NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
POLITEHNICA OF BUCHAREST
FACULTY OF MATERIALS SCIENCE AND ENGINEERING
DOCTORAL SCHOOL OF MATERIALS SCIENCE AND ENGINEERING

PhD Thesis

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Bucharest 2025

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PhD THESIS SUMMARY

RESEARCH ON THE USE OF INERT CERAMIC BIOMATERIALS AND MODERN PROCESSING TECHNOLOGIES IN THE FABRICATION OF DENTAL PROSTHESES

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THEORETICAL PART

CHAPTER 1. Recent Developments in Dental Prostheses Based on Inert Ceramic Biomaterials

1.1. Clinical and Technical Aspects of Dental Prostheses

The primary objective of dentistry is the preservation of oral health and, when required, the alleviation of pain. This aim is accomplished through the prevention of oral pathologies, the mitigation of painful symptoms, the optimization of masticatory efficiency, the enhancement of phonetic function, and the correction of dento-facial aesthetics. Since the attainment of these objectives frequently necessitates the replacement or modification of dental structures, a central challenge in the evolution of the field has been the identification and application of biocompatible, durable restorative materials, suitable for both direct restorations and indirectly fabricated prostheses, and capable of withstanding the complex biomechanical and biochemical conditions of the oral cavity [1]. Prosthodontics represents a specialized discipline of dentistry dedicated to the design, fabrication, and clinical integration of artificial dental substitutes, as well as to the functional and aesthetic rehabilitation of existing dentition. The significance of this domain is substantial, as the success of therapeutic interventions requires a high degree of precision, while patient-reported outcomes may range considerably between satisfaction and dissatisfaction. In general, the principal challenges identified by patients relate to four essential parameters: comfort, functionality, social integration, and aesthetics.

The selection of restorative materials must be guided by their capacity to reproduce, as accurately as possible, the mechanical and structural properties of natural dental tissues. Critical characteristics include hardness, modulus of elasticity, viscoelastic behavior, and resistance to fracture. The term *prosthesis* is broadly defined as the substitution of lost organs or tissues by means of artificial materials, fulfilling both functional and aesthetic roles. Within dentistry, the replacement of missing teeth and/or supporting oral tissues is achieved through prosthetic devices. From a clinical standpoint, prostheses are classified into two principal categories: fixed prostheses and removable prostheses, the distinction being based on whether insertion and removal are performed exclusively by the clinician or may also be undertaken by the patient.

1.2. Inert ceramic biomaterials used in dental prosthetics

The materials used in the restoration of teeth and the re-establishment of dental aesthetics occupy a central position within the field of biomaterials. In this context, the most widely utilized classes include metals (such as titanium alloys and stainless steel), bioceramics (either bioinert or bioactive), and biodegradable polymers, such as polylactic acid or

copolymers of lactic and glycolic acids [8,9]. rom a microstructural perspective, ceramics can be characterized according to the relative proportion of the vitreous and crystalline phases. Although the microstructure of ceramic materials exhibits substantial variability, they can be classified into four principal compositional groups, each defined by specific structural and functional characteristics.

Table 1.1 Classification of ceramic materials according to the ratio of the vitreous to the crystalline phase [19]

Group	Composition
1	Predominantly vitous, silica-based (SiO_2) systems;
2	Silica-based vitreous systems, which contain dispersed crystalline phases (such as leucite - $KAlSi_2O_6$ or, more recently, lithium disilicate - $Li_2Si_2O_5$);
3	Crystalline matrix systems (especially alumina-based – Al_2O_3) in which a vitreous phase is integrated;
4	Compact polycrystalline materials such as alumina (Al_2O_3) and zirconia (ZrO_2).

Inert ceramics, as materials used in dental restorations, present multiple advantages well-documented in the literature, including optical properties closely resembling those of natural dentition, high biocompatibility, dimensional stability, resistance to wear, and the ability to be etched to facilitate adhesion. However, their clinical application is limited by two major limitations: a high susceptibility to sudden and catastrophic fracture due to the intrinsic brittleness of the material, and a tendency to induce abrasive wear on opposing teeth.

EXPERIMENTAL PART

CHAPTER 2. The objective of the thesis. Experimental work plan. Materials, methods and equipment used

2.1. Objective of the thesis

This doctoral thesis comprises three research studies, with the primary objective of evaluating the clinical use of fixed dental prostheses made from different inert ceramic biomaterials. The first study of the experimental part consisted of conducting a detailed clinical examination on a group of patients, which included both the analysis of dento-periodontal status and the identification of functional and aesthetic particularities of the dento-maxillary system. This initial stage provided a comprehensive overview of the oral rehabilitation needs and of the clinical limitations specific to each investigated case. The second experimental study carried out within this doctoral thesis aimed to investigate the effect of CAD/CAM technology on the surface properties of three fixed dental crowns manufactured from prefabricated ceramic

blocks. The purpose was to compare surface properties and identify the restorative material with the best clinical performance suitable for intraoral use. The third study aimed to compare the performance of four types of fixed dental prostheses, highlighting the influence of the material's chemical composition and processing technology on the final performance of prosthetic restorations. In this context, the following aspects were investigated: surface and cross-sectional morphology, elemental composition, surface chemical composition, and mechanical behavior under specific oral environmental stresses. Furthermore, the correlation between mechanical properties and clinical performance was explored, with a focus on durability and resistance to functional stresses, to identify the optimal materials for achieving high-quality prosthetic restorations.

2.2. Experimental Materials and Methodological Framework of Study I

The fabrication of the ceramic dental restorations used in this study—crowns, bridges, and prostheses—was carried out following standardized technological protocols. The sequence of procedures was identical, with variations determined exclusively by the type of material employed and the specific requirements of the prosthetic restoration. The main stages were as follows: *1. Impression taking; 2. Digital scanning* of the obtained models; *3. Mounting of plaster casts in the articulator* based on intermaxillary records, enabling the reproduction of mandibular movements and the analysis of occlusal relationships; *4. Digitization of the three-dimensional model and delineation of the prepared tooth; 5. CAM planning,* involving the positioning of the restorations within the material block or disc designated for milling, in order to optimize material use and minimize processing time; *6. Definition of functional parameters* (guidance, mandibular trajectories) in the digital environment, allowing simulation of the real dynamics of occlusion and verification of the functional adaptation of the restoration; *7. Occlusal contact analysis* performed in CAD software, followed by digital adjustments to eliminate interferences and ensure optimal occlusal functionality; *8. Morphological configuration of the crown; 9. CAD/CAM milling* of zirconia blocks or other selected materials, converting the virtual design into a physical restoration; *10. Post-milling intermediate processing*; *11 Sintering of the restorations*; *12. Final check on the working model.*

2.3. Experimental Materials and Methodological Framework of Study II

The materials used in this study were in the form of prefabricated blocks of: Zirconia-reinforced lithium silicate (Celtra Duo), feldspathic ceramic (CEREC Blocs), and lithium disilicate (CEREC Tessera). The investigations were carried out both on the dental works obtained and on the ceramic blocks subjected to the milling process. The interest in the use of

CAD/CAM technology in dentistry is justified by the high precision of this method, the reproducibility of the restorations obtained, and the reduction of operative time. This technology enables the creation of personalized dental crowns tailored to the clinical characteristics of each patient. The experimental work plan included the following steps: Selection of materials; Obtaining restorations by CAD/CAM milling; Analysis of elemental composition by EDS spectroscopy; Non-destructive investigations by computed tomography (CT); Morphological analysis by scanning electron microscopy (SEM); Evaluation of surface properties: determination of roughness by the method of profilometry, respectively of wettability by measuring the contact angle and determining the free surface energy.

Experimental samples used in the first study

The dental works obtained from the Celtra Duo, CEREC Blocs, and CEREC Tessera blocks were coded with A1, A2, and A3, respectively. The chemical composition of these blocks, according to the data provided by the manufacturer, as well as the macroscopic appearance of the dental crowns obtained from the prefabricated blocks, are presented in Table 2.1. and Figure 2.12.

