Zirconia dental implants: An alternative for today or for the future? (Part II)

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Abstract

Introduction: Recent research suggests that titanium (Ti) dental implants may have more side effects than previously believed. In addition to the fact that metals compromise esthetics, emerging technologies involving zirconia (Zr) ceramics were recently introduced in dentistry, which are proving as effective as Ti, but in metal-free rehabilitation. The clinical/histological outcomes of ceramics (ZrO_2), driven by the awareness of patients seeking esthetics without metals, have increased their demand. **Objective:** To find a viable alternative to Ti implants and identify the ceramic systems amenable to use by humans, taking into account biocompatibility and longevity, while pointing out their advantages and disadvantages. **Methods:** Extensive and detailed literature review. **Conclusions:** Although ISO standards need to be reviewed, it has been found that zirconia (Y-TZP) dental implants show a promising future. Zirconia increases the longevity of oral rehabilitation given its diminished bacterial adhesion. The following Zr implant systems were found in the studies: CeraRoot, Sigma, Z-Systems, Ziterion Zit-Z, Easy-Kon, Zeramex, White Sky, Denti Circon Implants, Zimplant-Biosyr, Omnis-Creamed, White Implants and Ziraldent. Among the disadvantages are a high production cost, the need for protectors during healing, and potential hydrothermal degradation of the material. Based on international scientific publications, it was concluded that Zr (Y-TZP) dental implants are now a viable substitute for Ti, although not yet recommended for routine clinical practice.

Keywords: Osseointegration. Allergy and immunology. Biomedical materials. Materials test. Dental Implants. Experimental implants.

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Introduction

Extensive studies have been conducted on the chemical stability of biomaterials used in Dentistry.[1-5] Among these, certain metals have been found to induce nonspecific immunomodulation and autoimmune diseases (multiple sclerosis, rheumatoid arthritis, amyotrophic lateral amyotrophic).[2,3] It is believed that even titanium (Ti), which is considered inert, is a likely inducer of toxicity and type I or IV allergic reactions[2] due to metal ions released into the bone-implant interface, and via the systemic route over time.[3,4] Studies focusing on hypersensitivity and accumulation of Ti particles and gold in the lymph nodes of chronically exposed patients demonstrate that these metals should not be considered biologically inert.[2]

Allergy to Ti may be the cause of dental implant failure in some patients.[2,5] These factors, combined with the galvanic effect of Ti in saliva, and fluorides,in addition to the fact that metals on the oral mucosa can be unsightly - especially in thin gingival phenotypes -has sped up the search for metal-free materials.[4,6,7]

Y-TZP (tetragonal poly crystalline zirconium stabilized with yttrium) ceramics, called here zirconia (Zr), may be an alternative given its excellent chemical stability, biomechanical properties, radiopacity and high osseointegration potential.[6,7,8] Used for more than three decades in orthopedic surgery to replace metals, or combined with these,[6] Zr has also been tested in terms of desirable properties for Dental Implantology.[7,8,9] Several studies confirm excellent results with Y-TZP implants, whose osseointegration proved equal to or better than that of Ti, with superior esthetics and soft tissue response.[7-16] However, few systematic reviews of the literature have been published investigating the possibility of using Y-TZP as an alternative material for Ti dental implants.[9]

In light of all the scientific knowledge available today and the demands regarding the use of metal-free reconstructions by patients with high esthetic expectations and/or a history of allergy to Ti and its by products released into the body, rehabilitation with metals should be reviewed.[6]

After evaluating the physicochemical properties of Zr ceramics and the clinical data with respect to the bone-implant contact area (BIC) *in vitro* and animal *in vivo* studies,[9] this second article sought to identify the Zr dental implant systems available in the international literature, taking into account biocompatibility and longevity through clinical trials in humans, while also pinpointing their downsides and market outlook.

