Zirconia Implants: The New Arrival in the Armoury of Successful Aesthetic Implant Dentistry

Fiber Posts: Cementation Techniques

Dissolution Process of Bioactive Glasses

Comparison of Over Flared Root Canals of Mandibular Premolars Filled with MTA and Resin-Based: An In-Vitro

Insights into Services Provided by Maxillofacial Prosthetists in the UK

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ABSTRACT
Implant treatment is currently overriding other prosthetic solutions especially in the case of replacing anterior teeth in the aesthetic zone. Aesthetic complications that may follow such treatment are a major concern as the sole reason for patients seeking treatment may be to improve aesthetics. The introduction of zirconia dental ceramics provided a multitude of solutions to overcome complications encountered with titanium implants via using tooth coloured abutments, titanium implants with soft tissue-zirconia collar and most recently, zirconia dental implants. The aim of this paper is to introduce zirconia dental implants, scrutinise in vivo, in vitro and clinical research evidence regarding their properties and performance and finally, present five clinical cases to demonstrate clinical technique and final outcome of a novel two-piece, root-form, soft tissue level zirconia implant system after several follow ups.

KEYWORDS
Zirconia, Ceramics, Abutments, Dental Implants, Aesthetics.

INTRODUCTION
Replacing missing teeth with osseointegrated dental implants can be regarded as the most significant breakthrough in the dental profession.1 Implant dentistry began more than four decades ago when the first titanium dental implant was placed by Brånemark.1-3 Since then, a plethora of changes involving design features, surface treatments and placement techniques of dental implants have evolved in an attempt to improve the outcome of this treatment modality which has a significant positive impact on the quality of patients’ lives.4 These changes however spared to a large extent, materials from which implants are made.

Owing to its’ excellent biological,5,6 physical5,7 and mechanical properties,8,9 commercially pure titanium earned an exclusive recognition as the gold standard material for osseointegrated dental implants.10 The outstanding long-term serviceability of this material has been proved by high quality experimental and clinical research that is well documented in the dental literature.2,11,12

Recently, titanium implants were challenged by newly emerging issues13-discussed in the next section- which in turn, made researchers investigate other biomaterials to compensate for potential inadequacies of titanium.

As in all other fields of dentistry, ceramics were on the top of candidates’ list and received great attention from biomaterial scientists. As cited by Andreiotelli et al.,13 implants made of mono and poly-crystalline alumina were among the earliest ceramic implants to be investigated. Unfortunately, their performance was not adequate for them to be recommended in routine clinical use which was attributed to their brittleness and poor mechanical properties. Lately, zirconia bioceramics have been recognised as potential implant materials after being subjected to thorough investigations which they succeeded but as biomedical orthopaedic implants, fixed dental prostheses and implant abutment materials.14-16

This paper is structured in a way to; explain the rationale of using and studying zirconia dental implants, review main properties of the material alongside with provision of in vivo, in vitro and clinical research evidence, highlight the main clinical studies that have investigated the performance of these implants and finally, take the reader through clinical cases in which zirconia implants -White Implant System (White Implant Development Corp., The Netherlands)- are placed in fresh extraction sockets to replace anterior teeth which successfully could meet aesthetic demands of patients.
**ZIRCONIA AS ADJUNCT OR ALTERNATIVE TO TITANIUM IMPLANTS: FACTORS DRIVING THIS TREND**

Titanium implants have the longest traceable record of predictable clinical performance with a cumulative success rate of 98.8% for 15 years. This is attributed to high biocompatibility, favourable bone and soft tissue response and adequate strength and corrosion resistance of commercially pure titanium.

Only recently has there been a move toward seeking alternatives to commercially pure titanium. This has been instigated in order to counteract some drawbacks associated with titanium dental implants. Andreiotelli et al. classified those drawbacks as the following:

**Aesthetic Challenge**
The tremendous increase in patient’s demands and expectations from dental implant treatment is progressively growing which has made clinicians not only interested in the osseointegration and survival of implants, but also concerned with the aesthetic outcome of this treatment.

Implant dentists are also under extraordinary pressure from their patients to speed up the process of implant treatment as patients finding it difficult to cope with provisional restorations, especially when it comes to replace missing teeth within the smile line. Therefore, more dentists are now considering immediate implant placement and in some cases immediate loading of the prosthetic superstructure. These advances, however, come at the expense of aesthetic complications as it has been found that post extractive placement using titanium dental implants can be associated with aesthetic compromise such as wound dehiscence and mid buccal recession. While there is strong evidence suggesting that it is possible to successfully load dental implants immediately or early after their placement in selected patients, though it has been suggested that not all clinicians may achieve optimal results. Trends suggest that immediately loaded implants fail more often than those conventionally loaded, but less commonly than those loaded early. However, if a clinician wishes to load the implants early, it might be wiser to load them immediately (within 1 week) rather than waiting for 1 or 2 months.