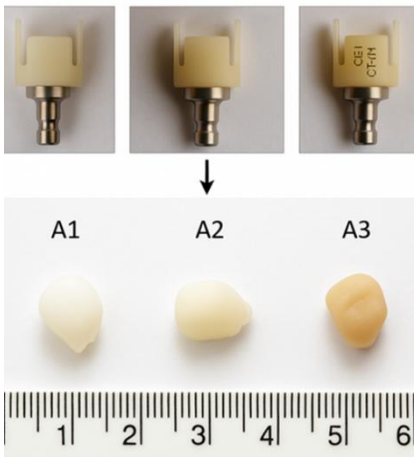


Figure 2.12 Macroscopic images of the experimental samples obtained

Table 2.1 Chemical composition of CEREC blocks used in CAD/CAM technology

Ceramics material	Commercial name of the product CEREC	Encoding	Chemical composition of CEREC block [% mass]
Zirconia Reinforced Lithium Silicate	Celtra Duo	A1	58% SiO_2; 18,5% Li_2O; 5% P_2O_5; 10,1% ZrO_2; 1,9% Al_2O_3; 2% CeO_2; 1% Tb_4O_7
Feldspathic ceramics	CEREC Blocks	A2	56 - 64% SiO_2; 20 - 23% Al_2O_3; 6 - 9% Na_2O; 0,3 - 0,8% CaO; 0,0 - 0,1% TiO_2 6-8% K_2
Lithium disilicate	CEREC	A3	90% $Li_2Si_2O_5$ 5% Li_3PO_4 5% $Li_{0,5}Al_{0,5}Si_{2,5O6}$

2.4. Experimental Materials and Methodological Framework of Study III

The experimental materials employed in this study were selected to encompass the widest possible spectrum of solutions applicable to fixed dental prostheses: yttria-stabilized tetragonal zirconia polycrystals (Y-TZP), lithium disilicate ($Li_2Si_2O_5$ – LiS_2), and leucite-reinforced feldspathic porcelain, which was applied both on zirconia frameworks and on metal frameworks (Co-Cr alloy). The experimental workflow included the following stages: selection of the experimental materials; fabrication of prosthetic restorations using different processing methods, namely CAD/CAM milling, sintering, heat pressing, and glazing; surface characterization by scanning electron microscopy (SEM); analysis of elemental chemical composition by energy-dispersive X-ray spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS); and mechanical testing to evaluate performance under conditions simulating functional stresses within the oral cavity.

Experimental samples used in study II

In the second experimental study, four types of fixed dental restorations were investigated, namely dental prostheses made of different materials, commonly used in clinical practice. The selected materials show significant structural and chemical differences, which allowed for a rigorous comparative evaluation of their functional and mechanical performance. Their coding is presented in Table 2.3.

Table 2.3 Coding of experimental samples

Code	The material used for dental prostheses
P1	Co-Cr alloy/ feldspathic porcelain (metal-ceramic)
P2	ZrO_2 / feldspathic porcelain (ceramic-ceramic)
P3	Zirconia
P4	Lithium disilicate

2.5. Methods and equipment used

The investigative methods and equipment employed in this doctoral thesis are summarized in Table 2.4.

Table 2.4 Investigation techniques and equipment used

PURPOSE	METHOD	EQUIPMENT
Morphology of the surface and cross-section	Scanning electron microscope (SEM)	Scanning Electron Microscope ESEM Quattro S (Thermo Fisher Scientific Inc., Waltham, MA, USA)

Elemental composition	Energy dispersive X-ray spectroscopy (EDS)	Spectrometer EDS Thermo Fisher Scientific Inc., Waltham, MA, USA)
Chemical composition of the surface	X-ray photoelectron spectroscopy (XPS)	Spectrometer K-Alpha (Thermo Fischer Scientific, Waltham, SUA)
Mechanical properties	Universal mechanical testing	Universal Testing Machine (Instron 34TM-10)
Surface morphology after mechanical testing	Scanning electron microscopy (SEM)	Scanning Electron Microscope ESEM Quattro S (Thermo Fisher Scientific Inc., Waltham, MA, SUA)
Identification of internal defects, initiation of cracks after testing	Computed tomography (CT)	Computer tomograph Nikon XT H 225 (Nikon Metrology, California, SUA)
Macroscopic analysis after mechanical testing	Stereomicroscopy	Stereomicroscopy (Nikon SMZ 1270, Nikon, Amstelveen, Olanda)
Wettability	Contact Angle (θ)	Equipment Krüss Drop Shape Analyzer DSA100 (A. Krüss Optronic GmbH, Hamburg, Germania)
Surface roughness	Profilometry	Profilometer Form Talysurf I-Series PRO Range (Taylor Hobson Ametek, Illinois, SUA)

CHAPTER 3. Experimental research on the clinical use of fixed dental prostheses using different inert ceramic biomaterials

3.1. Experimental Investigations on the Clinical Application of Fixed Dental Prostheses

Based on the clinical data obtained, the selection of the type of prosthetic restoration was grounded on functional, biomechanical, and aesthetic criteria. In this context, an effort was made to correlate the individual clinical conditions with the performance of the prosthetic materials and the available manufacturing techniques, with the aim of identifying the optimal therapeutic solution for each situation. Thus, the clinical evaluation and the choice of treatment type for dental rehabilitation represented essential stages of the experimental research, serving as the foundation on which the dental restorations investigated within this thesis were subsequently designed and analyzed.

3.2. Results and Discussions – Study I

CLINICAL CASE 1. In the first clinical case, a 47-year-old patient was examined, presenting with extensive partial edentulism affecting both the maxilla and the mandible, associated with clinical and radiographic evidence of advanced periodontitis. A comprehensive oral

rehabilitation was undertaken, which included the extraction of compromised teeth, bone augmentation using Bio-Oss, the placement of dental implants, and the delivery of fixed prosthetic restorations. This therapeutic approach resulted in a stable and long-lasting functional and aesthetic outcome, markedly superior to the initial clinical condition.

CLINICAL CASE 2. In the second clinical case, a 68-year-old patient was examined, presenting with multiple fixed prosthetic restorations in the form of dental crowns and bridges, located in both the maxilla and the mandible, across both hemiarches. The remaining natural teeth, particularly those in the region of teeth 17 to 25, were rehabilitated with fixed prosthetic restorations. Implant-supported prostheses were also fabricated, employing a combination of modern techniques: screw-retained restorations in the region of units 26 and 41–46, and cement-retained restorations in the region of 31–36. This therapeutic approach underscores the integration of diverse contemporary prosthetic methods, tailored to the patient's specific clinical condition, with the objective of achieving a comprehensive, stable, and functionally efficient oral rehabilitation.

CLINICAL CASE 3. In the third clinical case, a 74-year-old patient was examined, with radiographic analysis revealing multiple clinico-pathological alterations in both the maxilla and the mandible. The therapeutic plan for this case consisted, in the initial stage, of the extraction of teeth 32–42 and 16, due to their advanced mobility incompatible with arch preservation, as well as the extraction of the residual root of tooth 17. Subsequently, complete endodontic treatment was performed on all remaining teeth in both arches, followed by corono-radicular reconstructions (CRRs) with fiberglass posts, aimed at ensuring the stability and functionality of the preserved dental structures. In the final stage of rehabilitation, the patient received complex prosthetic restorations, namely: a zirconia framework–based prosthesis consisting of 12 units, and a zirconia-supported, ceramic-veneered prosthesis consisting of 10 units.

CAZ CLINIC 4. In the fourth clinical case, a 40-year-old patient was examined, who presented with multiple prosthetic restorations in the form of crowns and metal-ceramic bridges, applied at the level of both arches. The established therapeutic plan involved: bilateral insertion of two dental implants on each side, extraction of teeth 23 and 26, bone augmentation procedures, corono-radicular reconstruction of teeth 21 and 22 with the help of IOS type pivots.

CLINICAL CASE 5. In the fifth clinical case, a 58-year-old patient was examined, presenting with extensive edentulism in both the maxilla and the mandible. Multiple titanium implants were used in both arches, and the final prosthetic restoration demonstrated appropriate osseointegration and functional adaptation, with the observation of a slight gingival inflammation.

