Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Zirconia abutments and restorations: From laboratory to clinical investigations

M. Ferrari[a,*], A. Vichi[a], F. Zarone[b]

[a] Fixed Prosthodontics and Dental Biomaterials, Department of Medical Biotechnologies, University of Siena, Siena, Italy

[b] Fixed Prosthodonics, University Federico II, Naples, Italy

ARTICLE INFO

Keywords:
Zirconia
Chipping
Zirconia abutments
Zirconia restorations
Ceramics
Metal-free
Clinical trials
In vitro
Mechanical properties

ABSTRACT

In last years the use of zirconia in dentistry has become very popular. Unfortunately, the clinical indications for a dental use of zirconia are not completely clear yet, neither are their limitations.

The objective of this review was to evaluate the basic science knowledge on zirconia and to discuss some aspects of the clinical behavior of zirconia-based restorations. In particular, one of the goals was highlighting the possible correlation between *in vitro* and *in vivo* studies. The definition of concepts like success, survival and failure was still debated and the correlation between *in vitro* results and predictability of clinical behavior was investigated.

Contents

* Corresponding author. Tel.: +39 0577 233131; fax: +39 0577 233117.
E-mail address: ferrarm@gmail.com (M. Ferrari).

http://dx.doi.org/10.1016/j.dental.2014.11.015

1. Introduction

Since its introduction into the dental market, zirconia (polycrystalline zirconium dioxide) has been widely used to produce fixed partial dentures (FPDs) and implant abutments. Zirconia properties are highly suitable for a dental use: high mechanical properties, natural-tooth appearance, unsolubility in water environment, no cytotoxicity, reduction of bacterial adhesion, radiopacity and low corrosion potential [1,2].

Zirconia can mainly be employed according to two different technical solutions. The first, as a 'white metal' for manufacturing copings (for single crowns) and frameworks (for multi-unit fixed prostheses); such supporting structures need finally to be veneered with porcelain, in order to achieve the final occlusal/anatomic shape and to exploit the high esthetic potential of this material [3,4]. This allows to highly improve the esthetic properties of zirconia restorations, although a problem arises: the need of matching mechanical properties and behavior of the two different bilayered materials. As a matter of fact, the most frequent complications of zirconia–ceramic restorations is chipping of the veneering material itself; for this reason, more recently the possibility of using zirconia as a "monolithic" material, shaped in the final anatomic and esthetic tooth morphology, has been advocated.

In its specific form of "yttria-stabilized zirconia polycrystal (Y-TZP)", zirconia is a high-strength ceramic. The much higher mechanical performances of this material (flexure strength, fracture toughness) compared to most of the other metal-free materials, make framework bulk fractures quite unlikely [5,6]. On the contrary, a major concern is the chipping of the esthetic ceramic veneer, showing a high incidence, as demonstrated by the majority of clinical trials and systematic reviews [17–25]. The problem is specific to the bilayer nature of these restorations, as discussed later, and is multifactorial.

Various *in vitro* studies were performed in order to test the zirconia mechanical properties as a dental material [7–11]; at the same time, a large number of *in vivo* studies (clinical trials) were carried out aimed at the clinical performance of the zirconia-based restorations over time, focused on single crown copings and, prevalently, on FDP frameworks and on implant abutments [12–15].

The problem is, both extrapolating the clinical predictability of a certain kind of restoration from *in vitro* data and correlating its success and failures reported in clinical trials with the material properties emerging from *in vitro* data do not lead to correct interpretations of scientific results. This is mainly due to the lack of homogeneity in the goals of the *in vitro* and *in vivo* study protocols, together with an objective difficulty of controlling too many variables in the tested samples. The designs of *in vitro* studies usually take into account only single variables (*e.g.*, the thickness of porcelain layer and/or of zirconia coping, etc.), whilst *in vivo* trials are usually conditioned by a high number of variables, not easy to control and often confounding the results of the analyses.

After the widespread diffusion of zirconia as a dental material, two main problems have been evidenced in the clinical practice: chipping of porcelain veneering in single crowns and FDPs and fracture of zirconia abutments [11–15].

In particular, chipping/delamination of the veneering ceramic has been described as the most frequently occurring problem of bilayered zirconia restorations [16–25].

This paper was aimed at identifying a possible correlation between the most relevant properties of zirconia, as shown under laboratory conditions, and the most significant results of clinical trials, pointing out concepts like clinical success, survival and failure of such restorations.

2. *In vitro* data

First of all, it has to be noticed that the design of an *in vitro* research protocol is very sensitive to the technical variables; *e.g.*, the value of zirconia fracture toughness is highly dependent upon the shape/dimension of the notch that is used to initiate the fracture experimentally [26]. This makes the results of such studies quite hard to compare.

To date, many factors have been reported to be related to the prosthetic complications in zirconia restorations [1,2]: pressing and structural defects of the frameworks, grinding damages, improper cooling rates, not compatible coefficients of Thermal Expansion, incorrect surface treatment procedures (*e.g.* aggressive sandblasting), wrong framework design and thickness, type of finishing margins, incorrect luting procedures, material aging.

3. Pressing and structural defects

Zirconia mechanical properties are affected by grain size and pressing modalities: higher temperatures and longer sintering times induce the formation of larger grain sizes [27–30]. Above a critical size, zirconia is less stable and more vulnerable to spontaneous t–m transformation than with smaller grains (<1 μm) [31]. Moreover, below a certain grain size (approximately 0.2 μm), the transformation is not possible, leading to a reduction in fracture toughness. The fabrication process of zirconia frameworks may introduce defects into the material itself [28]. The possible presence of structural defects, such as micro voids and flaws within the material, can concentrate stress resulting in a starting site of internal fracture under loading [32].

4. Grinding damages

Grinding procedures are often performed in three different phases of the realization of zirconia restorations: the first during machining procedures [33–35], the second when reshaping and finishing the morphology and surface of the zirconia copings/frameworks before proceeding with ceramic veneering by dental technicians, [36–38], the third when, after the final cementation, occlusal adjustment are needed in the dental office.

It should be considered that such procedures are often due to a poor CAD programming and/or to an inaccurate occlusal design, so the main operative recommendation is to perform a CAD CAM programming in strict compliance with the final design of the restoration. However, it is undeniable that adjustment procedures are not infrequent in the daily