Annals of the University of Craiova
The Chemistry Series
Volume XLVIII, No. 1 (2022) 56-62
homepage: chimie.ucv.ro/annals/

The use of X-ray spectrometry in forensic expertise. Dental alloy control

Research article

Adina Bunget[1], Monica Delia Bîcă[2], Iuliana Carmen Bărbăcior[2], Liviu Chirigiu[1], Larisa-Marina-Elisabeth Chirigiu[2]*

[1]University of Medicine and Pharmacy, Craiova, Romania
[2] University „Constantin Brâncuși", Târgu Jiu, Romania
*E-mail: liviu.chirigiu@asociatiadidactica.ro

Received: 02.07.2022 / Accepted: 02.09.2022 / Published: 15.09.2022

Abstract
The analysis of dental materials in forensic investigations is very important. Identifying the victims of accidents or attacks sometimes requires the analysis of their dentures. In this paper, X-ray spectrometry was used as a method to determine the chemical composition of a dental material. In this case, it was established that it was a dental alloy (Cr-Ni-Mo) with a percentage composition of 23.58% Cr, 64.32% Ni and 10.82% Mo.

Keywords: X-ray spectrometry, dental prostheses, forensic analysis

1. INTRODUCTION

The analysis of dental materials by X-ray spectrometry is an important method in forensic analysis. The diversity of materials from which dental prostheses are made as well as the action of the environment in the oral cavity (specific to each individual), make each dental prosthesis acquire an air of individuality. The analysis of the chemical composition and appearance of these dental materials can provide valuable information for the forensic specialist.

Dentistry has much to offer law enforcement in the detection and resolution of crimes or in civil proceedings. Forensic dental fieldwork requires an interdisciplinary knowledge of dental science in order to correctly diagnose cases. Most often, the role of the dentist is to establish a person's identity. Teeth, with their physiological variations, pathologies and effects of therapy, record information that remains throughout life and even after. Teeth can also be used as weapons and, in certain circumstances, can leave information about the identity of the bite. Forensic dentistry has an important role in recognizing abuse among people of all ages. Dental professionals have a major role to play in keeping accurate dental records and providing all necessary information so that legal authorities can recognize malpractice, negligence, fraud or abuse and identify strangers [1].

In cases where the dentist needs to establish a person's identity, an orthodontist can sometimes be very helpful [2].

The analysis of bite marks is the second major responsibility of the dentist [3].

The general practitioner has a major role to play in providing accurate dental records on which much of the forensic activity is based [3].

Forensic dentistry involves the management, examination, evaluation and presentation of dental evidence in criminal or civil proceedings, all in the interests of justice. The dentist assists the legal authorities by examining the dental evidence in different situations [4]. The oral cavity is a rich and non-invasive source of DNA and can be used to solve social, economic or legal problems [5].

In this paper, a method to determine the chemical composition of a dental alloy (Cr-Ni-Mo) by X-ray spectrometry was presented.

2. MATERIALS AND METHODS

2.1. Materials

Ten samples of a dental prosthesis metal alloy have been analyzed for their composition.

The test sample was first cleaned by washing with warm water and detergent, to remove traces of dirt, then rinsed with clean water and dilute hydrochloric acid solution, to remove calcium and magnesium carbonate deposits (if any). Then rinse 4 – 5 times with double-distilled water and leave to dry in a desiccator for 4 – 5 hours.

2.2. Analysis methods

With the development of laboratory equipment, the methods of analysis have also evolved. A multitude of devices for the study of metal alloys have been launched on the market, some being very expensive. They can perform the analysis of surfaces, chemical composition, mechanical strength, etc. For the identification and analysis of dental materials, we used an Olympus portable X-ray spectrometer, Delta Professional type, Rh source, Detector: Silicon Drift.

The X-ray spectrometer is based on the principle of excitation of metals in the alloy composition by bombarding them with radiation with short wavelength, so high energy (X-rays).

These radiations have a sufficiently high energy capable of snatching electrons from the inner atomic orbitals, so to ionize the atoms. In this state the atoms become excited and unstable. Under these conditions the orbital that becomes monoelectronic by removing the electron expelled by photoelectric effect, will be occupied by an electron from a higher level, releasing the energy corresponding to the energy difference of the levels involved, either by emitting an X photon or by transmitting energy to one of the atomic electrons. The first case

corresponds to X-ray fluorescence, the second to Auger emission, the two processes being in competition.

Based on this X-ray emission spectrum, qualitative analyzes can be performed to identify the component metals (each atom emits de-excitation quanta with certain specific wavelengths), but also quantitative analyzes (determining the composition of these materials, the energy intensity being directly proportional to the concentration).

Samples were analyzed using an Olympus portable X-ray spectrometer, Delta Professional type, Rh source, Detector: Silicon Drift.

The characteristics of the device and the working procedure are presented in Table 1.

Table 1. Working parameters for Olympus portable X-ray spectrometer, Delta Professional type, Rh source, Detector: Silicon Drift

Reading	Date	Time	Mode	Pass/Fail	Instrument	Model	Tube	Unit
1	10/9/2021	10:36:04	Alloy	PASS	544238	Delta	Rh	%

3. RESULTS AND DISCUSSION

Dental alloys are the materials used in dentistry to make dental prostheses. These are mixtures of two or more elements, one of which is metal.