Clinical trials in humans

Among others, Ulrik Volz spearheaded the use of zirconia dental implants (Y-TZP) in humans with intolerance to metals. Following the principles of holistic medicine for over 10 years, this author has succeeded in carrying out totally metal-free reconstructions, achieving complete osseointegration, biocompatibility and incomparable esthetics (Fig 1 and 2).[10] However, Kohal and Klaus were the first to publish a case in the literature involving the technique of immediate replacement on an upper incisor with a Z-Look3 implant (Z-Systems AG, Oensingen, Switzerland).[17]

Figure 1 - Surgical kit Z-Systems, with FSZ (fully stabilized zirconia) ceramic tools.

Figure 2 - Z-Systems, Z-Look3 and LockBall (at right) implants.

Clinical survival is the most widely accepted measure of success in the research on human implants. In 2006, 189 Zr implants (Z-L3) with a mean load time of 8.2 months were assessed after 1 year. The parameters for success in clinical/radiographic evaluations stood at 93%. Compared with Ti implants, Zr had a good performance, and esthetic benefits. In view of the encouraging sampling results, Zr was indicated to replace Ti in future dental Implantology, while encouraging further long-term studies.[11]

Another study compared the survival rates of Zr and Ti implants for a period of up to 45 months using 237 two-piece Ti implants (3i/Osseotite) and 139 one-piece Zr implants (Z-L3) (Fig 3). The non-selected patients, mean age 51, received implants and esthetic protectors. The transmucosal abutments were loaded onto the mandible after 3 months, and 6 months on the maxilla. Ti survival rate was 95.23% in the maxilla and 94.44%

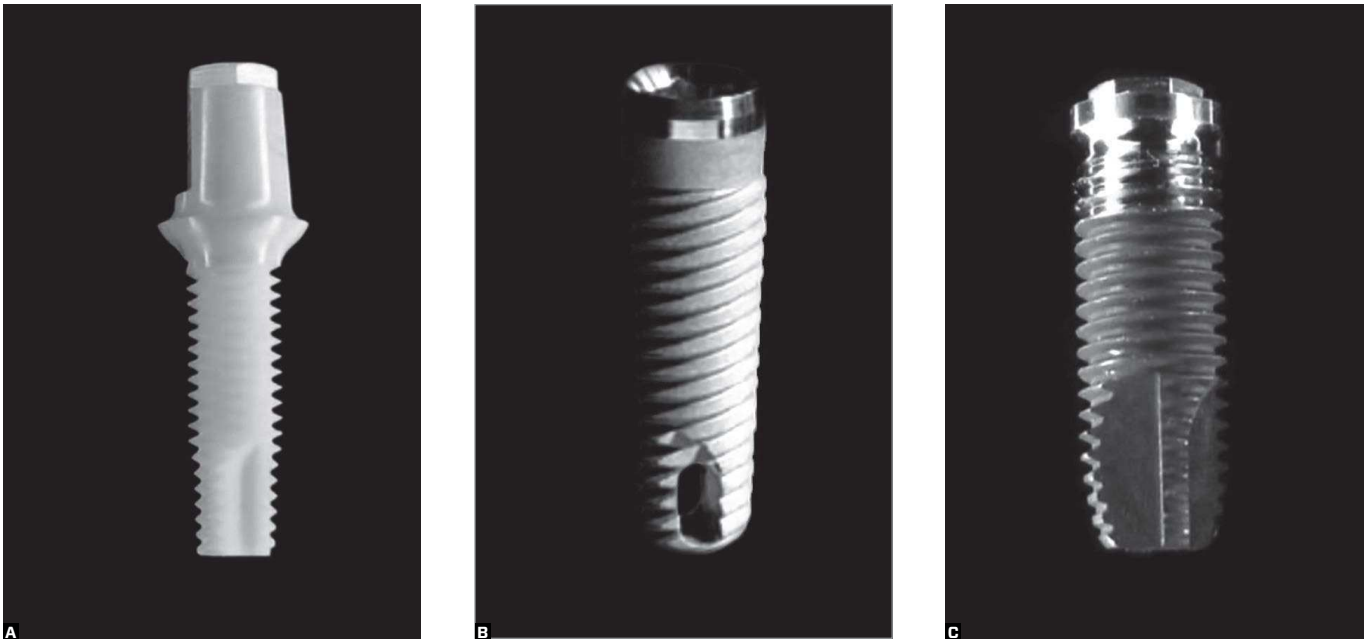

Figure 3 - Zr and Ti implants used in the study of Lambrich.[12] (Source: Lambrich,[12] 2006).