CLINICAL CASE 6. In the sixth clinical case, a 24-year-old patient was evaluated, presenting with aesthetic and functional impairments caused by pronounced demineralizations in the upper anterior region (teeth 13–23). Within the therapeutic plan, it was decided to replace the compromised esthetic restorations and to perform endodontic retreatments on teeth 13 and 21, followed by corono-radicular reconstructions using fiberglass posts. Subsequently, minimally invasive preparations were carried out, aiming to preserve as much sound dental structure as possible, in order to facilitate the placement of pressed ceramic crowns (K–K system). These restorations were designed to re-establish both the esthetics and the functionality of the upper anterior segment (teeth 13–22). At the level of tooth 23, treatment consisted of applying a vestibular veneer of light-curing composite resin to improve the esthetic appearance and restore the continuity of the dental arch.

CHAPTER 4. Experimental Investigations on the Functional Properties of Fixed Dental Prostheses Fabricated from Various Inert Ceramic Biomaterials

4.1. Results and discussions - Study II

4.1.1. Results of scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (EDS) on the dental prosthetics obtained

The scanning electron microscopy (SEM) images obtained for the three prosthetic crowns under investigation (samples A1, A2, and A3), at magnifications of 100×, 500×, and 10,000×, are presented in following figure. SEM analysis revealed that all samples exhibited morphologies characteristic of the CAD/CAM milling process, with moderate surface roughness and no evidence of visible porosities or microcracks. These findings confirm uniform processing and appropriate structural integrity, representing favorable conditions for clinical integration.

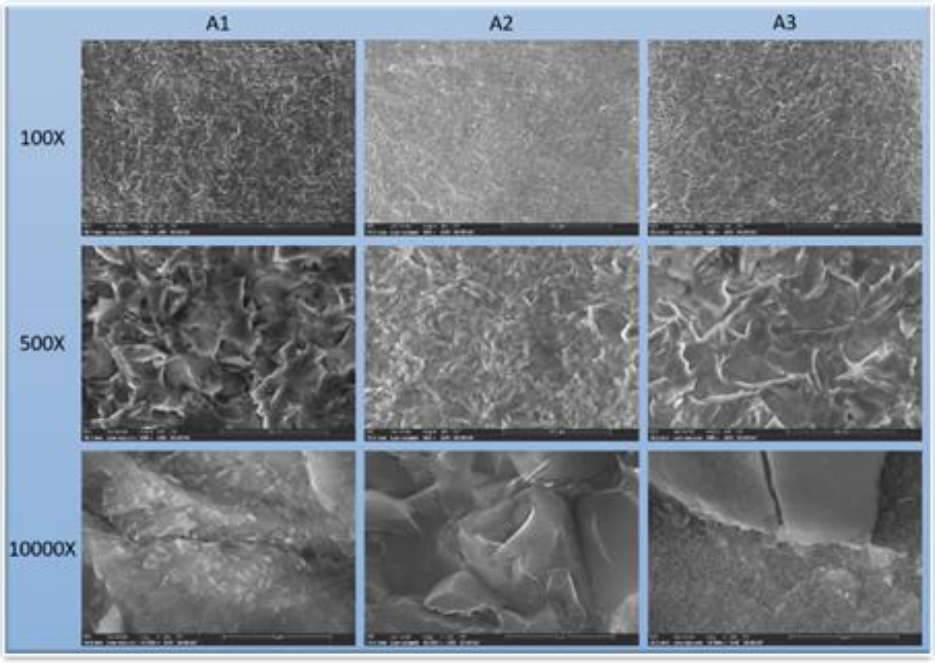


Figure 4.1-4.3 SEM images on experimental prosthetic crowns analyzed at different sizes

The EDS spectra obtained for all the investigated samples revealed that oxygen and silicon are the major elements in the composition of the specimens (Table 4.1-4.3).

Table 4.1 EDS elemental composition of sample A1

Element	Mass percentages, %	Error	Atomic percentage, %	Error
O	53.84	± 0.62	71.04	± 0.81
Na	0.75	± 0.07	0.69	± 0.07
Mg	0.22	± 0.06	0.19	± 0.05
Al	1.59	± 0.10	1.24	± 0.08
Si	30.54	± 0.22	22.96	± 0.17
Cl	0.32	± 0.04	0.19	± 0.03
K	2.42	± 0.06	1.31	± 0.03
Zr	10.33	± 1.30	2.39	± 0.30
Total	100.00		100.00	

Table 4.2 EDS elemental composition of sample A2

Element	Mass percentages, %	Error	Atomic percentage, %	Error
O	48.11	± 0.45	61.68	± 0.58
Na	7.30	± 0.12	6.51	± 0.11
Al	12.40	± 0.14	9.43	± 0.10
Si	26.70	± 0.20	19.50	± 0.14
K	5.49	± 0.10	2.88	± 0.05
Total	100.00		100.00	

Table 4.3 EDS elemental composition of sample A3

Element	Mass percentages, %	Error	Atomic percentage, %	Error
O	58.52	± 0.49	73.64	± 0.61
Na	0.58	± 0.10	0.51	± 0.09
Mg	0.36	± 0.05	0.30	± 0.04
Al	1.73	± 0.08	1.29	± 0.06
Si	30.91	± 0.19	22.16	± 0.13
K	1.22	± 0.04	0.63	± 0.02
Zr	6.66	± 0.80	1.47	± 0.18
Total	100.00		100.00	

4.1.2. Computed tomography (CT) results

The CT analysis was conducted to evaluate whether the fabrication of the three fixed samples using CAD/CAM technology induced internal alterations or structural defects that could affect clinical performance. The results demonstrated the absence of pores or other significant imperfections, confirming that the mechanical integrity and functional reliability of the restorations were preserved. Furthermore, the anatomical configuration of the prosthetic crowns exhibited a high degree of geometric accuracy, with faithful preservation of the occlusal morphology, consistent with the reference model obtained through digital scanning.

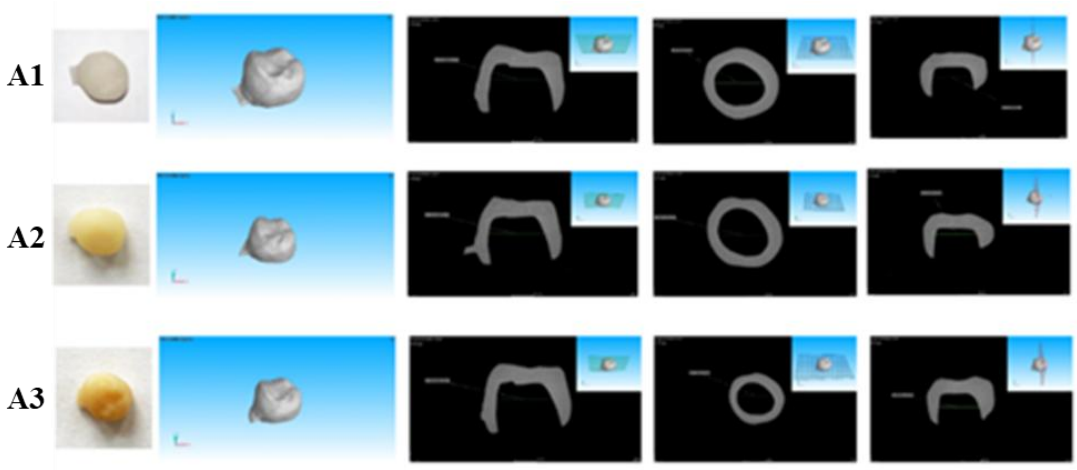


Figure 4.5-4.7 CT images of the analyzed experimental samples

4.1.3. Evaluation of the roughness of dental prostheses

In this doctoral thesis, in order to allow a rigorous comparative analysis, the determination of roughness was performed both on the samples obtained (A1, A2, A3) and on the ceramic blocks subjected to the milling process.

