driven by a high speed motor. Mucosal and dental surface are not processed so as not to modify their adaptation to the prosthetic field.

Polishing was performed in a galvanic bath in order to obtain perfectly smooth and uniform surfaces (fig.9).

Figure 9. Metal framework after processing

RESULTS AND DISCUSSIONS

The macroscopic analyze was carried out through direct visual examination, and with the magnifying glass.

Macroscopic homogeneity defects, such as gas, sulphide or investment material inclusions, may be noticed on the surface.

Pores are spherical micro cavities determinate by gas inclusions inside or on the metal surface, as a result of some technological errors: alloy overheating, the molten alloy reservoir undersized or misplaced (not exactly in the center of the mould), and a low intensity of the casting force (fig.10).

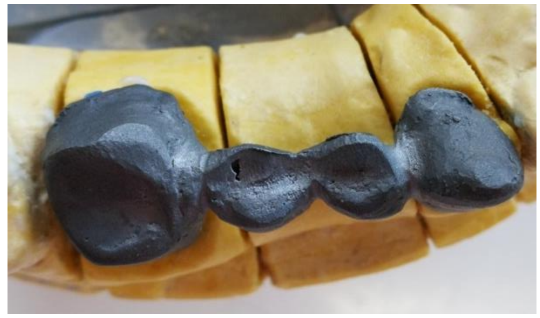

Figure 10. Pores on the metal surface

The shape and volume of the cast piece can be modified due to partial faults (holes) (fig.11).

Casting partial faults are caused by a low quantity of alloy, melt too cold, mould too cold, ceramic crucible not preheated, insufficient torque in centrifuge, wax up pattern too thin, sprues too thin, the presence of gases in the mould, casting delayed too long.

Figure 11. Casting partial faults

The shape and volume of the prosthetic piece can be modified by alloy excesses on the surface, which can have different shapes (spherical or lamellar) (fig.12).

The spherical shape (beads) is the most frequently found and is caused by the following errors: wax surface was not tension reduced, investment mixted without or inadequate vacuum.

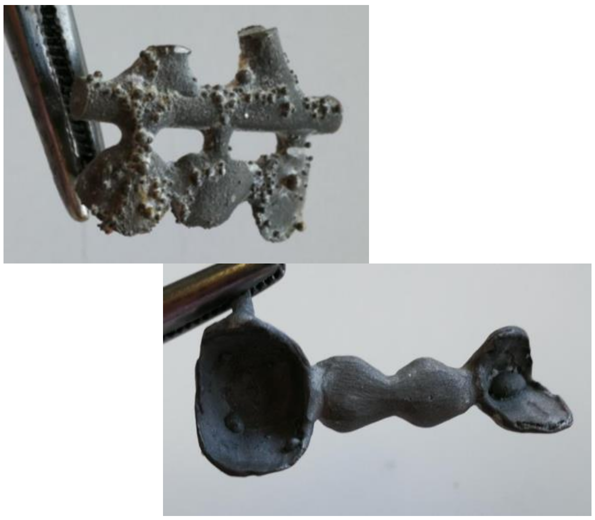

Figure 12. Spherical excesses on the framework

CONCLUSIONS

The initial study level is observation and represents the domain of interest for the clinician.

The chemical composition of different Co-Cr alloys is approximately similar and is not determining on its won the physical, mechanical and chemical properties of alloys. These features depend on the relationship between components.

To obtain appropriate structures it is mandatory to respect the technological steps the specific parameters of melting and fusion.

The alloys used for the metal framework have to be characterized by good mechanical resistance, chemical stability, low thermal conductibility, and low specific weight and to be well tolerated by the oral tissues.

The defects present in the metal framework will determine an inadequate prosthetic restoration. The integration into the oral equilibrium will no longer be met.

The macroscopic defects occur according to the working regime and the technical particularities specific to each working step.

The clinical integration and longevity of the prosthetic restoration represent an important target for the dental team, both the dentist and the technician.

The rigorous observance of the technological process ensures the conditions to gain a good prosthetic cast piece, with longevity and optimal biomechanical parameters.

The clinical integration of the prosthetic appliances into the oral balance will preserve the homeostasis of the stomatognathic system.