in the mandible. Survival of Zr implants was 84.37% in the maxilla and 98.41% in the mandible. Protection of Zr implants with a prosthetic device during the healing period was crucial for osseointegration.[12]

A retrospective study compared the survival rates of 361 implants (234, Ti and 127, Zr) in 124 unselected patients. One-piece Zr implants (Z-L3) were protected from premature loading. Survival of Ti implants was 98.4% in the maxilla and 97.2% in the mandible, while Zr reached 84.4% in the maxilla and 98.4% in the mandible. The difference of 14.0% for Zr implants in the maxilla was attributed to low stability (torque <35Ncm^2), post-graft placement, premature loading or the poor protection afforded by mucosa-supported dentures (Fig 4). In cases of low primary stability, it was recommended to protect Zr with prosthetic devices, preferably supported on stable proximal teeth (Fig 5).[13]

Figure 4 - Z-Look 3 (Z-Systems) implants insertion with graft. (Source: Lambrich and Iglhaut,[13] 2008).

Figure 5 - Protectors for one piece Zr implants in the posterior region, made with acetate and acrylic plates in the anterior region (observe the inner relief zones). (Source: Lambrich and Iglhaut[12,13]).

In a 5-year follow-up, 378 patients with an average age of 48 years, were instructed to avoid chewing in the implant region during the first two months. The 831 one-piece Zr implants (CeraRoot, Barcelona, Spain) with three different surfaces, received restorations after 4 to 8 months or more, concurrently with bone regeneration. All were left in infra-occlusion and adjusted for lateral/protrusive excursions. The subjects were followed-up at 1, 3, 6 and 12 months and annually, with implants being documented in terms of mobility, pain and sulcus depth, with panoramic and/or periapical radiographs. The mean survival rate was 95% (Tables 1 and 2). The implants with acid etched surface were more successful than the other two groups, and peri-implant probing depth was between 2 and 3 mm. Based on this study, the authors concluded that the Zr implants with rough surfaces can be a viable alternative for tooth replacement, but suggest a long-term follow-up.[14] Insertion quality of peri-implant soft tissues related to Zr implants and abutments was investigated in a systematic review which compared the clinical results within a five-year period. Sixty-five Z-L3 implants were inserted in 34 patients, who were evaluated after complete healing and with prosthetic structure in function. Throughout 22 months of use, adhesion of plaque, type of bacterial colonization, and its influence on peri-implant tissues were evaluated in histological examinations. Compared with Ti implants, all Zr implant and abutment data were equally good, or better. In clinical evaluations, the probing depth was 2-3 mm. Regarding the presence of plaque and bleeding, Zr averages were above what is considered good. Even in difficult cases, the protective periodontium appeared esthetically appealing, with encouraging results.[15]

Table 1 - Zirconia implants distribution in surface types, in a 5-year period of use in humans.[14]

Implant surface	N° insert.	Segment	Gender		Smoker	Regeneration		Implant location				Flap	Immediate prov.
			Male.	Fem.		Bone graft	Sinus elev.	Maxilla		Mandible			
								Ant.	Post.	Ant.	Post.		
No treat.	249	2-5 a.	99	150	33	55	11	59	93	25	73	95	32
Treated	249	2-5 a.	91	158	42	42	15	51	99	12	87	102	35
Acid et.	**333**	**1-4 a.**	**128**	**205**	**53**	**65**	**21**	**82**	**113**	**22**	**115**	**126**	**70**
Total	831	1-5 a.	318	513	128	162	47	192	305	59	275	323	137

In bold, the implants with acid etched surface.