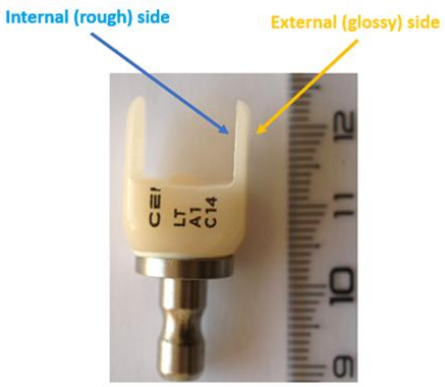


Figure 4.8 The inner area, with a rough appearance, and the outer area, with a smooth and glossy appearance, of the ceramic block remaining after the CAD/CAM milling process

The profilometric analysis (Table 4.4) revealed significant differences in surface roughness among the three investigated materials. The parameters determined included Ra (arithmetic mean roughness), Rq (root mean square roughness), and Rsk (profile skewness). Comparative evaluation of the analyzed areas demonstrated that, in all cases, the final samples exhibited the highest surface roughness values, followed by the internal surface of the ceramic block, while the lowest values were recorded for the external surface of the block.

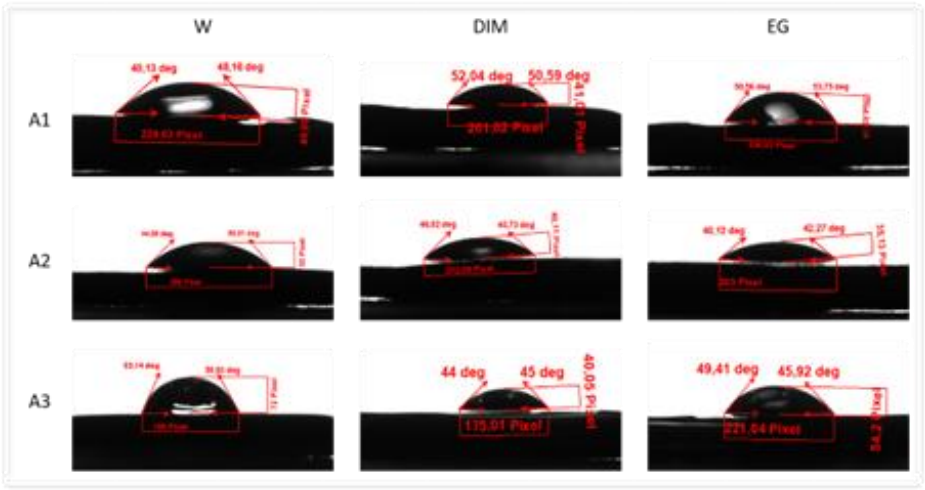
Table 4.4 Roughness parameters of the analyzed samples and of the inner and outer sides of the remaining block material

	Ra [µm]	**Rq [µm]**	**Rsk**
A1	**Prosthetic work**		
	1.9715	2.7405	-1.1601
	Inner part		
	1.8038	2.2854	-0.1891
	Outer part		
	0.2013	0.8079	-11.9274
A2	**Prosthetic work**		
	1.9148	2.8214	-2.2669
	Inner part		
	1.7077	2.1848	-0.2938
	Outer part		
	0.4326	0.6799	-1.8274
A3	**Prosthetic work**		
	2.8647	4.3593	-2.8007
	Inner part		
	1.8304	2.3576	-0.0663
	Outer part		
	0.0766	0.1940	-10.4699

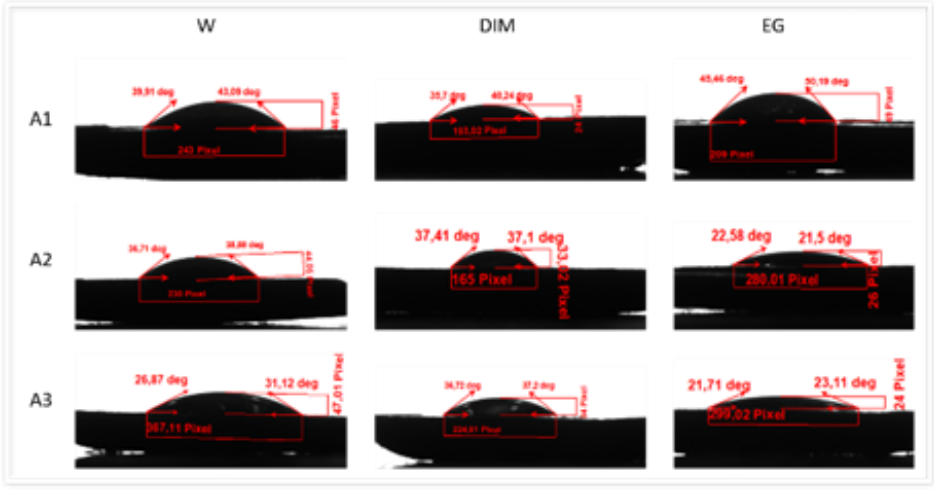
4.1.4. Evaluation of the wettability of dental prostheses

Wettability and free surface energy are essential parameters in the evaluation of the performance of bioceramic materials used for dental restorations, as they influence both susceptibility to bacterial colonization and compatibility with adhesion agents used in clinical practice. According to the literature, materials with an accentuated hydrophilic character and with high values of free surface energy show an increased tendency to attract bacteria, a phenomenon correlated with the presence of active ions at the surface level [134].

Following the analysis of the values obtained for the contact angle corresponding to the three types of liquids tested (W-water, diiodometan-DIM and ethylene glycol), it was found that the investigated materials presented, overall, a comparable behavior. However, notable differences were observed between the areas analyzed.



(a)



(b)

Figure 4.6 Values of the contact angle determined on: (a) the external surface and (b) the internal surface of the ceramic blocks from which the prosthetic works were obtained

Table 4.5 Mean values of the contact angle and surface free energy for the external and internal surfaces of the investigated ceramic blocks

Sample	Average contact angle [º]			Free surface energy [mN/m]		
	W	DIM	Ethylene glycol	W	DIM	Ethylene glycol
Outer part						
A1	43.28 ± 7.0831	50.23 ± 8.0253	50.23 ±5.4351	128.64	95.97	101.56
A2	46.30 ± 4.81	45.13 ± 4.83	42.31 ±7.17	23.27	68.60	45.95
A3	64.73 ± 4.18	45.35 ± 2.59	45.65 ±4.90	48.83	58.15	46.14
Inner part						
A1	42.48 ± 4.97	35.68 ± 5.74	39.10 ±10.52	78.32	26.06	58.81
A2	38.30 ±4.36	37.05 ± 3,45	23.74±7.98	132.47	88.73	59.67
A3	31.41 ±4.47	37,49 ± 3,21	23.24 ±3.21	145,59	97,71	35.95

4.2. Results and discussions - Study III

4.2.1. Experimental results of scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDS) on the obtained dental prostheses

The SEM results for the investigated experimental samples are presented in the following figure. Both surface and cross-sectional images of the yttria-stabilized ZrO_2 prosthesis revealed the characteristic morphology of materials processed by CAD/CAM technology, defined by a relatively uniform topography with randomly distributed asperities measuring approximately 1–5 μm. In the case of the $Li_2Si_2O_5$ dental prosthesis (lithium disilicate, P4 sample) obtained by thermal pressing, the surface analysis revealed a roughness comparable to that of the P3 sample (ZrO_2 prosthesis stabilized with yttrium), but the higher fragility of this material determined the appearance of microcracks visible in the SEM images. For the stratified samples (P1, P2) the SEM analysis highlighted notable differences between the two types of restorations: feldspathic porcelain/Co-Cr and feldspathic porcelain/zirconia. The EDS analysis was performed to identify and quantify the constituent chemical elements of the samples investigated. The results obtained confirmed the elemental composition, in accordance with both the data from the literature and the specifications of the manufacturers of the materials used.