There have been significant concerns as far as stability and longevity of soft tissue aesthetics—synonymously called pink aesthetics—and subsequently patient satisfaction which has been found to be underexposed in the dental literature. The aesthetic complications of immediate replacement techniques are more evident in patients with thin gingival biotype who are more prone to recession which leads ultimately to greyish shimmering through the mucosa which jeopardises the aesthetic outcome and patient satisfaction. In fact, it has been shown in a recent clinical trial that more than 30% of patients who received single immediate implant treatment needed further surgical procedure namely, connective tissue grafting, after 12 months of placement due to major alveolar process remodelling and advanced midfacial recession. It is worthwhile to remark that implants were placed using flapless surgery and only patients with thick gingival biotype and intact labial bone plate after extraction were included in this study.

The correction of the aforementioned aesthetic complication is possible and well documented in literature using different grafting procedures; yet, there is only limited weak evidence in the dental literature suggesting that augmentation at implant sites with soft tissue grafts is effective in increasing soft tissue thickness improving aesthetics and furthermore, although there is limited number of randomised controlled studies showing that surgeries used to increase the height of keratinised mucosa using autografts or an animal-derived collagen matrix were able to achieve their goal, these studies also revealed that the above intervention came at the price of a worsened aesthetic outcome.

**Health Related Issues with Ti**

Unfortunately, it is no longer the case that titanium is considered as completely bioinert material. In contrast, titanium is thought to be the “New Allergen” as demonstrated by several reports and studies. Recently, Evard et al. concluded that there was an increase in the prevalence of oral allergies to metals, including inert materials like gold and titanium, used in dentistry especially in patients with history of allergy to other metals. They also maintained that titanium oral implants can induce toxicity or type I or IV allergic reactions which can be responsible for unexplained failure cases of dental implants in some patients.

A histological study on retrieved titanium hip implants showed a quite strong inflammatory response to these implants and was regarded as a contributing factor for failure. In addition, Sicilia et al. reported a 0.6% prevalence of allergy to titanium in patients who received dental implants and recommended allergy tests in some cases.

Significant concerns about titanium ion release due to corrosion and wear and subsequent allergies and sensitisation have been raised recently. High concentrations of titanium ions were detected locally i.e. bone in the vicinity of implants, and systemically as in regional lymph nodes, internal organs, serum and urine which is potentially hazardous to human body. Despite the aforementioned findings, the significance of these concerns is not clear in light of huge amount of reports that proved safety of commercially pure titanium for oral use and testing patients for Ti allergy on regular basis still cannot be easily justified.
Metal-Free Prosthetic Reconstructions

The steadily growing concerns about the aesthetics and potential health problems associated with metal alloys have rendered some dental patients metal-phobic.13,42 This has been substantiated by the constantly emerging reports correlating systemic diseases43 and genetic mutations44 to ion release from metallic restorations.

Nowadays, it is a routine situation that clinicians face in dental practice where patients are reluctant to receive metallic prostheses and asking for metal-free alternatives which makes researching and learning about ceramic implants highly required.

Breakthroughs in Bioceramics’ Development

Advances in biomaterial science and ceramic manufacturing technology have allowed production of high strength and biocompatible ceramics that can be used as biomedical devices and implants. The introduction of Ytetrria- Partially Stabilized Tetragonal Zirconia Polycrystals (Y-TZP), Powder Injection Moulding (PIM) and Hot Isostatic Pressing (HIP) techniques were the hallmarks of this development.13,45

Other developments such as the use of zirconia toughened alumina and Ceria-doped zirconia to minimise the incidence and halt the progression of zirconia aging are also considered as key steps in the growing popularity of zirconia as a bioceramic.46

ZIRCONIA IMPLANTS FROM THE PERSPECTIVE OF EVIDENCE BASED DENTISTRY

Partially stabilized zirconia ceramics have distinct mechanical and optical properties and exhibit a very high biological compatibility with the oral environment; consequently, a huge amount of research has been directed toward this material.

As it is the case with all new dental materials, clinicians should bear in mind that the evidence available about zirconia is largely based on in vitro studies that might be inapplicable to all clinical situations and that long term clinical trials are scarce. In general, clinical data about this material is of a short term and unfortunately, some contradictory findings are present.47 The following sections will briefly explain the functional, aesthetic, and biological characteristics of this material.

Biocompatibility

The success of biomedical implants is extensively dependent on the biocompatibility of materials used.48 Such devices should induce favourable tissue response which has no adverse effects on surrounding tissue as well as implants. This can be ensured by testing all materials intended for biomedical use in vitro and in vivo to demonstrate that they are unable to provoke or initiate inflammatory, allergic, immune, toxic or neoplastic processes.49

Zirconia showed a high level of biocompatibility and safety which allowed its’ use as biomedical implant which can be traced back to late sixties.50 The use of zirconia heads in total hip arthroplasty was reported by Christel et al. in late eighties.51 In mid-seventies, zirconia was used to coat base metal alloy implants in an attempt to enhance stability of dental implants in dogs.52

The following sections highlight scientific findings that led to rationalisation of the use of zirconia in implant dentistry.

