The evolution in ceramic implantology: A review of the literature and report of two cases with two-piece zirconia implants

Dino Re*, Andrea Enrico Borgonovo, Andrea Emanuele Luca, Susanna Ferrario, Sammy Noumbissi**, Virna Vavassori

Dental Aesthetics Department, ISI, University of Milan, Milan, Italy
*Head of Dental Aesthetics Department
**President, International Academy of Ceramic Implantology, Silver Spring, Maryland USA - Zirconia Implant Research Group (Z.I.R.G), Silver Spring, Maryland USA

KEYWORDS

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ABSTRACT

Aim: *In recent years, research in oral implantology has focused on alternative materials to titanium. Zirconia bioceramic composites have emerged as reliable and predictable alternative implant materials. Zirconia implants, used initially in their one-piece variant, have been further developed and we now have available two-piece versions of ceramic implants. The present review aims to describe the peculiarities of two-piece zirconia implants, based on scientific literature in order to understand the success rate of these implants, their indications, morphological characteristics, advantages and disadvantages as well as clinical indications and most particularly in full-arch rehabilitations.*
Case report: *Two cases are reported in which the two-stage technique was used. During the first stage patients wore an immediate removable prosthesis with soft direct relining giving time to the implants to osseointegrate with minimal risk of premature load. For the final prostheses wax models and duplicates of the provisional models where used. Final results are reported at the 3-year and 18-month follow-up..*
Conclusion: *The growing demand for metal-free restorations even for complex treatments, such as full-arch restoration in edentulous patients, spurred research on alternatives such as zirconia implants. Two-piece zirconia implants are indicated in cases where obtaining implant parallelism is a challenge, poor bone quality (bone D3/D4), partial edentulism, restoration of the posterior quadrants, regenerative therapy, complex implant placement and in full-arch and full mouth oral rehabilitation.*

Introduction

The search for biocompatible materials as an alternative to titanium for dental implants has led dentistry to the use of innovative materials that can overcome some of the issues observed with titanium. Additionally, the increasing aesthetic demands from patients, particularly for their anterior teeth, shows that failing to achieve a highly aesthetic restoration ultimately means an overall unsuccessful result, despite having functional success (1).

Aluminium oxide (Al2O3) was one of the first ceramic materials used for implants. However, it was quickly abandoned because, although it achieved good osseointegration, in the longer term its mechanical properties proved insufficiently resilient to mastication and function. As a result ceramic implants lost their appeal and eventually manufacturers withdrew them from the market. The arrival of zirconia a material with good mechanical properties, high biocompatibility and with excellent aesthetic result encouraged researchers to investigate its possible use as a material for endosseous implants.

Zirconia implants have enabled modern implantology to overcome the limitations of titanium, which are not just in terms of restoration, such as the anterior quadrant in patients with thin gingival biotype, but also in terms of immunological response to the implant material. It has been established that and according to the Gell and Coombs classification, type IV immunological reactions can occur following placement and/or restoration when using titanium and titanium alloys. These reactions result in sensitization and proliferation of a population of reactive T-lymphocytes followed by an inflammatory cascade which leads to clinical symptoms and even peri-implant tissue loss. This kind of situation is difficult to ascertain diagnostically because of the unreliability and inaccuracy of skin patch tests (2). The literature indicates the presence of a demonstrable immunological reactivity in about 5% of patients with titanium implants. Using more

sophisticated and sensitive diagnostic methods, such as LTT lymphocyte transformation tests, it has been possible to reveal immunological reactions in patients exposed to titanium implants (3) at even higher percentages.

The first zirconia implants produced were in one-piece. Acknowledging the limitations of one-piece implants, ceramic implant manufacturers have recently introduced the two-piece type which consist of an implant fixture and a standalone prosthetic that can be connected to the implant by internal or external connection using a screw or with cementation.

Choosing between two-piece or one-piece implants

One-piece implants were the first zirconia implants introduced in for clinical use and proved to perform well in terms of osseointegration and clinical implant success (4,5,6,7). One-piece implants definitely have advantages, but also a number of limitations due to their morphology.