Table 4.6 Elemental composition obtained by EDS for stratified feldspathic porcelain/ZrO2 and feldspathic porcelain/Co-Cr restorations

Elemental composition of layered restorations [%]										
feldspar porcelain / ZrO_2	**O**	**Na**	**Al**	**Si**	**K**	**Ca**	**Ti**	**Zn**	**Y**	**Zr**
	32.44	<0.1	0.05	1.20	0.43	<0.1	<0.1	<0.1	6.10	59.78
feldspar porcelain / Co-Cr	**O**	**Na**	**Mg**	**Al**	**Si**	**K**	**Ca**	**Cr**	**Fe**	**Zn**
	51.82	6.80	<0.1	2.03	18.96	2.06	0.53	6.53	4.64	6.63

Table 4.7 Elemental composition obtained by EDS for restorations of ZrO_2 and $Li_2Si_2O_5$

Elemental composition of prosthetic restorations								
ZrO_2	**O**	**Na**	**Al**	**Si**	**K**	**Y**	**Zr**	
	72.23	0.1	0.06	1.52	0.30	2.44	23.35	
$Li_2Si_2O_5$	**O**	**Na**	**Mg**	**Al**	**Si**	**K**	**Ca**	**Zn**
	65.99	5.47	0.26	2.16	22.84	2.01	0.56	0.71

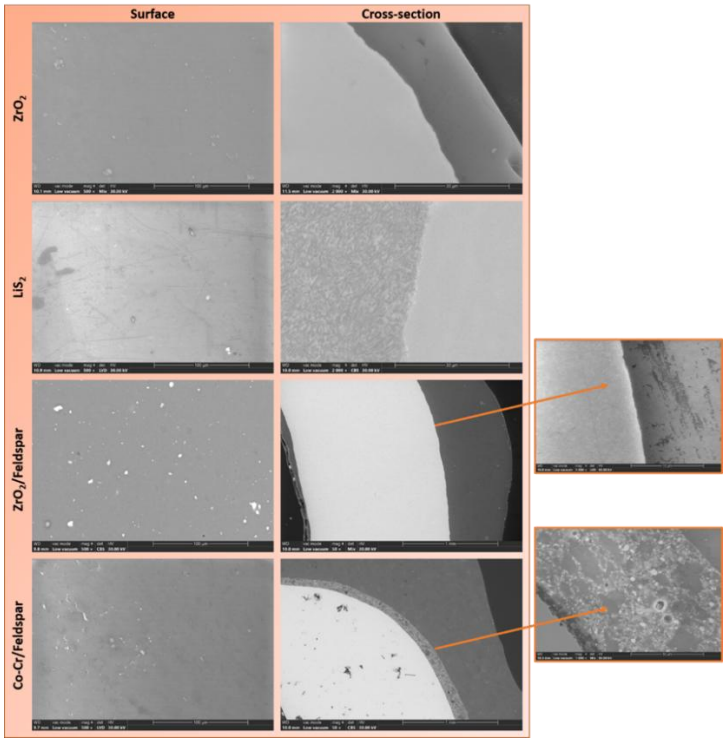
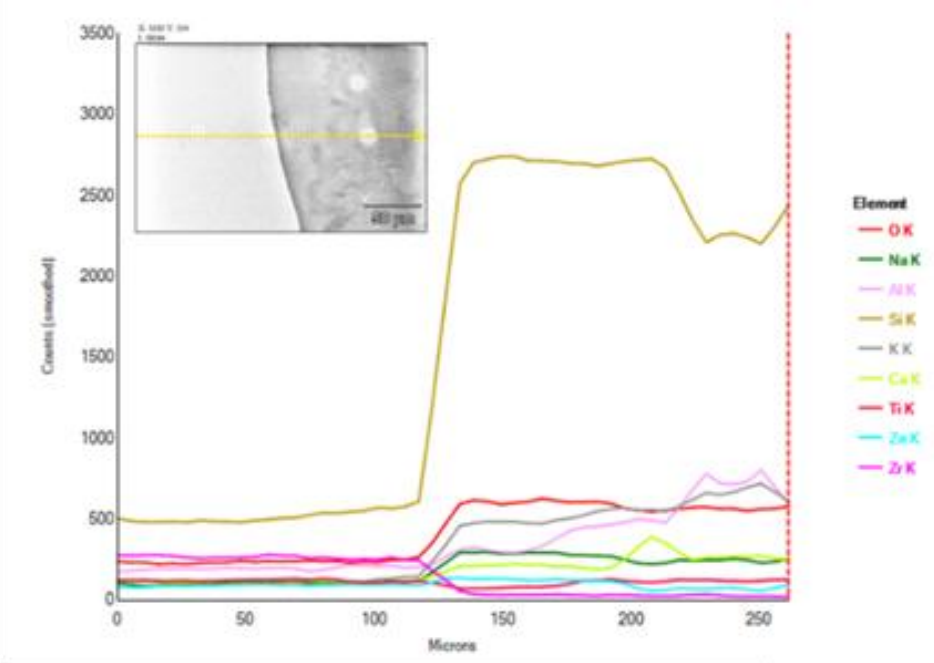


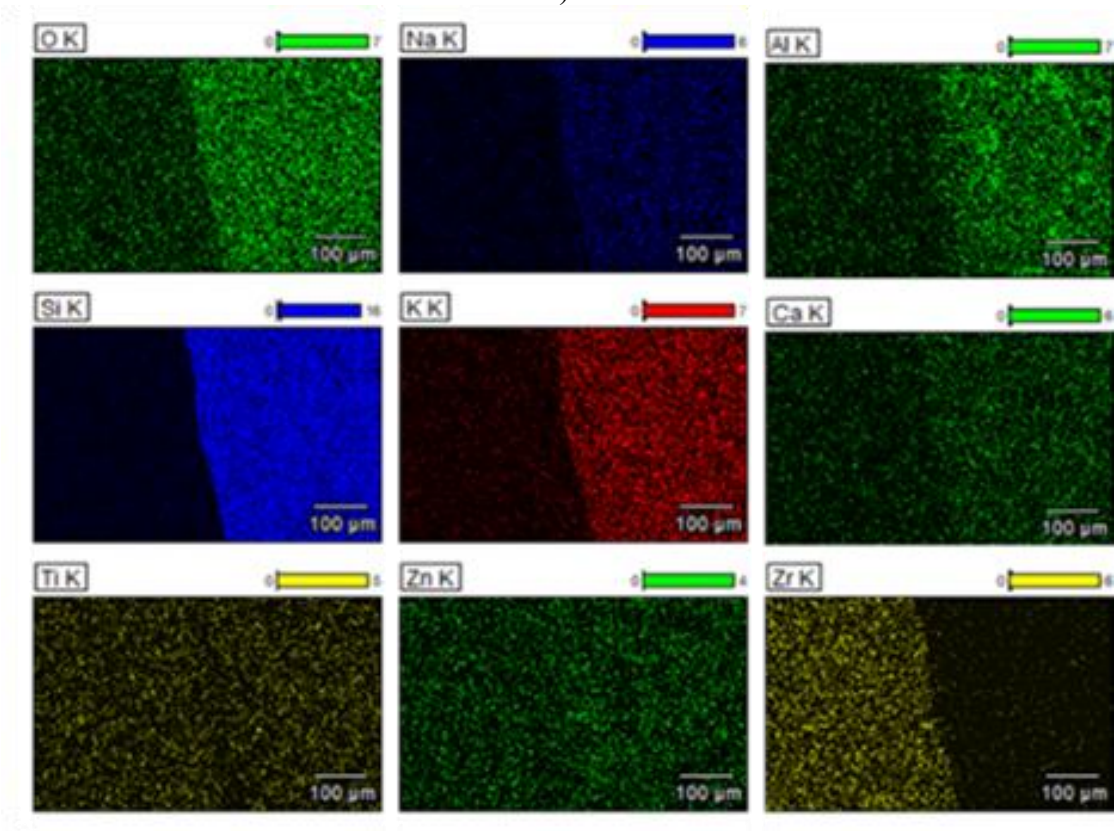
Figure 4.12-4.13 Morphology of the surface and cross-section on the analyzed dental prostheses

For a more detailed understanding of the distribution of chemical elements at the interface between the substrate and the ceramic coating (P1, P2), additional analyses were

performed, including EDS line scans and elemental mapping. These methods enabled not only the identification of the chemical elements present but also the visualization of their spatial distribution within the analyzed structure.

