

SERGEY DOROZHKIN

CALCIUM ORTHOPHOSPHATES

Applications in Nature, Biology, and Medicine



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Contents

Preface

xiii

1. Calcium Apatites and Other Calcium Orthophosphates	1
1.1 Introduction	1
1.2 Geological and Biological Occurrences	3
1.3 The Members of Calcium Orthophosphate Family	8
1.3.1 MCPM	15
1.3.2 MCPA (or MCP)	17
1.3.3 DCPD	17
1.3.4 DCPA or DCP	18
1.3.5 OCP	19
1.3.6 β -TCP	20
1.3.7 α -TCP	21
1.3.8 ACP	22
1.3.9 CDHA (or Ca-def HA)	25
1.3.10 HA (or HAp, or OHAp)	27
1.3.11 FA (or FAp)	29
1.3.12 OA (or OAp, or OXA)	31
1.3.13 TTCP (or TetCP)	32
1.3.14 Multiphasic and Polyphasic Calcium Orthophosphate Compositions	33
1.3.15 Ion-substituted Calcium Orthophosphates	35
1.4 Biological Hard Tissues of Calcium Orthophosphates	36
1.4.1 Bone	38
1.4.2 Teeth	51
1.4.3 Antlers	59
1.5 Pathological Calcification of Calcium Orthophosphates	62
1.6 Biomimetic Crystallization of Calcium Orthophosphates	66
1.7 Conclusions and Outlook	72

2. Amorphous Calcium (Ortho) Phosphates	153
2.1 Introduction	153
2.2 Basic Definitions and Knowledge on the Amorphous State of Solids	154
2.3 Amorphous Calcium Phosphates (ACPs)	158
2.3.1 History	158
2.3.2 Preparation	161
2.3.2.1 Wet-chemistry	161
2.3.2.2 Non-aqueous solutions and solvents (sol-gel)	164
2.3.2.3 Mechanical and pressure-induced techniques	165
2.3.2.4 Thermal	166
2.3.2.5 Irradiation	167
2.3.3 Morphology of Precipitated ACPs	168
2.3.4 Chemical Composition	169
2.3.4.1 Precipitated ACPs	169
2.3.4.1 Other types of ACPs	174
2.3.5 Structure	175
2.3.6 Thermal Properties	181
2.3.7 Amorphous-to-Crystalline Transformations in Aqueous Solutions	183
2.4 ACP <i>in vivo</i>	187
2.5 Biomedical Application of ACPs	189
2.6 Conclusions	192
3. Nanodimensional and Nanocrystalline Calcium Orthophosphates	221
3.1 Introduction	221
3.2 General Information on “Nano”	223
3.3 Micron- and Submicron-Sized Calcium Orthophosphates Versus the Nanodimensional Ones	226
3.4 Nanodimensional and Nanocrystalline Calcium Orthophosphates in Calcified Tissues of Mammals	229
3.4.1 Bones	229
3.4.2 Teeth	230
3.5 The Structure of the Nanodimensional and Nanocrystalline Apatites	231

3.6 Synthesis of the Nanodimensional and Nanocrystalline Calcium Orthophosphates	237
3.6.1 General Nanotechnological Approaches	237
3.6.2 Nanodimensional and Nanocrystalline Apatites	237
3.6.3 Nanodimensional and Nanocrystalline TCP	247
3.6.4 Other Nanodimensional and Nanocrystalline Calcium Orthophosphates	249
3.6.5 Biomimetic Construction Using Nanodimensional Particles	252
3.7 Biomedical Applications of the Nanodimensional and Nanocrystalline Calcium Orthophosphates	253
3.7.1 Bone Repair	253
3.7.2 Nanodimensional and Nanocrystalline Calcium Orthophosphates and Bone-related Cells	258
3.7.3 Dental Applications	260
3.7.4 Other Applications	262
3.8 Summary and Perspectives	266
3.9 Conclusions	269
3.10 Post-Conclusion Remarks	271
4. Calcium Orthophosphates as Bioceramics	329
4.1 Introduction	329
4.2 General Knowledge on Biomaterials and Bioceramics	331
4.3 Bioceramics of Calcium Orthophosphates	334
4.3.1 History	334
4.3.2 Chemical Composition and Preparation	335
4.3.3 Forming and Shaping	337
4.3.4 Sintering and Firing	340
4.4 The Major Properties	343
4.4.1 Mechanical Properties	343
4.4.2 Electrical Properties	347
4.4.3 Possible Transparency	348
4.4.4 Porosity	349
4.5 Biomedical Applications	357
4.5.1 Cements and Concretes	362
4.5.2 Coatings	364