Cellular Toxicity

Viability of cells in the vicinity of biomedical implants is the most fundamental prerequisite for success of implantation procedure. For dental implants, fibroblasts, osteoblasts and immune cells within blood are the cells of concern as they are the most abundant ones in peri-implant soft and hard tissues.49

Early in vitro studies showed high toxicity of zirconia wear products on fibroblasts.53 However, Tateishi et al.54 remarked that testing conditions, ratio of impurities and powder characteristics can influence the results of these tests. In 2008, Raffaelli and co-workers55 used more objective criteria to test the effect of zirconia on fibroblasts and concluded that zirconia ceramics have low cytotoxicity, strongly promote adhesion capacity and increases cellular growth rate of fibroblasts. Recently, it has been shown that fibroblasts’ viability increases by 1.3 folds with zirconia implants that received MDS treatment (acid etched/ sand blasted) when compared to control titanium and zirconia implants.56 This indicates that surface roughness may affect behaviour of cells and may enhance bone and soft tissue interaction with zirconia implants.

The effect of zirconia on osteoblasts was among the most attractive topics for researchers as was the case with titanium. The most fundamental and widely cited work in this field was performed by Josset et al.57 who found that zirconia does not induce cellular or DNA toxicity and can favourably interact with osteoblasts in vitro. In addition, it does not hinder or interfere in physiological mechanisms of protein and extracellular matrix production.

As far as immune cells are concerned, Sterner et al.58 found that alumina and titanium induce reactivity of human monocytes to a greater extent when compared with zirconia. Other in vitro studies showed no difference between the effect of zirconia, alumina and/or titanium on macrophages and lymphocytes.59,60

Finally, zirconia was found to be safe on various cellular components of connective tissue which was substantiated by Hisbergues et al.49 in which they comprehensively reviewed the studies on the effects of zirconia on immune cells, fibroblasts and osteoblasts.

Osseointegration

Osseointegration of dental implants can be considered as a provision of an anchorage mechanism utilising non-vital components (dental implants) that can be reliably and predictably incorporated into living bone in such
way that this anchorage can persist under all normal conditions of loading. Clinically, this is translated as a non-mobile implant with no evidence of radiolucency around it. The prerequisite to achieve this is to get a direct structural and functional connection between ordered living bone and the surface of the implant which should be osseconductive in nature.\textsuperscript{61,62}

Zirconia ceramics are thought to have the characteristics to prime, initiate and maintain osseointegration as they have no toxic effects on bone tissue - as described in the previous section- and are able to promote physical attachment of bone that can grow on the material surface. Hempel et al.\textsuperscript{63} indicated that zirconia mediated a significantly stronger adhesion, proliferation and differentiation of the studied osteoblast-like cells when compared with titanium in vitro. They also remarked that topography of the surface of zirconia had minor effects on osteoblast biology.

An animal study conducted by Scanarolo et al.\textsuperscript{64} demonstrated that unloaded zirconia implants osseointegrate when inserted in rabbits' tibia bones without any signs of inflammation or mobility. In another study on rabbits, it has been reported that modified (roughened) zirconia implants have superior osseointegration capacity when compared to machined ones and similar resistance to removal when compared to oxidised titanium implants.\textsuperscript{65} Loaded zirconia implants were studied and compared to titanium implants by Kohal et al.\textsuperscript{66} who concluded that there was no difference in osseointegration level between the two groups. In contrast, Akagwa et al.\textsuperscript{67} reported evident crestal bone loss around loaded zirconia implants when compared to an unloaded group. Yet, bone-implant contact of the two groups was similar in this study. Five years later, the same research group reported possible long term and stable osseointegration of loaded and unloaded zirconia implants.\textsuperscript{68}

Finally, a recent systematic review by Andriotelli et al.\textsuperscript{41} found nine animal studies that fulfilled the inclusion criteria and concluded that zirconia implants osseointegrate as well as their titanium analogues\textsuperscript{13} which supports the findings of Wenz et al.\textsuperscript{41} who reached the same conclusion in their systematic review one year earlier and found an average bone-implant contact of 60% (possibly better than titanium, as reported in some studies they have reviewed).

Periintegration

\textit{In vitro} experiments on zirconia showed a favourable response in terms of adhesion and proliferation of various cellular components of connective tissue. This provides basis for thinking of zirconia as a material of choice for periintegration. These findings were substantiated by Groessner-Schreiber et al.\textsuperscript{69} who found significant improvement in human fibroblast adhesion to titanium discs when coated with zirconium nitride in comparison to control which indicates a potentially stronger soft tissue cuff around implants.