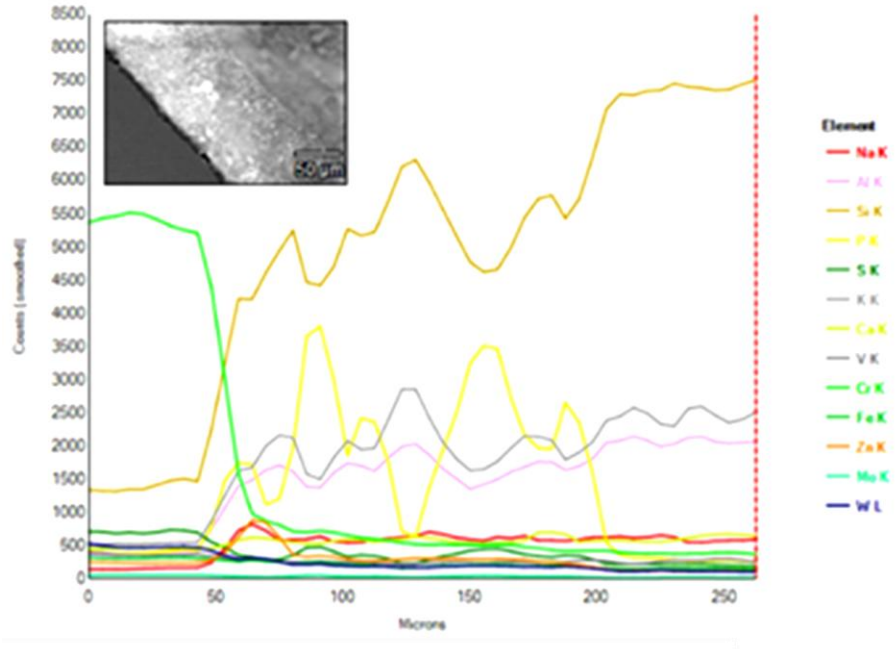


a)

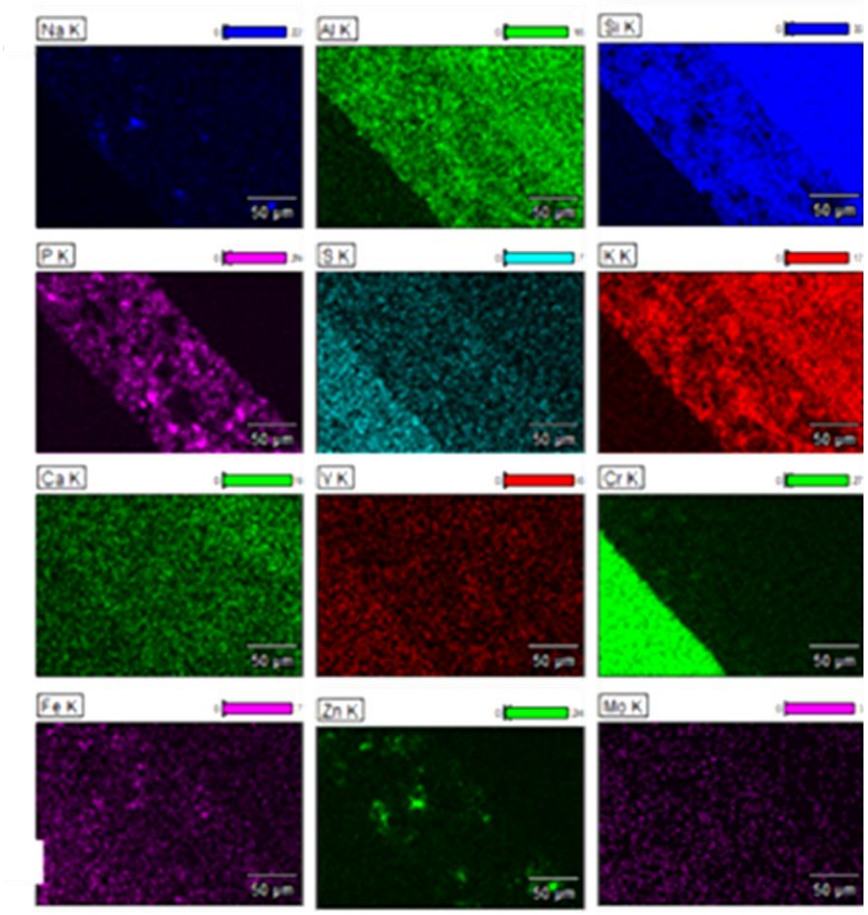


b)

Figure 4.15 EDS Linear Scan (a) and elemental distribution (b) of feldspathic porcelain/ZrO_2 layered restorations



a)



b)

Figure 4.16 EDS Linear Scan (a) and elemental distribution (b) of feldspathic porcelain/CcCr alloy layered restorations

4.2.2. Experimental results of X-ray photoelectron spectroscopy (XPS)

X-ray photoelectron spectroscopy (XPS) analysis provided detailed information on the chemical composition of the surface layer of the prostheses, complementing and confirming the results previously obtained by energy dispersive X-ray spectroscopy (EDS).

4.2.3. Experimental results after mechanical testing on the dental prostheses obtained

Figure 4.18 shows the characteristic force-displacement curves corresponding to the four types of fixed dentures (PDF), which highlight the mechanical peculiarities specific to each material during the compression test. In addition, Table 4.8 summarizes the values of the experimentally determined essential mechanical parameters

Table 4.8 Experimental results obtained from mechanical tests carried out on the four fixed dental prostheses (FDPs)

Probă	F_1 [kN]	DF_1 [mm]	Fmax [kN]	DFmax [mm]	Stiffness R [kN/mm]
P1	0.8909	0.282	1.9121	0.5441	3.098 – 6.989
P2	0.5690	0.2148	0.7200	0.2795	1.451 – 4.489
P3	0.3779	0.2395	0.6825	0.2966	0.907 – 6.483
P4	0.5467	0.1646	0,9379	0.2273	1.202 – 6.673

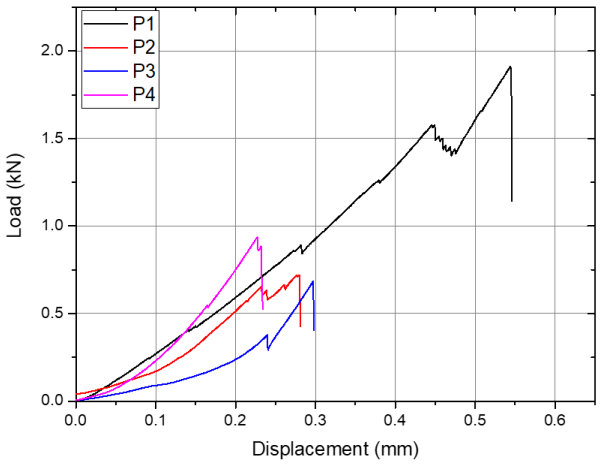


Figure 4.18 Force–displacement curves corresponding to the four types of fixed dental prostheses (P1–P4)

4.2.4. Computed tomography (CT) results on dental prostheses obtained

Figure 4.20 shows computed tomography (CT) images of the analyzed samples after mechanical testing. CT analysis was performed with the aim of highlighting the internal characteristics of the fracture and the patterns of crack propagation.

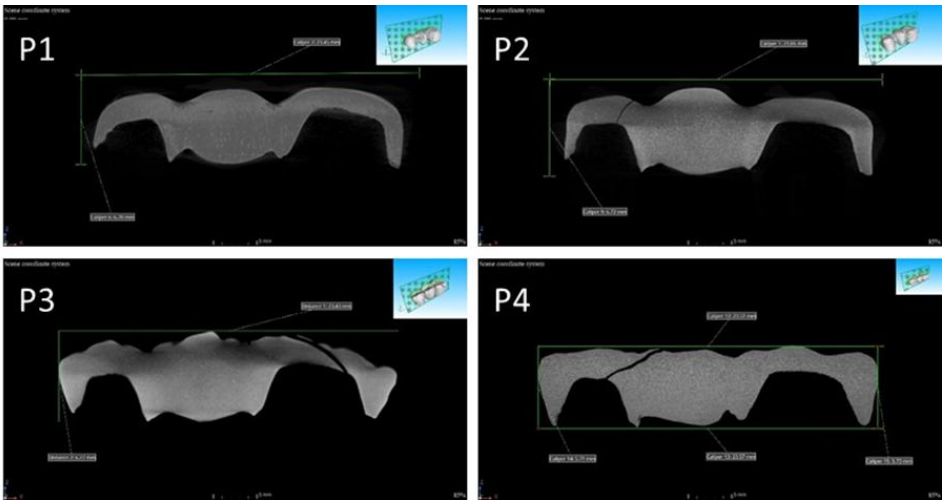


Figure 4.20 CT images taken following mechanical tests for the four types of fixed dentures

4.2.5. Results of fractographic analysis on dental prostheses obtained after mechanical testing

In order to identify the mechanisms of crack propagation following mechanical testing, the samples were subjected to a thorough fractographic examination. This analytical step allowed the detailed examination of the post-rupture characteristics, contributing to the understanding of how cracks propagate and the nature of the rupture (brittle or ductile). Thus, the fractographic analysis provided essential information for correlating the mechanical behavior observed in the case of bending stress.

