Micro-Computed Tomography

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Micro-computed tomography (micro-CT) is a consolidated imaging technology allowing non-destructive three-dimensional (3D) qualitative and quantitative analysis by the observation of microstructures with high resolution. This paper Ten Years of Micro-CT in Dentistry and Maxillofacial Surgery: A Literature Overview (https://doi.org/10.3390/app10124328) aims at delivering a structured overview of literature about studies performed using micro-CT in dentistry and maxillofacial surgery (MFS) by analyzing the entire set of articles to portray the state of the art of the last ten years of scientific publications on the topic.

Keywords: micro-computed tomography ; In Vitro and In/Ex Vivo Applications ; Bone Tissue Regeneration ; X-ray microtomography ; review ; micro-CT ; Bioengineering ; Biomaterials ; Dentistry ; Maxillofacial surgery

1. Introduction

The first X-ray microtomography or micro-computed tomography (micro-CT) system was conceived in the early 1980's, and in 1994, the first commercially available bone micro-CT scanner was presented [1][2].

Nowadays, micro-CT systems are present as lab instrumentations at main laboratories and companies to perform different types of investigations and for various applications, including educational purposes [3][4]. Micro-CT represents one of the main methods to perform non-destructive analysis and one of the most common microscopy methods [5] where the very fine scale internal structure of objects is imaged, providing high resolution volumetric data at a micron level. It allows for the investigation of microstructures, the accuracy detection of the geometries [6][7][8][9], eventually defects and difference in density and morphology. It does not require specimen preparation, staining and slicing; settings and parameters were extensively studied for specific structures [10].

It has great potential for biomedical and bioengineering applications [11]. The analyses carried out by micro-CT can be helpful also in terms of compliance to international standards, regulations, and in forensic practice [12][13]. Microtomographic analyses can affect the validation process of materials and the quality assessment of final devices. Recently, in the medical device sector, the growing interest in emerging manufacturing techniques as the additive ones, allowed to recognize micro-CT as one of the major tools for the product quality assessment and for the quality control of additive manufacturing (AM) products and materials [6][14][15][16].

Dentistry and maxillofacial surgery (MFS) represent two sectors that affect the biomedical engineering context and in which there was an extensive use of the micro-CT due to the necessity to acquire detailed information of small and complex objects, mineralized structures [17][18][19], and with different densities. The market is characterized by innovative materials and solutions that require advanced technology in routine-based activity of dental labs and clinics as the micro-CT scanning [20], whose capabilities turn out to be indispensable [21][22][23].

The authors have extensive knowledge and experience about micro-CT and its application in biomedical studies and in both fields addressed here [6][7][24][25][26][27][28][29][30][31]. Specifically, in this work, the first author (I. Campioni) independently reviewed and organized the records identified from the database searches to assess the initial eligibility and both the authors (I. Campioni and R. Pecci) fully reviewed the search results. Disagreements were resolved by reaching a consensus or consulting the third and senior author (R. Bedini). In the early 2000's, R. Bedini believed in such technology and had engaged many research funds in the purchase of equipment to perform three-dimensional (3D) microtomography and to undertake research collaborations to study the effectiveness of this 3D methodology compared to the traditional ones, such as histology and electron microscopy [7][8][14][15][24][25][26][27][28][30][31][32].

The aim of the present Paper is to deliver a structured overview of the literature, highlighting the main applications of micro-CT in dentistry and MFS, and considering the set of articles published in English from 2010 to January 2020 in PubMed/MEDLINE and Scopus (excluding Medline records from search results). Furthermore, the work has the goal to

address the studies involving lab-based applications of micro-CT for research and clinical purposes, thus it does not include the synchrotron-radiation-based X-ray micro-CT [2][33][34][35][36][37][38] and related applications of the latter with other technologies [39].

2. Conclusions

Micro-CT is an established technique that has demonstrated various advantages for many applications. In the last ten years, the improvement in image analysis allowed to highlight some opportunities offered by microtomographic technology, which until a decade ago, were considered only as potential benefits.

The main detected records confirmed that an established range of micro-CT applications are related to studies performed to investigate new biomaterials and their effects on osseointegration, bone structure, bone grafts, and tissue response in dentistry.

This overview dedicated a section to the challenges of microtomographic evaluations combined with other technologies and techniques, highlighting the growing possibilities and the potential extension of the field of applications.

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