The second important pillar of periintegration is the inflammation-free environment as the inflammatory process can collaterally damage soft tissue attachment to dental implants by releasing various proteases in an attempt to compact bacterial infections.

Angiogenesis – new blood vessels formation- is believed to be a strong indicator of the inflammatory status in soft tissues. Presence of angiogenic factors and the enzymes they express such as VEGF and nitrous oxide synthases I & II is indicative of inflammatory process as they are released by neutrophils in response to bacterial infection.\textsuperscript{49} Degidi et al.\textsuperscript{70} demonstrated using angiogenic markers, a lower inflammatory response in biopsies from peri-implant soft tissues around zirconia healing caps when compared to titanium.

Clinical studies have shown that peri-implant tissues’ response and health are optimum around zirconia abutments.\textsuperscript{71} Moreover, zirconia and titanium abutments have been clinically assessed by van Brakel et al.\textsuperscript{72} who found that there was no significant difference between the two groups. However, zirconia abutments were associated with shallower sulcus depths after 3 months in this study. In the clinical trial by Bianchi et al.\textsuperscript{73}, it was found that the hybrid implant system performed better than titanium controls in terms of probing depth, bleeding on probing and plaque index. Also, rapid stabilization of peri-implant tissues was documented in the first year and survival rate after two years found to be 100%. However, this clinical trial seems to be at a high risk of bias as there was not enough information about randomisation and allocation concealment, a small sample size and no information about assessors’ blinding.

In the light of these research findings, zirconia possesses significant features that justify considering it as the material of choice to promote and maintain periintegration and peri-implant soft tissue health.

Antibacterial Properties

As all natural teeth and dental prostheses do, dental implants and their components act as a scaffold on which bacteria can accumulate and form a bacterial biofilm which can lead to peri-implantitis. A huge amount of research tackled biofilm formation on titanium and the effect of various treatments and surface textures on this process. This was driven by the increase of incidence and severity of peri-implantitis and the fact this condition is one of the most common causes of dental implant failure with neither current consensus on how to treat it nor how effective current treatments are.\textsuperscript{74}

Reduction in bacterial colonization was studied by Groessner-Schreiber et al.\textsuperscript{69} who concluded that zirconium nitride-coated titanium discs harbour significantly less bacteria when compared to other coatings and controls. In addition, it has been concluded that zirconia surfaces accumulate significantly less
bacteria when compared with titanium ones. This in vitro finding has been confirmed by a human study conducted by Scarano et al. who found reduced early colonisation of bacteria on zirconia discs inserted in the mouth for 24 hours. Finally, zirconia and titanium blasted with zirconia discs showed significant reduction of bacterial adhesion especially after coating with saliva pellicle when compared with titanium controls.

**Mechanical Properties**

Zirconia or “Ceramic Steel” poses outstanding biomechanical properties as a result of the unique transformation toughening mechanism in which transformation of material between different phases acts as strengthening process to counteract cracks that lead to failure of the material. As a result of this adjunct toughening mechanism, the outstanding mechanical parameters of this material such as flexural strength and fracture toughness exceeding 1200 MPa and 16.0 Kgf/mm² respectively, made zirconia feasible to be used as bio-medical implants.

In their artificial mouth investigation using chewing simulator and fracture toughness tests, Kohal et al. found that one piece zirconia implants restored with Procera all-ceramic crowns could possibly fulfil the biomechanical requirements for anterior teeth. In another in vitro study, fracture strength of one-piece zirconia implants was investigated after chewing simulation and found to be within the limits of clinical acceptance. However, preparation of the implant head to receive prosthesis significantly compromised fracture strength. The authors concluded that long-term clinical data is necessary before one-piece zirconia implants could be recommended for clinical practice. Five years later, the principle investigator of the latter study reported with his co-workers that one piece zirconia implants restored with Procera all-ceramic crowns could possibly fulfil the biomechanical requirements for anterior teeth. In another in vitro study, fracture strength of one-piece zirconia implants was investigated after chewing simulation and found to be within the limits of clinical acceptance. However, preparation of the implant head to receive prosthesis significantly compromised fracture strength. The authors concluded that long-term clinical data is necessary before one-piece zirconia implants could be recommended for clinical practice. Five years later, the principle investigator of the latter study reported with his co-workers that one piece zirconia implants restored with Procera all-ceramic crowns could possibly fulfil the biomechanical requirements for anterior teeth. In another in vitro study, fracture strength of one-piece zirconia implants was investigated after chewing simulation and found to be within the limits of clinical acceptance. However, preparation of the implant head to receive prosthesis significantly compromised fracture strength. The authors concluded that long-term clinical data is necessary before one-piece zirconia implants could be recommended for clinical practice.