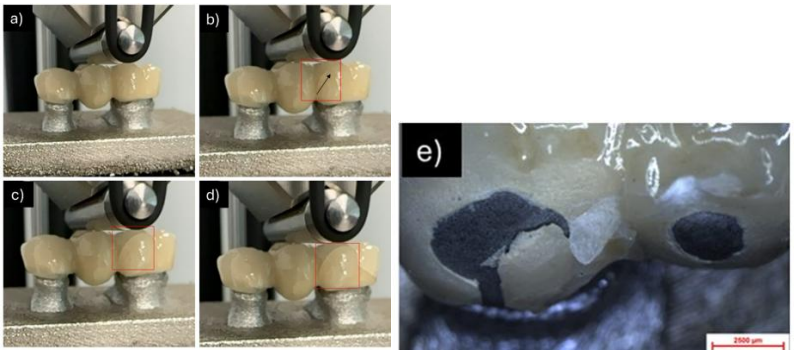


Figure 4.21 The mode of propagation of cracks in the case of metal-ceramic dental prostheses during mechanical testing

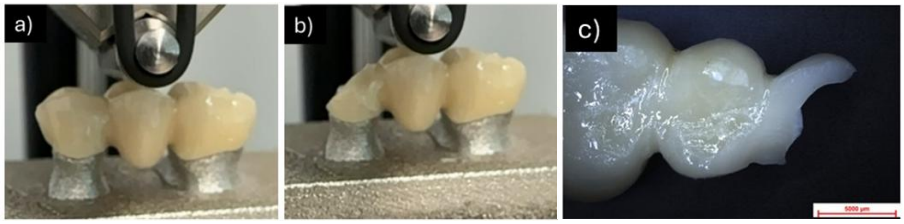


Figure 4.22 How cracks propagate in P2 dental prostheses during mechanical testing



Figure 4.23 How cracks propagate in the case of dental prostheses P3

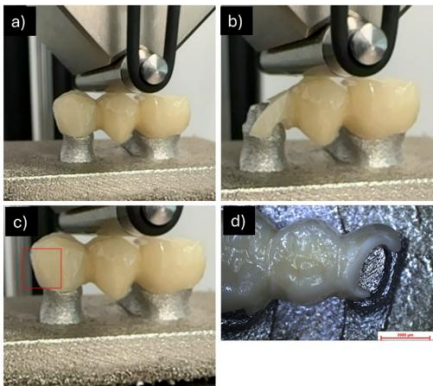


Figure 4.24 How cracks propagate in the case of dental prostheses P4

The images obtained by scanning electron microscopy (SEM), presented in Figure 4.25 provide information on the morphology of the fracture surfaces of the fixed dental restorations (FDP) tested, providing complementary information to those obtained by stereomicroscopic examination and CT reconstruction.

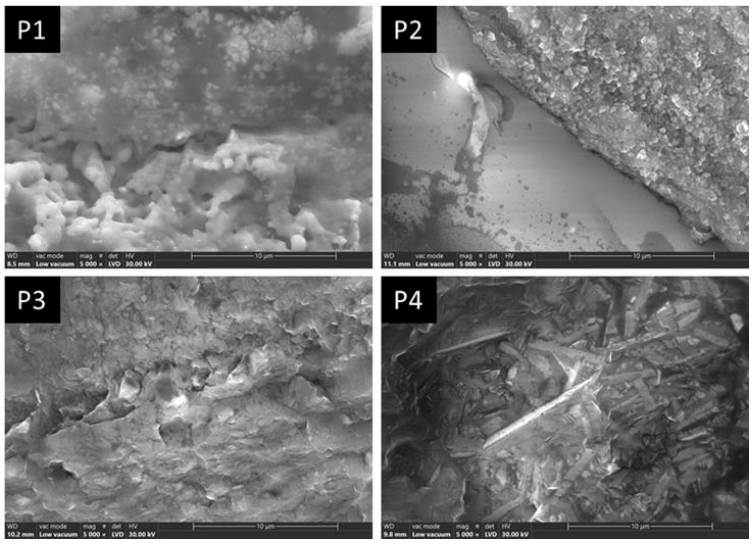


Figura 4.25 Fractographic images obtained by SEM of fractured of dental prostheses

CHAPTER 5. Conclusions and Personal Contributions

5.1. General Conclusions

Based on the theoretical studies and experimental research conducted within this doctoral thesis, the following general conclusions and assessments can be drawn:

- In recent decades, various biomaterials have been used in different dental applications, namely metallic, ceramic, polymeric, and composite biomaterials. Several studies have shown that the effectiveness of biomaterials in dental prosthetics depends on multiple parameters, demonstrating that the evaluation of biofunctional properties cannot be made only on the basis of the individual properties of a material, since different factors combine to produce a complex response.
- Based on the literature review conducted, a series of parameters that influence the performance of dental prostheses have been identified: the properties of the biomaterials used and their structure, the oral cavity environment, mechanical stresses, the technologies applied for the processing of biomaterials in order to obtain dental prosthetic restorations, surface properties, and aesthetic properties.
- Inert ceramic biomaterials are preferred for the fabrication of dental prosthetic restorations compared to other types of biomaterials.
- The development and characterization of dental prosthetic restorations usually involve a significant amount of analysis. The use of studies and numerical simulations offers a various advantages, such as investigating biomechanical performance as a function of different combinations of relevant parameters, leading to optimization. The finite element method has proven to be a useful tool for such parametric studies, resulting in a drastic reduction in the number of experimental tests.
- The need to improve the interaction of dental prosthetic restorations with dental tissues, as well as the requirement to withstand a combination of clinical stresses, has led to numerous studies and research focused on the development of modern processing technologies for inert ceramic biomaterials, particularly CAD/CAM technology, as well as the creation of new inert ceramic biomaterials or treatments for modifying surface properties.
- There is a wide variety of processing technologies for inert ceramic biomaterials used in dental prosthetics. A comprehensive review of the scientific literature has revealed that CAD/CAM processing technologies for various inert ceramic biomaterials provide superior results compared to other processing methods. Furthermore, the literature highlights the absence of experimental comparative studies between different biomaterials processed using

the same technologies, with existing comparisons being limited mainly to variations in the biomaterials used, aesthetic outcomes, and clinical performance of dental prostheses.