Acknowledgements

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BIBLIOGRAPHY

1. Craig, R.G. Powers, J.M. Wataha, J.C. Dental materials-properties and manipulation Mosby 2004.
2. Vitalariu A., Leata R., Chelariu R., Munteanu C., Cimpoesu R., Ilie M., Comaneci R., Moisei M., Influence of the Casting Conditions on the Structure and Properties of a Co-Cr-Mo Dental Alloy, REV.CHIM. (Bucharest), Vol.66, No.12, 2015
3. Watha J.C. Alloys for proshodontics restorations. J. Prosthet. Dent. 2002; 87: 351-63.
4. Diaconu D., Tatarciuc M., Particularităţi tehnologice în realizarea punţilor ceramice, Ed. Performantica, Iaşi,2015
5. Forna N., (coordonator), De Baat C., Bratu D., Mercuț V., Petre Al., Popșor S., Trăistaru T., *Protetică Dentară Vol. I, II*, Editura Enciclopedică, București, 2011

6. Diaconu-Popa D., Vitalariu A., Holban Cioloca C., Aungurencei A., Luca O., Tatarciuc M., Researches On The Influence Of Thermal Treatment On The Mechanical Properties Of Titanium Dental Prostheses, REV.CHIM. (Bucharest), Vol. 68, No. 10, 2017
7. Givan D.A., Precious Metals in Dentistry, Dent. Clin. N. Am. 51(2007): 591- 601
8. Mareci D, Nemtoi G, Aelenei N, Bocanu C, The electrochemical behavior of various non-precious Ni and Co based alloys in artificial saliva. Eur Cell Mater 2005; 10:1-7, discussion 1-7.
9. Okazakia Y, Gotoh E. Comparison of metal release from various metallic biomaterials *in vitro*. Biomaterials 2005; 26:11-21.
10. Mihai A., M. Voicu, F. Stefanescu, G. Neagu, St. Funar, *Introducere în defectoscopia nedistructivă*, Ed. Printech, 2008
11. Stelea O., Panaite St., Morariu C., *Metalurgie stomatologică şi biomateriale*, Editura Apollonia, Iaşi, 2000.
12. Zegan, G., Anistoroaiei D., Golovcenco L., et al., Physicochemical properties of advanced nanostructured materials, for dental microimplant coatings, Revista de Chimie, 68(9), , 2017, 2052-2054
13. Posarac-Markovic M., Veljovic Dj., Devecerski A., Matovic B., Volkov-Husovic T., *Nondestructive evaluation of surface degradation of silicon carbide–cordierite ceramics subjected to the erosive wear*, Materials and Design 52, p.295–299, 2013
14. Meola C., Raj B., *Nondestructive Testing and Evaluation: Overview* Reference Module in Materials Science and Materials Engineering, 2016
15. https://www.dentalstoff.de/laborbedarf/gusslegierungen-draehte/460/heraeus-kulzer
16. https://www.bego.com/fileadmin/_products/pdf/de_82093_0004_br_en.pdf
17. www.bredent-medical.com/it/bredent
18. Zegan,G., Carausu, E.M., Golovcenco, L., et al., Nanoparticles deposition on mini-implants for osseointegration and antibacterial properties improvement, Revista de Chimie, 68(12), 2017, pg. 2929-2931
19. Asaftei, I.V, Sandu,I.G., Mihail,L,et al, Conversion of ndustrial fedstock mainly with butanes and butenes over B-HZSM-5 and Zn-HZSM-5 modifed catalysts, Revista de Chimie, 66(3),2015, pg.336-341
20. Matei,M.N.,,Earar, K., Trinca, L.C., Degradation characteristics of poly-tetrafluoroethylene coatings on stainlesssteel orthodontic wires immersed in tuna fish derived products, Revista de Chimie, 67(4), ,2016, pg.800-807
21. Matei ,M.N., Chiscop, I, Earar K., et al., Evaluation of corrosion resistance of NiTi Nb orthodontic wires in tomato juice, Revista de Chimie, 66(12),2015, pg.2009-2012
22. Mareci, D., Earar, K., Zetu, I., Comparative electrochemical behaviour, of uncoated and coated Ni Ti, for dental orthodontic wires, Revista de Chimie, 52(2), 2015, pg, 150-153