On the other hand, several studies showed that aging can be minimised to biologically acceptable levels by optimising manufacturing process, use of proper crystal size, remove impurities and embracing the use of various aging-resistant material such as alumina-zirconia composites and Ceria-doped zirconia. Furthermore, zirconia blanks showed no significant deterioration in mechanical properties after being embedded into the medullary cavity of the tibia of rabbits for a period of 30 months. It was also reported in the later study that zirconia can be used clinically as it retains a bending strength of over 700 MPa after being immersed in 95°C saline solution for over 3 years. Consistent findings were reported by Cales et al. who concluded that zirconia implants used in hip replacement surgeries maintained sufficient mechanical properties when recovered two years after implantation procedure. They also remarked that conflicting data on the survival and strength of these implants can be attributed to the microstructural design and quality of the ceramic manufacturing.

Finally, Jerome Chevalier is the brightest name in field of zirconia aging with numerous widely cited publications on this subject. In his extensive review on zirconia biomedical implants’ aging, he along with his co-workers concluded that although in the 1990s 3Y-TZP ceramics were considered very promising materials for biomedical applications, long-term follow-up is needed to address the critical problem of aging in vivo and its negative impact on orthopaedic implant durability. As 600,000 patients to date have been implanted with zirconia hip joint heads, a careful explant analysis must be conducted, with a special emphasis on LTD-microstructure relationships. However, most zirconia implants were processed at a time when aging was not yet fully understood. Methods to assess a priori the aging sensitivity of a given zirconia ceramic have been developed and should lead to safer implants. In the meantime, new zirconia or zirconia-based materials that overcome the major drawback of the standard 3Y-TZP are now available.

It has been shown that stabilizer type and content, residual stress and grain size are the main factors controlling the aging phenomenon. An in vitro experiment has shown that Young’s modulus and hardness of Y-TZP bars were reduced by 30% when they were subjected to hydrothermal cycling. The authors also concluded that the increase of monoclinic-tetragonal phase ratio is associated with microcracking and responsible for the decline in mechanical parameters. The other important aspect in LTD is the increase of wear rate and wear particles release from aged surfaces which may elicit immune response and is believed to be the cause of aseptic failures of many zirconia implants used in total hip arthroplasty procedures.

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Optical Properties
The white colour of zirconia is considered as the major advantage over metallic alloys which always have been challenged by the greyish discoloration they might cause to surrounding soft tissues. Introduction of zirconia ceramics with different shades and opacities has also added to the value of zirconia in aesthetically challenging cases.

Colour changes in soft tissues of different thicknesses induced by titanium and zirconia were assessed using spectrophotometry in the experiment by Jung et al. who concluded that zirconia induces the least colour changes when compared to titanium even in case of 1.5mm soft tissue thickness. This may indicate that zirconia abutments and implants are theoretically useful in cases of thin gingival biotype and may negate the need for further complicated and potentially morbid soft tissue grafting procedures to augment peri-implant soft tissues in anterior region.

Clinical Research
The number of clinical studies that investigated the survival of zirconia implants is considerably less than laboratory experiments. In addition, it is not surprising that quality of these studies is not as high as those available for titanium dental implants as they either have short follow-up period and/or small sample size rendering the evidence supporting the use of zirconia dental implants inconclusive.

A recent systematic review on different types of dental implants found no randomised controlled trials describing implants made or coated with materials other than titanium. However, studies providing lower level of evidence were reviewed by Andreiotelli et al. who found three retrospective cohort studies on one-piece zirconia dental implants that met the inclusion criteria of their systematic review. The first two studies were by Mellinghoff et al. and Oliva et al. who investigated 189 and 100 zirconia implants and found 1-year survival rates of 93% and 98%, respectively. Most failed implants did so in the healing phase, in which increased mobility was noticed. Only one implant failed after prosthetic reconstruction due to implant fracture. Lambrich & Iglhaut observed 127 zirconia and 234 titanium implants for a mean observation period of 21.4 months. In this study, zirconia implants performed as well as titanium counterparts when inserted in mandible (98.4% vs 97.2%) while titanium implants performed significantly better in the maxilla (98.4% vs 84.4%). Again, all failures were in the healing phase due to increased implant mobility.

The final conclusion of the aforementioned systematic review was that despite the fact that scientific data from animal and human studies show that zirconia implants osseointegrate as well as titanium and zirconia is a promising material in implant dentistry yet, these findings should be supported by long-term clinical data before recommending zirconia implants as a viable alternative to titanium implants. These findings have been confirmed recently by Depprich et al. who found only 17 clinical studies on zirconia implants conducted between 2006 and 2011 in which, survival rate was between 74–98% after 12–56 months. The authors remarked that all of the studies had significant shortcomings and thus, well designed controlled trials are urgently needed.

Earlier this year, Payer et al. published their results after two years follow up of immediately loaded 19 zirconia implants. They reported 95% two-year survival according to the clinical and radiographic parameters they examined. These results are consistent with the data published by Oliva et al. in 2010 who followed up 831 one-piece zirconia implants placed in 371 patients for five years and found a survival rate of 95%. In the later study, three groups of implants with different surface roughness were investigated. The acid-etched implants were found to be superior to the coated and machined ones.