4.5.3	Functionally Graded Bioceramics	368
4.6	Biological Properties and <i>in vivo</i> Behavior	371
4.6.1	Interaction with Surrounding Tissues and the Host Responses	372
4.6.2	Osteoinduction	374
4.6.3	Biodegradation	376
4.6.4	Bioactivity	377
4.6.5	Cellular Response	382
4.7	Calcium Orthophosphate Bioceramics in Tissue Engineering	384
4.7.1	Tissue Engineering	384
4.7.2	Scaffolds and Their Properties	385
4.7.3	Bioceramic Scaffolds from Calcium Orthophosphates	388
4.7.4	A Clinical Experience	390
4.8	Conclusions and Outlook	391
5.	Self-Setting Calcium Orthophosphate Formulations: Cements, Concretes, Pastes, and Putties	459
5.1	Introduction	459
5.2	General Information and Data	462
5.3	Two Major Types of Calcium Orthophosphate Cements	474
5.3.1	Apatite Cements	474
5.3.2	Brushite Cements	478
5.4	Various Properties	481
5.4.1	Setting and Hardening	481
5.4.2	Mixing	483
5.4.3	Rheological Properties of the Self-setting Formulations	485
5.4.4	Properties Improving	488
5.5	Bioresorption and Replacement of the Cements by Bones	494
5.6	The Mechanical Properties	499
5.7	Reinforced Formulations and Concretes	504
5.8	Clinical and Medical Applications	508
5.8.1	Dental Applications	509
5.8.2	Craniofacial and Maxillofacial Applications	510
5.8.3	Orthopedic Applications	511
5.8.4	Vertebroplasty and Kyphoplasty Applications	512

5.8.5 Drug Delivery Applications	512
5.8.6 Brief Conclusions on the Medical Applications	514
5.9 Future Developments	516
5.10 Conclusions	522
6. Calcium Orthophosphate-Based Biocomposites and Hybrid Biomaterials Nomenclature	579
6.1 Introduction	580
6.2 General Information on Composites and Biocomposites	585
6.3 The Major Constituents of Biocomposites and Hybrid Biomaterials for Bone Grafting	589
6.3.1 Calcium Orthophosphates	589
6.3.2 Polymers	590
6.3.3 Inorganic Materials and Compounds	594
6.3.3.1 Metals	594
6.3.3.2 Glasses and glass-ceramics	595
6.3.3.3 Ceramics	596
6.3.3.4 Carbon	596
6.4 Calcium Orthophosphate-Based Biocomposites and Hybrid Biomaterials	597
6.4.1 Biocomposites with Polymers	597
6.4.1.1 Apatite-based biocomposites	603
6.4.1.2 TCP-based biocomposites	609
6.4.1.3 Other calcium orthophosphate-based biocomposites	611
6.4.2 Calcium Orthophosphate Cement-Based Biocomposites and Concretes	613
6.4.3 Biocomposites Based on Nanodimensional Calcium Orthophosphates and Nanodimensional Biocomposites	616
6.4.4 Biocomposites with Collagen	619
6.4.5 Biocomposites with Other Bioorganic Compounds and/or Biological Macromolecules	626
6.4.6 Injectable Bone Substitutes (IBS)	629
6.4.7 Biocomposites with Glasses, Inorganic Materials, Carbon and Metals	633
6.4.8 Functionally Graded Biocomposites	638

6.4.9 Biosensors	642
6.5 Interaction Among the Phases in Calcium Orthophosphate-Based Biocomposites	643
6.6 Bioactivity and Biodegradation of Calcium Orthophosphate-Based Biocomposites	652
6.7 Some Challenges and Critical Issues	654
6.8 Conclusions	656
7. The Dissolution Mechanism of Calcium Apatites in Acids	761
7.1 Introduction	761
7.2 Critical Analysis of the Dissolution Models of Calcium Apatites	762
7.2.1 Diffusion (or Transport) and Kinetically (or Surface) Controlled Models	762
7.2.2 Mono- and Polynuclear Models	764
7.2.3 Self-Inhibition (Calcium-rich Layer Formation) Model	766
7.2.4 Stoichiometric/Non-Stoichiometric (congruent/incongruent) Dissolution	768
7.2.5 Chemical Model	771
7.2.6 Etch Pit Formation	772
7.2.7 Ion Exchange Model	775
7.2.8 Hydrogen Catalytic Model	776
7.3 Summary on the Dissolution Models	778
7.4 A Reasonable Classification of the Dissolution Models	779
7.5 Brief Information on Apatite Structure	780
7.6 Necessary Assumptions and Limitations	781
7.7 Creation of the General Dissolution Mechanism	782
7.7.1 Atomic (Ionic) Description for the Perfect Crystals	782
7.7.2 The Influence of Dislocations and Surface Defects	788
7.8 Conclusions	790
8. The History of Calcium Orthophosphates from 1770s till 1950	803
8.1 Introduction	803

8.2 Knowledge on Calcium Orthophosphates in the 18 th Century	804
8.3 Chemical Investigations on Calcium Orthophosphates in the 19 th Century and the First Half of the 20 th Century	806
8.4 Early Publications on Calcium Orthophosphates of Geological Origin	814
8.5 Early Studies on Calcium Orthophosphates in Living Organisms	814
8.6 Early Attempts to Treat Various Diseases by Calcium Orthophosphates	817
8.7 Artificial Grafts in the 19 th Century and Before	818
8.8 Calcium Orthophosphates as Bone Graft Substitutes: A Historical Perspective	823
8.9 Conclusions	826
<i>Index</i>	<i>845</i>