Table 2 - Failure proportion on Zr implants, according to the surface type, in a 5-year period in humans.[14]

Implant surface	N° insert.	Fail number	% failure	Gender		Smoker	Regeneration		Implant location				Flap	Period/ failure			Immediate prov.
				M.	F.		Bone regen.	Sinus elev.	Maxilla		Mandible			< 1y	≤ 2y	> 2y	
									Ant.	Post.	Ant.	Post.					
No treat.	249	18	7,23	9	9	11	4	3	2	7	1	8	2	17	2	0	32
Treated	249	16	6,43	6	8	12	2	4	2	7	1	6	2	13	2	0	35
Acid et.	**333**	**8**	**2,40**	**3**	**5**	**6**	**2**	**2**	**2**	**2**	**1**	**3**	**1**	**8**	**0**	**0**	**70**
Total	831	42	5,05	18	22	29	8	9	6	16	3	17	4	38	4	0	137

In bold, the implants with acid etched surface.

Dental Implantology's achievement: From Europe to the world

Extensive research on Y-TZP ceramics has yielded positive results and recommends it as a new biomaterial for dental implants thanks to its fracture toughness, excellent osseointegration and periointegration, surface dimensioning and conditioning.[7-15] Some histological results with zirconium showed new bone formation at the interfaces, or a "biofunctional-composite-osteogenesis."[16]

Despite scarce clinical/histological and biomechanical data in the international literature,[17,18] Zr implants are booming in Europe. The main systems found to be commercially available are: Z-Systems (Oensingen, Switzerland, Fig 2),[11-13] White Sky (Bredent Medical, Germany),[18] Sigma (Incermed, Switzerland),[19] CeraRoot System (Barcelona, Spain, Fig 6),[14,20] Zeramex (DentalPoint, Switzerland),[21] Easy-Kon (General Implants, Liechtenstein),[16] Ziterion Zit-Z (Uffenheim, Germany, Fig 7),[22] Denti Circonium Root (Budapest, Hungary, Fig 8)[23] and Zimplant-Biosyr (Bucharest,Romania).[24] Besides the European (EC) certifications, some systems also obtained authorizations from FDA/Canada[14,20] and ANVISA, Brazil.[11-13]

Studies of these Zr implants in humans are still scarce. Table 3 shows a summary of some of these products surveyed between 2004-2012, compared to Ti samples and results.

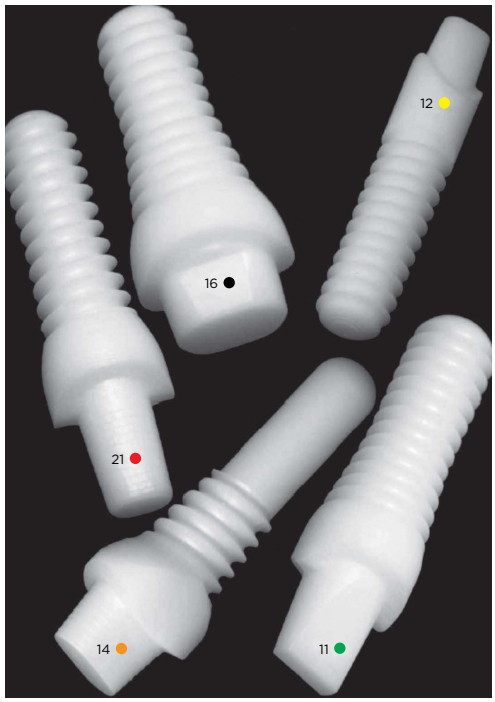

Figure 6 - CeraRoot implant for different indications (incisors, canines, pre-molars and molars). (Source: Oliva J, Oliva X, Oliva D[14,20]).