In contrary, Kohal et al. found that immediately restored one-piece zirconia implants have one-year cumulative survival rate comparable to titanium counterparts. However, they remarked that the incidence of bone loss shown on radiographs (more than 2mm) after follow up period is considerably higher than that for titanium implants and thus, the studied implants cannot be recommended for clinical use.

Recently, two case reports were published about using laser acquisition techniques to scan extracted roots and mill truly anatomic, root-analogue zirconia implant using CAM technology to replaces extracted teeth after few days. The authors claim good performance of these implants after 30 months. They also alleged potential benefits of being atraumatic and the fact that this procedure negates the need of augmentation surgeries. However, the presence of bone defects due to previous infections may be the major challenge to this approach thus; careful case selection should be warranted.

IMMEDIATE REPLACEMENT OF EXTRACTED CENTRAL MAXILLARY INCISOR USING NOVEL TWO-PIECE ZIRCONIA IMPLANT SYSTEM: CASE SERIES

The promising research findings regarding the use of zirconia as dental implant material led to the emergence of several zirconia implant systems with different surfaces and designs. The following five clinical cases will demonstrate the procedure of immediate post-extraction replacement of maxillary central incisors with or without immediate loading using White Implant system (White Implant Development Corp., The Netherlands).

White Implant is a novel implant system consisting of; root-form, soft tissue level zirconia fixture to which, a glass fibre-reinforced composite abutment is cemented and prepared utilising standard techniques used for all-ceramic crowns preparation. This system can be used for early or delayed loading procedures as will be explained in the next section. (Fig 1)
The following treatment sequence was followed:

Step 1: Extraction (Fig 3)
- Atraumatic extraction of the tooth using maxillary anterior forceps utilising pure gentle rotational movement.
- Careful sounding of the alveolus which was intact apart from the mesial wall.
- Socket curettage and copious saline irrigation were carried out in order to clean the socket.

Step 2: Osteotomy & Implant Placement (Fig 4)
- Osteotomy site preparation using sequence of drills recommended by the manufacturer for placement of 6mm diameter and 13mm long implants.
- Osteotomy drills are pushed against palatal wall of alveolus without involving labial bone plate.
- Apical part of alveolus was prepared in order to be engaged by the implant which is essential for primary stability.
- 6mm diameter and 13mm long Zirconia Implant (By White Implants Development Corp B.V.) was then inserted using motor-driven wrench until attaining 20Ncm⁻¹. Hand-wrench then was used until achieving 45Ncm⁻¹ which allowed immediate loading.

Step 3: Abutment Cementation and Preparation (Fig 5)
- Haemostasis was achieved by means of compression followed by gentle packing of retraction cord around the head of implant.
- Inner surface of implant was etched with orthophosphoric acid 37% and primed using Zirconnect primer (Kuss Dental S.L, Madrid • Spain) prior to cementing the
corresponding glass fiber abutment (By White Implants Development Corp B.V) using Panavia F2.0 cement (Kuraray America, Inc).

- After complete setting of cement, abutment and coronal aspect of implant head were prepared using fine diamond bur as for all-ceramic crown.

Step 4: Temporization (Fig 6)
- Temporary acrylic crown was made utilising putty index of the tooth prior extraction.
- Occlusal adjustment was then carried out to ensure that the temporary crown is out of occlusion during centric occlusion and all excursive movements.
- Temporary crown is then cemented using Poly-F Plus cement (Poly-F Plus, Dentsply DeTrey and Durelon Maxicap, ESPE)

Step 5: Permanent Restoration (Fig 7)
- Six months later, temporary crown was removed and preparation was refined using fine diamond burs.
- Gentle packing of appropriate size retraction cord prior to standard crown impression making using two-viscosity silicone based impression material.
- Final all-ceramic crown (IPS e.max Press) was then cemented using RelyX, (3M-ESPE, USA).

Step 6: Follow-up (Fig 8&9)
- Patient was reviewed six months later and the implant was stable, no signs of inflammation or attachment loss around the implant despite the significant remodelling of the labia bone plate.
- Patient was pleased with the aesthetic outcome of the treatment.
- Peri-apical X-ray was taken to verify a bone level which was found to be stable beside obliteration of the angular defect which was presented preoperatively.

(Fig. 5) A: Retraction cord in situ and the inner side of the implant etched. B: Abutment cementation. C&D: standard all-ceramic crown preparation of the abutment and soft tissue collar of implant

(Fig. 6) Temporary crown in place. A: Immediately after surgery. B: 10 days, C: 2 months D: 5 months after surgery

(Fig. 7) A: Retraction cord in place and refined preparation. B: Final crown cemented (Frontal view). C: Incisal view demonstrate remodelling of labial bone plate yet, D: Stable levels of peri-implant soft tissues after 12 months

(Fig. 8) Comparative frontal views. A: Before. B: After 18 months of surgery

(Fig. 9) Comparative PA x-rays. A: Before surgery. B: 18 months after surgery
CASE 2
A 46 year–old female patient who was concerned about her appearance because of a black margin of old crown placed many years ago on her maxillary left central incisor which was associated with discomfort on intermittent occasions.