Preface

Calcium apatites and other calcium orthophosphates have been of considerable interest to mineralogists, chemists, material researchers, biologists, and clinicians for many decades. The reasons for this are clear: Calcium apatites form the mineral component of bones and teeth, while some other calcium orthophosphates are involved in biomineralization process in mammals. Furthermore, calcium orthophosphates are found in pathological calcifications. Therefore, calcium apatites and other calcium orthophosphates appear to be biologically friendly inorganics and, thus, they are increasingly used as implantable biomaterials for various types of bone fillers and bone substitutes. As a final point, calcium apatites and other calcium orthophosphates are widely distributed minerals in Nature, providing the worlds supply of phosphorus, particularly phosphates for the production of fertilizers.

Due to the aforementioned, the scientific databases reveal that the research on calcium orthophosphates has a very long history. However, it exploded in the 1960s, and since then the number of publications permanently increased. Simultaneously, the variety of both investigations and biomedical applications of calcium orthophosphates are greatly expanding. Namely, calcium orthophosphate-based bioceramics specific to the *in vivo* applications have been designed, synthesized, investigated, and applied. Furthermore, new synthetic processes for the fabrication of calcium orthophosphates with the desired properties (such as, the Ca/P ratio, crystallinity, phase composition, particle shape and dimensions, ion-substitutions, etc.) have been also developed. Methods of the structural and surface analysis have also greatly progressed. For example, in early studies, the biological responses of living tissues to implanted materials were evaluated by optical microscopy. Nowadays, the biological analysis is performed at the molecular level in combination with the high-end physical techniques. In addition, long-term clinical data are now available. All these findings give the important suggestions for designing new types of calcium orthophosphate-based formulations for biomedical applications.

Therefore, the aim in writing this monograph has been to provide an integrated account of the present knowledge on preparation, chemical composition, structure, properties, and applications of all available calcium orthophosphates, particularly in the biomedical context. Since the entire subject appears to be very broad (over 30,000 publications on calcium apatites and other calcium orthophosphates have been already published), a great number of references to the related publications detailing various specific aspects of the matter have been collected.

The monograph consists of eight chapters. The division arrangement of the chapters is generally based on the subject, with subdivisions on the major aspects, such as introduction, basic definitions and knowledge, structure, preparation, properties, biomedical application, and future directions, ended up by conclusions. This overall scheme is used to emphasize the mutual interrelationships among various calcium orthophosphates. The main purpose has been to group the material in the most natural way and, if appropriate, to provide cross-references from other sections. This is sometimes done explicitly and sometimes by giving section references, where other aspects of the specific subject are discussed. Namely, Chapter 1 contains the general information on all available calcium orthophosphates, including their geological and biological occurrence, chemical composition, structure, solubility, and a brief information on their location in calcified tissues of mammals (bones, teeth, and antlers), including the unwanted (pathological) calcifications. Furthermore, Chapter 1 also encloses an important section on biomimetic crystallization, including artificial simulating solutions. Chapter 2 is devoted to the structure, chemical composition, properties, and biomedical application of amorphous calcium orthophosphates (ACPs), which erroneously are considered as individual compound, whereas in reality, they are just an amorphous (or a very poorly crystalline) state of other calcium orthophosphates. Chapter 3 focuses on the similar topics of nanodimensional and nanocrystalline calcium orthophosphates. The following three chapters are mainly devoted to various aspects of the biomedical applications of calcium orthophosphates. Namely, Chapter 4 describes the available knowledge on bioceramics, Chapter 5 concentrates on the self-setting formulations, and Chapter 6 is devoted to biocomposites and hybrid biomaterials. Chapter 7 appears to be more specific because it is devoted to a narrower subject of the

dissolution mechanism of both hydroxyapatite (HA) and fluorapatite (FA) in acids. This subject provides the chemical fundamentals for both dental caries and osteoporosis. Finally, Chapter 8 gives a brief historical overview on the calcium orthophosphate matter, which is just interesting to read.

To conclude, this monograph represents the author's vision on the topic, which by no means is ideal. Furthermore, since not each and every possible aspect of calcium apatites and other calcium orthophosphates has been described, various imperfections are possible. Thus, any criticism, opinions, or suggestions are always welcome. However, it is worth mentioning that the main goal is not only further development of the subject itself but also making a possible contribution to the welfare of human beings, in particular those with diseases potentially treatable by calcium orthophosphates.

Finally, I would like to acknowledge the continuous encouragement of my mother, Tamara, my wife, Elena, and my son, Denis. Hopefully, publication of this book will help the author find a suitable position in science or industry to provide a better financial support to the beloved members of his family.

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Sergey V. Dorozhkin

Moscow, Russia

sedorozhkin@yandex.ru