Figure 7 - Zit-Z (Ziterion) implant in 2 pieces. (Source: Özkurt e, Kazazoğlu[30]).

Figure 8 - Denti Circonium root one piece and two pieces implant. (Source: Nevins et al[22]).

Table 3 - Studies of zirconia dental implants in humans - 2004 to 2012 (Zr =Zirconia, Ti=Titanium, w=with,pc=piece, m =month, y =year, BIC = bone implant contact).

Study	Implants used	Sampling / Time	Survival/Result
8	Zr (Y-TZP) and Ti	Systematic Review of literature	Ti = Zr orZr> BIC > 60%
11	Zr (Z-Look 3/Z-Systems)	71 pat./189 impl. Zr/ 12 m	93% survival
12	Ti w/ 2 pc / Zr (Z-Look3 w/1 pc)	237 Ti (3i+TSV) / 3 m 139 Zr / 3 m and 6 m	Ti w/ 95.23% load Zr 84.37 to 98.41%
13	Ti (2 pc)/ Z-Look3 (1 pc)	234 Ti / 127 Zr / 21.4 m	Ti 97.2 to 98.4% Zr 84.4 to 98.4%
14	Zr (CeraRoot) 1 pc	831 cases/load 4-5 y	95% survival
15	Zr (Z-Look 3) / Ti	65 cases / 22 m	>Zr or ≈ Ti
17	Zr (Y-TZP) with load	119 (65 w/1pc+27 w/2 pc.) /12 m	96.6 % survival
20	Zr (CeraRoot) 2 ± surf.	100 impl. Zr/ 36 pat/ 12 m	98% survival
21	Zr: Z-Look3 + Zeramex (2pc)	60% w/immed. exod./imed./load 6 m or +	100% survival
25	Zr (Y-TPS) and Ti (SLA)	surface treatment Zr	> removal torque
26	Zr/Ti abutments+ metal/ceram. crown	40 implants / 6 - 12 - 36 m	100% survival / esthetic Ti = Zr
27	Zr implants w/ roughness, blasted	6 + 12 (prepared) / 1 to 33 m	6 failures / 12 = 92% surv.
28	Y-TZP-ZiUniteTM(Nobel Biocare)	65 cases w/immed. load / 12 m	3 failed = 95.4% surv.
29	Z-Look3 Evo (Z-Systems)	51 w/load 8,4 m	100% survival

Discussion

Technological development has undoubtedly made strides in the search for dental materials that offer the benefits of biomechanical metals while keeping the naturalness of peri-implant tissues. Achievements were driven by advances in medical orthopedics in the last three decades.[9,29] The development of Zr ceramics has fulfilled the criteria for fracture strength, with biocompatibility and esthetics.[9,19,20,21,24,25]

The literature makes it evident that zirconium can be considered the best ceramics for dental use given its physical and chemical properties.[4,6-21] Results from *in vitro* and *in vivo* studies on Y-TZP ceramics corroborate zirconia's excellent biocompatibility and define it as a material of choice for applications in prosthetics or dental implants.[2-5,8,10,21,22,24-30]

Similarly to Ti osseointegration, the clinical success of Zr implants is related to surface properties.[14,20] Changes made with CO_2 lasers and several complex treatment systems impart to Zr a roughness comparable to that of Ti implants.[22,29] Depending on the surface treatment process, biointegration can act chemically or by mechanical irregularities, a determining factor in cell differentiation and maturation.[7-9,12-16,20-22,24-28]

The other advantage of Zr ceramic materials is its low bacterial adhesion.[25] A significant reduction in pathogenic bacteria has been observed, as well as low plaque adsorption and depolarization, with decreased bone resorption. These are key factors in preserving peri-implant health, and are directly related to restoration longevity.[15,20,23,27,29-33]

However, certain disadvantages are attributed to Zr implants, such as higher cost and more limited scientific documentation given its short clinical experience in terms of longevity.[17,18,28]