Clinical examination showed an upper left central incisor that is restored with PFM crown which has adequate margins. Yet, metal margin on the labial surface was showing as a result of gingival recession. Probing around the tooth showed no probing depths more than 3mm.

Radiographic examination revealed inadequate root canal filling with short, tapered, screw-type metal post in UL1 and signs of peri- radicular pathology. (Fig 10)

As part of diagnostic process, tooth was investigated under the dental operative microscope after removal of the post and crown. Examination revealed a subgingival crack extending mesio-distally in the palatal half of the root. The fact that crack was deep and there was no remaining tooth structure left to salvage the tooth, extraction was the treatment of choice. (Fig 11)

After discussing various treatment options with the patient, she chose immediate replacement using zirconia implant but with delayed loading to avoid the potential complications of immediate loading.

The treatment was commenced following the standard procedure explained in Case 1 where the tooth was atraumatically extracted and the osteotomy carried out and finally the implant placed. (Fig 12)

Afterwards, the implant was sealed using temporary filling material on top of a cotton pellet and a composite resin bridge was bonded to adjacent teeth for temporisation. (Fig 13)

Three months later, patient attended for construction of permanent restoration. The temporary bridge and filling that was placed to seal the implant were removed. Site was isolated by rubber dam and the abutment was built up directly using two glass fibre-reinforced posts (Snow post, Danville, Germany) bonded to the inside of the implant using Panavia F2.0 cement (Kuraray America, Inc). The coronal portion of the abutment was restored with direct composite and then prepared for all-ceramic crown as in natural teeth. This technique was used as that was the first case using this system and pre-fabricated abutments were not introduced at that time. (Fig 14)

Finally, all-ceramic crown was cemented in place and patient was reviewed after 2, 5 and 7 years. In all review
visits, implant was found to be stable and peri-implant tissues were healthy with no evidence of recession or attachment loss. Aesthetic outcome was excellent and patient was remarkably satisfied. (Figs 15&16)

CASE 3
This case also demonstrates how zirconia implant-supported all ceramic restorations can be invaluable approach to treat aesthetically challenging situations as the patient has high lip line. Standard procedure was followed and delayed loading was carried out. Patient was followed up for 5 years after which, treatment still working fine. (Figs 17-20)

CASE 4
This case highlights the virtue of incorporation of a low strength implant superstructure, i.e. glass fibre abutment and all-ceramic crowns. The patient had immediate replacement of failing UR1 using zirconia implant and all-ceramic crown which lasted 5 years after which she received a trauma in the anterior maxillary region which caused the crown to be cracked. Shortly after that, crown broke into two pieces. (Figs 21-23)

Presence of low-strength abutment provided a cushion which prohibited force from the trauma to progress to implant and supporting bone and confined the resultant
CASE 5

This is a case of 40 years old lady who was treated according to the standard immediate replacement protocol to replace failing UL1 using zirconia implant with delayed restoration. (Figs 24-30)

(Fig. 21) A: Preoperative frontal view showing aesthetically compromised UR1 with marked gingival inflammation. B: Pre-operative PA x-ray showing PA radiolucency associated with root treated UR1

(Fig. 22) A: Tooth was atrumatically extracted and implant was placed. B: Temporary bridge in place

(Fig. 23) A: Abutment was cemented and prepared. B: Permanent crown in place after 7 months. C: PA x-ray after 7 months. D: Permanent crown in place after 3 years

(Fig. 24) A: Frontal view showing crack in permanent crown on 5-years review. B: Gross fracture of the crown shortly afterwards. C: New All-ceramic crown after 2 years in service. D: 7 years post-operative PA x-rays

(Fig. 25) Comparative views showing A: Preoperative situation. B: 7 years post-operative situation. C: Pre-operative PA x-ray. D: 7 years post-operative PA x-rays

(Fig. 26) A: Preoperative frontal view showing aesthetically compromised UL1. B: Pre-operative PA x-ray showing PA radiolucency associated with apexectomised UL1

(Fig. 27) A: Tooth was atrumatically extracted and implant was placed. B: Temporary bridge in place immediately after surgery. C: Temporary bridge in place 3 weeks after surgery. D: PA x-ray after 3 months

(Fig. 28) A: Tooth was atrumatically extracted and implant was placed. B: Temporary bridge in place immediately after surgery. C: Temporary bridge in place 3 weeks after surgery. D: PA x-ray after 3 months

A new crown was made and patient was reviewed two years later with no signs of deterioration. (Figs 24&25)

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The roughened surface of these implants utilising sandblasting and acid etching (MDS treatment) is claimed to have superior biocompatibility, osseoconductivity and better survival by in vitro,56 in vivo (animal)65 and human studies.92 Surface roughness could also account for the rapid, optimal soft tissue response and behaviour as noticed in the clinical cases as it may provide a platform for soft tissue attachment and promote the so called periointegration. (Fig 31)

Feature designs incorporated in White Implant system are said to have major impact on the survival and durability. Longitudinal groove in the implant allows escape of bone residues which allow accurate placement of implant. Furthermore, the dimensions of the threads permit better engagement of bone and enhance primary stability. Rounded margins, smooth curves and robust implant head ensure high strength and fracture resistance during implant placement under high torque. The introduction of an external driver in initial implant placement has also reduced the incidence of implant head crumbling.