One-piece implants are particularly suitable for the anterior quadrants especially in the case of thin biotypes, in the restoration of single-tooth edentulism, and in patients who have optimum bone support that is able to withstand mastication or other forces during the osseointegration phase. However, even when there is good bone support, the monolithic structure of these implants can lead to difficulties in terms of surgical insertion in patients with limited opening, short clinical crowns and limited interocclusal space. Moreover, achieving paralellism of the abutments at the time of restoration may be very challenging since most one-piece implant manufacturers do not recommend grinding or adjusting the abutment due to the risk of inducing cracks in the implants. On the other hand, with two-piece implants, this problem is easily overcome by using angulated abutments whereas for one-piece implants it is rather necessary to modify the abutment in situ in order to obtain or create favourable angulation. Modifying the abutment in this way to adapt it to the requirements of the prosthesis results in structural alterations that could weaken the zirconia and make more vulnerable to fracture, a situation that should be avoided particularly in the posterior quadrant where the chewing forces are highest. Additionally, the use of one-piece implants necessarily involves the use of a temporary tooth that must be free of occlusion and lateral contact or a protective appliance. However, studies have shown that these implants are subjected to loads (8) linked to the physiological movements of the tongue and to uncontrolled forces in chewing cycles (9). This may undermine the osseointegration processes, particularly where the bone support is of poor quality, a clinical situation found frequently in the latero-posterior quadrants in the upper maxillary bone. It has been shown in the literature that an implant placed in poor quality bone with thin cortical bone and low trabecular density (D4) has a greater probability of failure compared to implants inserted in other types of bone quality (10). This occurs not only in situations where the bone does not have sufficient density at the time of implant placement, but also in sites where prior or simultaneous regenerative procedures such as GBR, sinus lift, trans-sinus lift have been carried out. Most two-piece ceramic implants on the market today are tissue level, they remain the best option to avoid premature load during bone healing and osseointegration phase (Figure 1, 2, 3).

Two-piece implants, on the other hand, are more versatile than one-piece implants in the situations described above, since the dentist can opt for submerged healing of the implant in cases where this situation is indicated and can choose between different types of abutment. For instance, in cases of rehabilitation of the posterior quadrant in patients who have significantly limited opening, two-piece implants are a better option since they also reduce the potential of premature occlusal load compared to straight abutments on monoblock implants. Furthermore, as already mentioned above, when the bone quality of a patient is poor or in cases where regenerative procedures are needed (Figures 4a,b,c,d,e), two-piece implants make provide the option to proceed with the two-staged implant placement approach.

However, compared to the single-piece implant, the two-piece ceramic implant systems can potentially undergo similar complications observed in titanium implants. These issues occur at the implant-abutment interface owing largely to the greater risk of bacterial colonization in the micro-gap that can be created at the abutment-implant connection (11). Nonetheless, it should be noted that zirconia has intrinsic characteristics and surface properties that allow limited plaque organisation and limited bacteria adherence and microbiota compared to titanium(12). The implant-abutment connection not only ensures high stability of the abutment, preventing potential rotational movements of the prosthesis with the hexagonal connection, but also a greater protection of the hexagonal seal provided by the conical seal that reduces the gap between implant and abutment thus preventing bacterial infiltration (13).

Clinical success of two-piece zirconia implants

The success and survival rate of implants in zirconia are comparable to that of titanium implants, and several authors have compared the two implants (Zr-Ti) in order to evaluate their clinical reliability (14). A recent review of the literature conducted by

Haro Adánez Mireira et al. (15) on 17 clinical studies observed that, for a total of 1704 zirconia implants (1521 one-piece, 183 two-piece), monitored for a period of between 1 and 7 years, the average survival rates were 95% (95% CI 91-97%).

In addition to the survival rate, the review also examined average marginal bone loss values after 1 year and at the end of the follow-up period. Overall, the marginal bone loss was respectively 0.89 mm (CI 95% 0.60-1.18) and 0.98 mm (CI 95% 0.79-1.18).

Regarding studies on two-piece zirconia implants, the results obtained in terms of implant success and survival have shown data comparable to those of titanium implants. Specifically, in a study conducted by Payer et al. (16), the success rate and survival rate were 93.3% for zirconia implants and 100% for