- Based on the extensive literature review conducted, inert ceramic biomaterials such as lithium disilicate, feldspathic ceramics, and zirconia can be considered optimal for the fabrication of dental prostheses, as they offer a balanced compromise with respect to biocompatibility, aesthetics, high strength, and biofunctionality requirements.
- It can be stated that studies and research on the evaluation of dental prosthetic restorations made of inert ceramic biomaterials represent a highly topical subject in the field of materials engineering, especially since complex correlations are being assessed between structural aspects, processing technologies, and functional properties that form the foundation of this field. The use of CAD/CAM processing technology is particularly noteworthy. The wide variety of methods employed for the evaluation of dental prosthetic restorations, as well as the fact that the phenomena involved are not yet fully elucidated, support the idea that every contribution in this area adds valuable progress to the development of this line of research.
- The objective of this doctoral thesis was the comparative evaluation of fixed dental restorations obtained from different materials and through different technological procedures. The analysis addressed both the clinical performance of various dental prosthetic restorations and the inert ceramic biomaterials used in the fabrication of dental prostheses, focusing on the influence of the chemical composition of the materials employed and the influence of processing methods applied to inert ceramic biomaterials on the functional and clinical performance of the restorations.
- Within the framework of this doctoral thesis, an initial research study was carried out, focusing on the evaluation of the clinical performance of different prosthetic work fabricated from inert ceramic biomaterials.
- Subsequently, two research studies were conducted, specifically focused on inert ceramic biomaterials and their processing technologies for the fabrication of dental prosthetic restorations. The main objective was the comparative evaluation of fixed dental restorations obtained from different materials and through different technological procedures. The analysis considered both the influence of the chemical composition of the materials used for the fabrication of dental prostheses and the impact of the processing methods on the functional and clinical performance of the restorations. The first study aimed to investigate how CAD/CAM technology influences the surface properties of fixed dental crowns fabricated from prefabricated ceramic blocks. The main parameters considered were surface morphology,

roughness, wettability, and chemical composition. The study sought to evaluate these properties in the context of selecting the restorative material with the best performance for intraoral applications. The second study was designed to comparatively evaluate four types of fixed dental restorations, highlighting how the chemical composition of the material and the processing technology affect the final performance of the restorations, through the analysis of surface properties and mechanical properties.

- Within the present doctoral thesis, only commercially available inert ceramic biomaterials were used, all of which are certified in terms of biocompatibility. Consequently, it was not necessary to conduct additional costly *in vivo* or *in vitro* tests to evaluate the biocompatibility of experimental biomaterials.
- The correlation of the experimental results regarding the structural characteristics of the ceramic biomaterials, together with the mechanical testing followed by a detailed fractographic analysis, confirmed the existence of differences dependent on the type of inert ceramic biomaterial used in terms of fracture behavior. These findings provide a solid basis for the variable interpretation of toughness and fracture resistance among the groups of dental prosthetic restorations evaluated, thereby contributing to a deeper understanding of their clinical performance.
- The experimental research demonstrated a clear relationship between the type of ceramic biomaterial, the processing technology, the mechanical strength, and the fracture behavior of the investigated samples.
- The investigation of mechanical properties and subsequent fractographic analysis emerge as essential components in the accurate evaluation of the performance of dental prosthetic restorations.
- The evaluation of surface properties is an important step; however, in the case of dental prosthetic restorations, it plays a complementary role since their biofunctionality and clinical performance rely primarily on biomechanical reliability and functional esthetics. The present doctoral thesis has demonstrated that prosthetic restorations manufactured from different inert ceramic biomaterials may exhibit similar surface properties but differ in costs and clinical performance, variations that are attributable to their distinct mechanical properties.
- In conclusion, the use of inert ceramic biomaterials has proven to be optimal for the fabrication of dental prosthetic restorations, which require a balanced compromise between mechanical strength, biocompatibility, and dental esthetics.

5.2. Personal Contributions

The research conducted has brought a series of novel contributions through the original results obtained and their theoretical interpretation. The original contributions are presented below, together with the most important findings:

1. As a result of the comprehensive literature review, design criteria and working parameters for CAD/CAM processing methods of inert ceramic biomaterials used in the fabrication of dental prostheses were established. Several dental prosthetic restorations from inert ceramic biomaterials were manufactured.
2. A complex testing procedure was carried out to demonstrate the functional properties of different dental prostheses in clinical practice.
3. A comprehensive characterization of the structure of inert ceramic biomaterials was performed using modern methods and equipment, namely scanning electron microscopy (SEM) coupled with energy-dispersive spectroscopy (EDS).
4. A complex characterization of dental prosthetic restorations made from inert ceramic biomaterials was performed, addressing both surface properties and mechanical characteristics.
5. A detailed fractographic analysis was conducted using stereomicroscopy, scanning electron microscopy, and computed tomography. It should be noted that in the framework of this PhD thesis, computed tomography was employed for fractographic analysis.
6. The set of studies carried out allows us to conclude that the main objective of the doctoral thesis has been achieved, namely the comparative evaluation of a series of fixed dental restorations obtained from different materials and through different technological procedures. The analysis addressed both the clinical performance of various dental prosthetic restorations, and the inert ceramic biomaterials used in their fabrication, focusing on the influence of the chemical composition of the materials employed for dental prostheses, as well as the impact of processing methods of inert ceramic biomaterials on their functional and clinical performance.

It should be emphasized that the experimental part was conducted predominantly in the laboratories of the Department of Metallic Materials Science and Physical Metallurgy, Faculty of Materials Science and Engineering, National University of Science and Technology Politehnica Bucharest, while additional experimental determinations were performed in other laboratories.

Far from claiming to exhaust the theoretical and experimental research in the field of biomaterials used for dental prosthetics, this work provides a valuable theoretical and practical contribution, offering a solid foundation for the selection of biomaterials and processing

technologies for the fabrication of dental prostheses, while at the same time opening new horizons for future research in this field.

5.3. Future Development Perspectives

This doctoral thesis presents several perspectives for future development, including:

• The extension of the studies by employing different methods for modifying the surface properties of inert ceramic biomaterials.

• The expansion of the research through the use of different configurations of inert ceramic biomaterials, particularly zirconia.

• The possibility of extending the investigations to include a comparative evaluation of prosthetic restorations fixed on dental implants, in various configurations.

• The broadening of experimental research by testing biofunctionality in specific clinical cases.

DISSEMINATION OF EXPERIMENTAL RESULTS

Articles Published in Indexed Journals and Databases (BDI) in the Field of the Doctoral Thesis

1. **FOCȘĂNEANU Sergiu-Ciprian,** Antoniac Iulian, Ciuca Ion, Kamel Earar, *CAD/CAM CERAMICS IN MODERN PROSTHODONTICS: EVALUATION OF SURFACE TOPOGRAPHY, ROUGHNESS, AND CLINICAL IMPLICATIONS,* Romanian Journal of Medical and Dental Education, Vol. 14, No. 4, 2025.

2. **FOCȘĂNEANU Sergiu-Ciprian**, Ciuca Ion, Antoniac Iulian, Kamel Earar, *COMPARATIVE INSIGHTS INTO SURFACE PROPERTIES OF CAD/CAM-PROCESSED CERAMIC MATERIALS: A REVIEW,* Romanian Journal of Medical and Dental Education, Vol. 14, No. 4, 2025.

ISI-Ranked Articles in the Field of the Doctoral Thesis

3. Nazem DAWOD, Dan Ioan STOIA, **Sergiu FOCȘĂNEANU**, Aurora ANTONIAC, Alina ROBU, Horațiu DURA, Ioana Dana CÂRSTOC, Bogdan Radu DRAGOMIR, *SHEAR STRESS ANALYSIS BY FINITE ELEMENTS OF A METAL-CERAMIC DENTAL BRIDGE ON A CoCr ALLOY SUPPORT*, UNIVERSITY POLITEHNICA OF BUCHAREST SCIENTIFIC BULLETIN SERIES B-CHEMISTRY AND MATERIALS SCIENCE, Volume 85, Issue 3, 2023 (Q4, IF = 0,3).

ISI-Ranked Articles Addressing the Subject of the Present Doctoral Thesis

1. Dorin Ioan Cocos, Alina-Ramona Dimofte, Gabriel Valeriu Popa, Mariana Pacurar, Doriana Agop Forna, Cristina Iordache, **Sergiu Focsaneanu**, Kamel Earar, *MANAGEMENT OF*

INCLUDED WISDOM TEETH: THERAPEUTIC APPROACHES AND PREVENTION OF TMJ DYSFUNCTIONS, Romanian Journal of Oral Rehabilitation, Volume 17, Nomber 1, 2025 (Q, IF = 1,1)

2. Kamel Earar, Mariana Jian, Norina Consuela Forna, **Sergiu Focsaneanu,** Alina Ramona Dimofte, Nicolae Sârbu, Ovidiu Sebastian Nicolaiciuc*, BENEFITS AND LIMITATIONS OF USING SURGICAL GUIDES IN IMPLANTOLOGY,* Romanian Journal of Oral Rehabilitation, Volume 17, 2025 (IF = 1,1)

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