The vast majority of Zr implants is manufactured in one piece to impart increased strength to the material. These implants therefore require a three-dimensional positioning in the dental arch, with very accurate planning and professional skill, while not allowing reversibility and requiring a protector.[17] Used correctly, protective devices are a decisive factor in osseointegration, especially in cases where no primary stability is achieved, i.e., insertion torque ≤35 Ncm.[2,7, 8,10-14] However, ceramic implants are now available in two pieces, such as Zit-Varioz (Zeterion, Fig 7),[20,30] Denti Circonium Root (Fig 8), Zeramex[24] (Fig 9),[21] Omnis-Creamed (Marburg, Germany)[34] White Implants (Amsterdam, Holland),[35,38] which render planning more versatile and similar to traditional Ti implant systems. However, few studies are cited in the literature regarding the strength of these systems.[14,17,18]

As yet, the ideal surface condition for Zr implants has not been well established, and their osseointegration speed is lower than that of Ti.[36] Since healing takes longer, the failure rate of ceramic implants in general is higher than Ti (grade 4) with an Sand-blasted, Large grit, Acid-etched (SLA) surface, considered standard in the international literature.[36]

Another problem with respect to Zr, since it started being used as biomedical material, is related to potential degradation at low temperatures.[8,37] A severely inadequate preparation of ceramic implants can cause micro or macro-cracks on its surface (Figs 10 to 12).[7,18] The resulting stresses can reduce some physical properties of the biomaterial.[14,18,20,36] Preparation made with fine diamond burs at high speed and with abundant irrigation seems to be the safest procedure.[38]

New concepts in the milling of grain and stabilizing agents such as yttria (Y-TZP), or in combination with alumina, such as Ziraldent-MetoxitAG (Thayngen, Switzerland) with Zircapore® surface, promise to speed up osseointegration and improve hydrothermal stability.[39] However, given that ZrO_2 is supplied by different vendors, it is necessary to use advanced, accurate techniques to assess their microstructure and their aging. A review of ISO standards is also necessary.[40]

Figure 9 - Zeramex two pieces implant. (Source: Andys[21]).

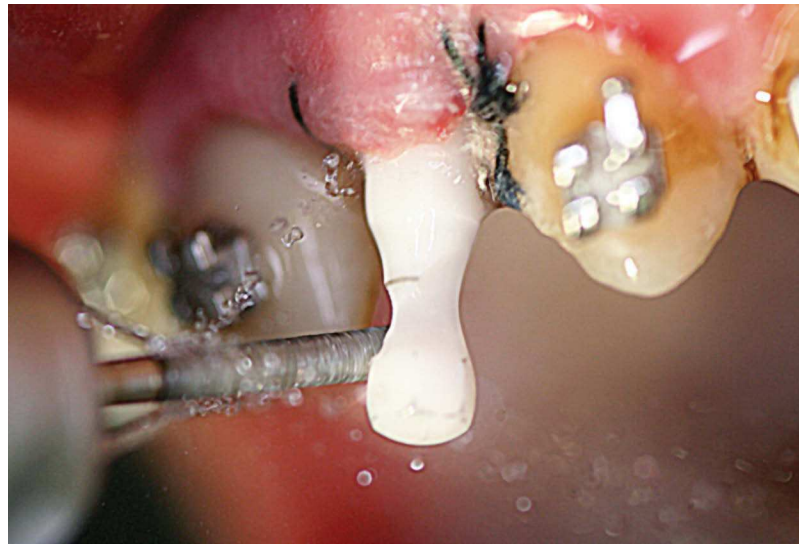

Figure 10 - Z-Look3 (Z-Systems) one piece implant, just inserted in the tooth #22 region.