Dental alloys can be classified into three broad categories:

- noble alloy,
- stainless alloys,
- titanium alloys and copper-based alloys.

The noble ones can contain: gold, silver, palladium, copper, platinum, iridium, etc.

The stainless alloys can contain: nickel, chromium, molybdenum, iron, etc.

The most commonly used titanium alloys are nickel alloys [6].

The usual chemical analysis of the composition of dental materials requires laborious, complicated operations and high consumption of reagents, involving the dissolution of the prosthesis in mixtures of concentrated acids, which is quite difficult, then separation of metal cations on individual components and only then determination

of each metal cation by different methods. Such an analysis requires long working time, specialized staff, large amounts of analytical reagents. The shortcomings of such a classical analysis consist in the fact that metals in very low concentrations, very often, can be lost during the analysis, their determination being quite difficult. At the same time, the sample is permanently destroyed, the possibility of identifying the dental imprint being eliminated.

10 determinations were performed on a denture sample in order to establish its chemical composition by X-ray spectrometry. The results of the determinations are presented in Table 2.

Using the Descriptive Statistics option in the Data Analysis, Excel utility, we calculated for all quantitative variables (Cr, Ni, Mo) the descriptive statistical parameters The statistical interpretation was performed and the results are listed in Table 3.

Table 2. Results of composition analysis of a denture sample determined by scanning with the portable Olympus X-ray spectrometer, Delta Professional type

Reading	Time	Cr	Mn	Fe	Ni	Cu	Nb	Mo
1	10:36:04	23,58	0,2514	0,5144	64,31	0,1674	0,3527	10,8314
2	10:37:54	23,68	0,2443	0,5607	64,27	0,1588	0,3590	10,8194
3	10:38:11	23,56	0,2640	0,4643	64,29	0,2372	0,3600	10,8184
4	10:39:22	23,55	0,2543	0,5211	64,37	0,1954	0,3596	10,7532
5	10:41:11	23,51	0,2257	0,5121	64,39	0,1849	0,3591	10,8224
6	10:43:36	23,62	0,2600	0,4883	64,23	0,2118	0,3606	10,8284
7	10:45:25	23,59	0,2543	0,4932	64,44	0,1757	0,3545	10,8789
8	10:47:06	23,54	0,2365	0,4817	64,31	0,1573	0,3097	10,8378
9	10:48:19	23,61	0,2642	0,4778	64,35	0,2111	0,3048	10,7843
10	10:50:21	23,59	0,2611	0,5001	64,29	0,2314	0,3589	10,7781

Using statistical parameters (arithmetic mean, median, modulus, asymmetry, vaulting) we estimated that the data follow the normal distribution.

Table 3. Statistical interpretation of the results of the analysis of the composition of the dental prosthesis determined by scanning with the portable Olympus X-ray spectrometer, Delta Professional type

Cr		Ni		Mo	
Mean	23,583	Mean	64,325	Mean	10,81523
Standard Error	0,015059	Standard Error	0,019734	Standard Error	0,011185
Median	23,585	Median	64,31	Median	10,8209
Mode	23,59	Mode	64,31	Mode	#N/A
Standard Deviation	0,047621	Standard Deviation	0,062405	Standard Deviation	0,035371
Sample Variance	0,002268	Sample Variance	0,003894	Sample Variance	0,001251
Kurtosis	0,932548	Kurtosis	-0,15247	Kurtosis	0,459392
Skewness	0,600649	Skewness	0,449181	Skewness	-0,13452
Range	0,17	Range	0,21	Range	0,1257
Minimum	23,51	Minimum	64,23	Minimum	10,7532
Maximum	23,68	Maximum	64,44	Maximum	10,8789
Sum	235,83	Sum	643,25	Sum	108,1523
Count	10	Count	10	Count	10
Largest(1)	23,68	Largest(1)	64,44	Largest(1)	10,8789
Smallest(1)	23,51	Smallest(1)	64,23	Smallest(1)	10,7532
Confidence Level(95,0%)	0,034066	Confidence Level(95,0%)	0,044642	Confidence Level(95,0%)	0,025303

4. CONCLUSION

A method for analyzing dental alloys by X-ray spectrometry has been developed.

The established method is fast, reproducible, does not require special reagents and is cheap.

The method is non-destructive, in the case of forensic investigations, this being a very important aspect, the shape of the dentures being essential in the investigation.

Statistical interpretation of the results showed that the method is safe and not affected by systematic errors of analysis.

REFERENCES

[1] S. L. Avon, *J. Can. Dent. Assoc.*, 70 **(2004)** 453-8.

[2] G. Reddy, V. P. Reddy, M. Sharma, M. Aggarwal, *Journal of Clinical and Diagnostic Research: JCDR*, 10 **(2016)** ZE01-3.
[3] D. K. Whittaker, *Quintessence Int.*, 25 **(1994)** 723-30.
[4] B. Sukul 1, U. Deb, S. Ghosh, *J. Indian Med. Assoc.*, 108 **(2010)** 769-70, 775.
[5] J. Ata-Ali 1, F. Ata-Ali, *J. Clin. Exp. Dent.*, 6 **(2014)** 162-7, doi: 10.4317/jced.51387.
[6] https://netdent.ro/dictionar-medical/despre-aliajele-dentare