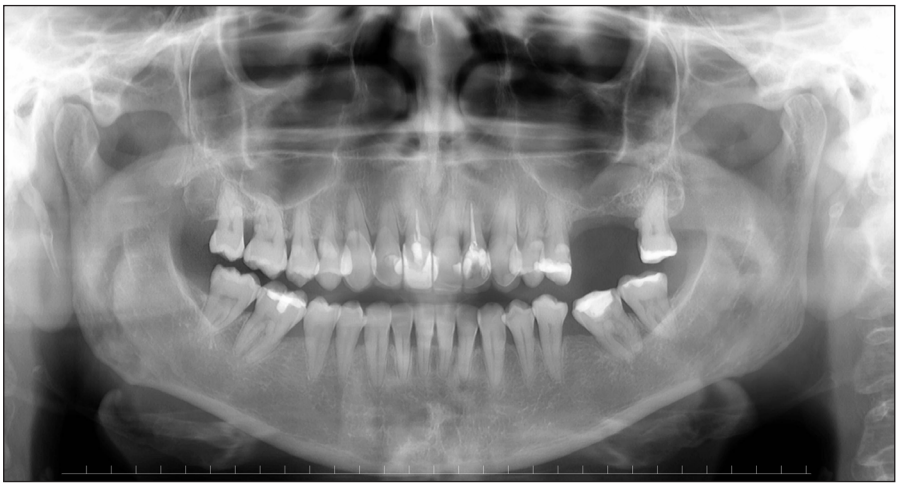

Figure 1 Initial orthopantomograph

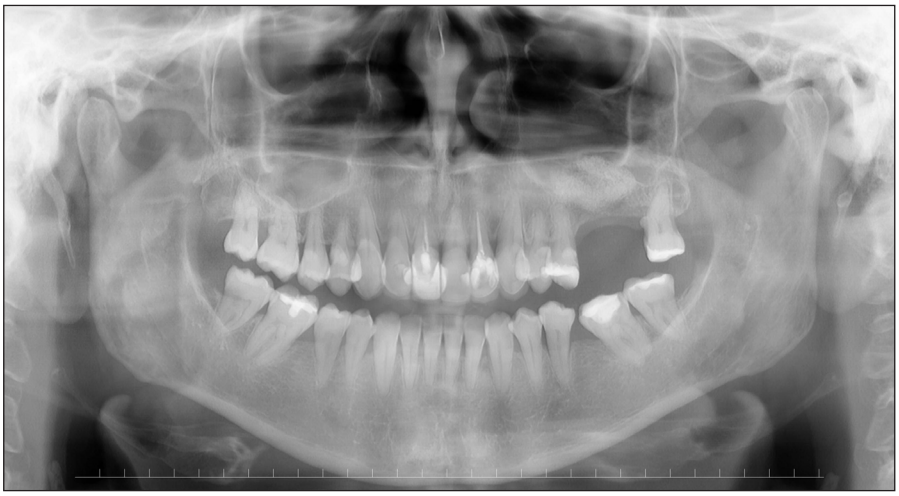

Figure 2 Orthopantomograph after sinus augmentation

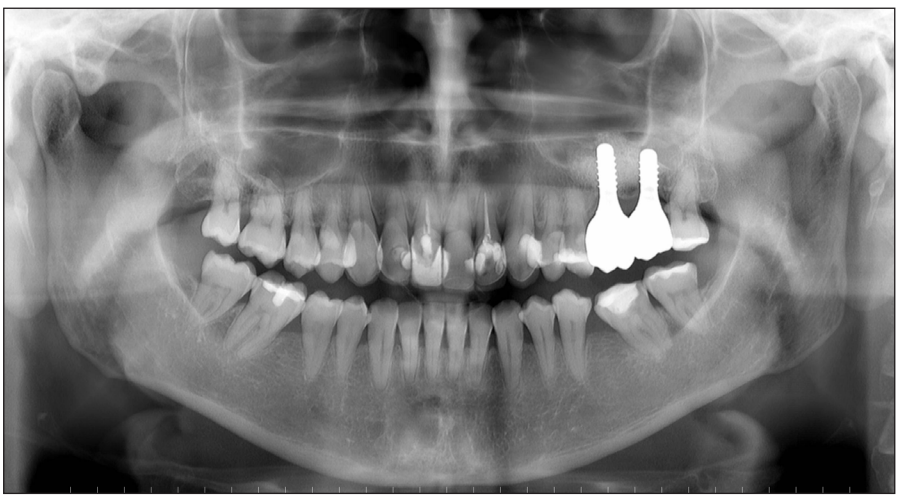

Figure 3 Orthopantomograph after implant placement

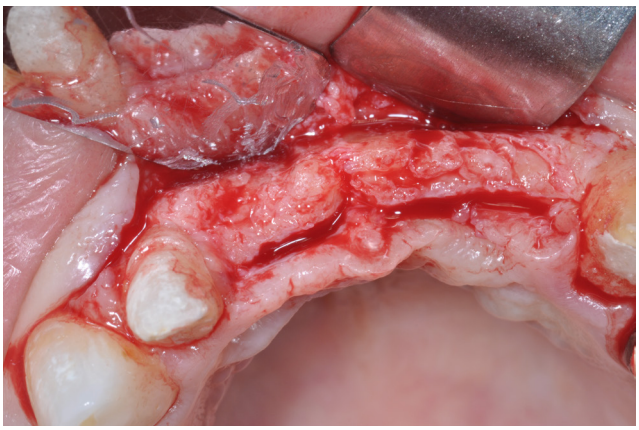