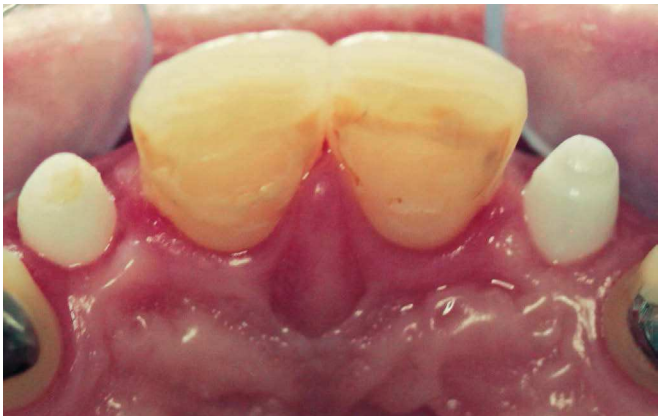

Figure 11 - Occlusal view of Z-Look3 prepared implants, replacing the adhesive fixed prosthesis, in case of maxillary lateral incisor agenesis.

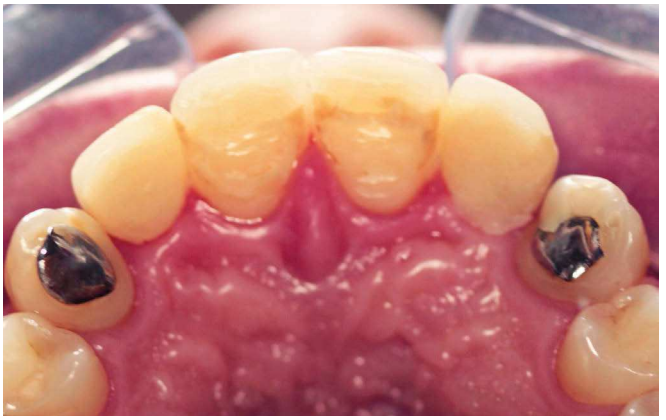

Figure 12 - Immediate provisional of ceramic implant with acrylic crowns.

With more than 100,000 clinical cases in Europe, Zr implants constitute a highly competitive and profitable market driven by an aging population and the growing awareness of patients who do not want metal to be used in their rehabilitation.[41] Soon, the demands and growing maturity of patients will be a key determinant in choosing the material from which their dental implants are manufactured.[6,41]

Computerized systems with advanced technology such as CAD/CAN enable the production of stronger abutments and restorations faster and at a lower cost, thereby improving manufacturing processes of ceramics, with greater precision and mechanical durability. These are mandatory requirements in future metal-free rehabilitations.[14,23,24,37,38,41] Zirconium/titanium in combination[25] with poly-crystalline glass-alumina, sintered by emerging nanotechnologies and new surface treatments, will decrease the diameter and osseointegration time of these new materials, raising the therapeutic possibilities for increasingly demanding audiences.[41,42]

Most studies in this review adopted the indication of Zr as a substitute for Ti in future Dental Implantology, but pointed out the need to ground their decision in further prospective clinical trials and long-term retrospective studies. Therefore, the authors of this study do not yet recommend its use in routine clinical practice.[3,4,6-23,25-30,36,38,41]

Conclusions

- Currently, Zr dental implants are a viable alternative to replace Ti implants in selected cases. However, clinical data regarding ceramic systems are still insufficient to recommend them in routine clinical practice.
- Compared with Ti, Zr ceramics features less bacterial adhesion, enabling an increased longevity.
- The Zr implant systems found in this review were: InCerMed, Cera Root, White Sky, Z-Systems, Easy-Kon, Zit-Z Ceramic, Zeramex, Denti Circon Implants, Zimplant-Biosyr, Omnis-Creamed, White Implants and Ziraldent.
- Besides the high cost and the need for protectors during healing, some ZrO2 ceramics may suffer early hydrothermal degradation. Given a lack of standardization of the materials surveyed in this study, new ISO standards are warranted.
- Finally, it is a very promising market due to technological advances and the increased awareness of patients, who seek metal-free healthcare and beauty treatments.

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