"If something is likely to fail, place it in an accessible location" is a sound engineering principle that is utilised in almost all fields of industry. This principle was introduced in the White Implant System via using a low-strength glass fibre-reinforced composite abutment that is cemented inside the implant to support an all-ceramic crown. In this case, the weakest part in the chain is abutment-implant bond (via adhesive cement), abutment itself or brittle all-ceramic crown. In case of failure of any of these parts, failures are still more likely to be favourable, less drastic and retrievable.

Embracing this design is conforming with treatment that is proven to be successful in dental practice namely, restoration of endodontically treated teeth with glass-fibre posts and full-ceramic crown coverage.97

DISCUSSION

In the era of aesthetic, minimally invasive dentistry and growing recognition of immediately placed dental implants in fresh extraction sockets to replace teeth in the aesthetic zone, adjuncts to titanium dental implants are urgently needed in order to overcome aesthetic complications arising from the latter with the least amount of morbidity, discomfort, cost and time.

Zirconia dental implants seem to be the best candidate for the time owing to their outstanding biocompatibility, high mechanical strength and aesthetic superiority. White Implant system is among the newly introduced zirconia implants which are manufactured according to one of the most developed techniques in ceramic industry namely, Ceramic Injection Moulding (CIM) which guarantees production of high-precision components with consistently adequate mechanical and surface characteristics.

Feature designs incorporated in White Implant system are said to have major impact on the survival and durability. Longitudinal groove in the implant allows escape of bone residues which allow accurate placement of implant. Furthermore, the dimensions of the threads permit better engagement of bone and enhance primary stability. Rounded margins, smooth curves and robust implant head ensure high strength and fracture resistance during implant placement under high torque. The introduction of an external driver in initial implant placement has also reduced the incidence of implant head crumbling.

“If something is likely to fail, place it in an accessible location” is a sound engineering principle that is utilised in almost all fields of industry. This principle was introduced in the White Implant System via using a low-strength glass fibre-reinforced composite abutment that is cemented inside the implant to support an all-ceramic crown. In this case, the weakest part in the chain is abutment-implant bond (via adhesive cement), abutment itself or brittle all-ceramic crown. In case of failure of any of these parts, failures are still more likely to be favourable, less drastic and retrievable.

Embracing this design is conforming with treatment that is proven to be successful in dental practice namely, restoration of endodontically treated teeth with glass-fibre posts and full-ceramic crown coverage.97

Introduction of cemented glass fibre abutment may also provide cushioning mechanism which prevent detrimental forces e.g. trauma, from being transmitted to the implant and surrounding bone as these forces are likely to break suprabony components first as
demonstrated in clinical case 4 where traumatic injury cracked the crown rather than implant which was easily repaired. It also may overcome the problem associated with other two-piece implant system which uses zirconia for fixture and abutment and found to be at increased risk of implant head fracture.79,80 In the meantime, preparation carried out with fine diamond burs in a high-speed hand piece under copious amount of water irrigation seems to be the safest.

White Implant system is considered as simple approach for provision of implant treatment with high aesthetic outcome. Using such a system negates the need for complex grafting procedures, reduces the number of implant components needed i.e. implant replicas, impression pick-ups and healing abutments, simplifies impression taking and laboratory procedures.

CONCLUDING REMARKS

• Titanium dental implants are still the irreplaceable gold standard and mostly recommended for patient’ use. However, several issues have led to seeking adjuncts to this material in order to simplify and enhance aesthetic outcome of immediately placed dental implants in the aesthetic zone.

• Due to outstanding mechanical, biological and aesthetic characteristics of zirconia dental ceramics, this material was found to be a good candidate to fulfill this purpose.

• In vitro and in vivo research finding support the use of zirconia dental implants, however, this need to be substantiated by long term well-structured randomised controlled trials.

• The presented novel design of zirconia dental implants (By White Implants Development Corp B.V.) in this cases report is based on valid scientific basis and may be considered as a new approach to optimise aesthetic outcome of immediate replacement technique in the aesthetic zone. It seems to promote and maintain optimum soft and hard tissue health and architecture. Yet, extensive in vitro and clinical studies should be carried out to validate its’ use.

REFERENCES