Figure 4a Full thickness flap

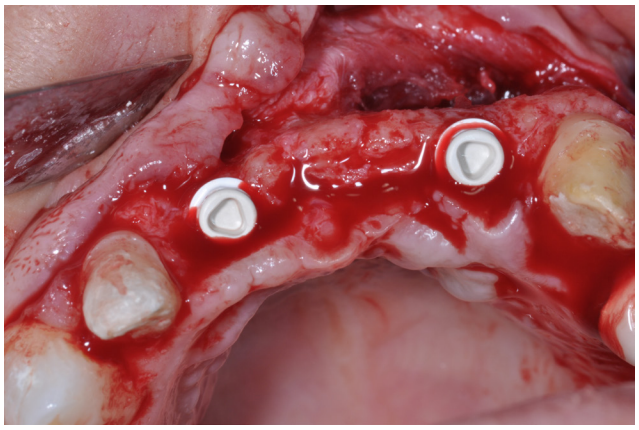

Figure 4b Placement of two-piece zirconia implants

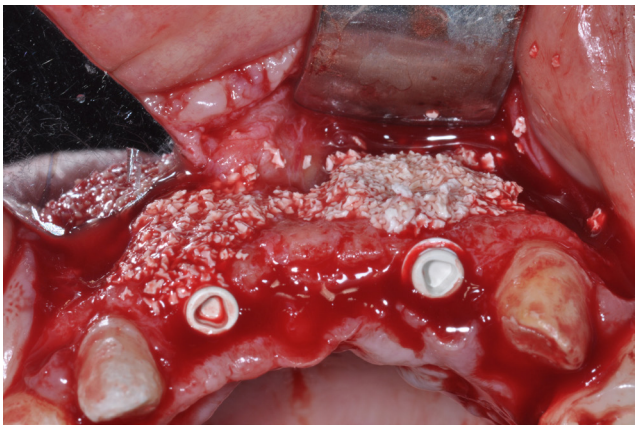

Figure 4c Bone graft

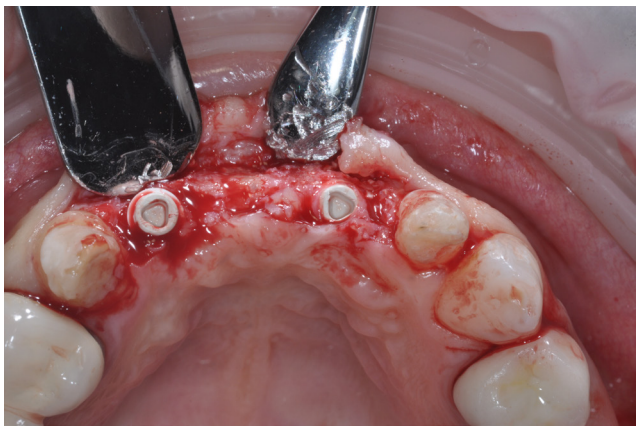

Figure 4d Re-opening

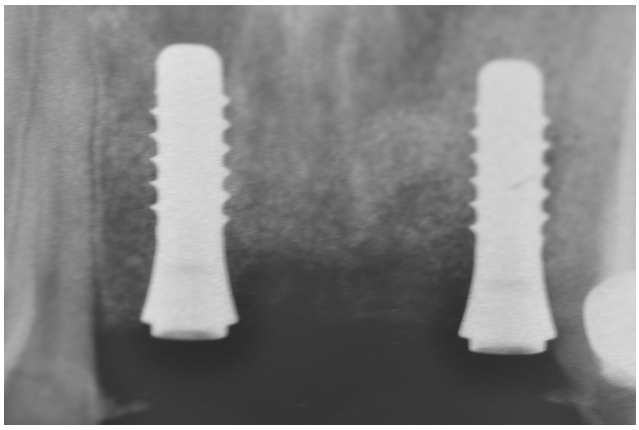

Figure 4e Intraoral radiograph of zirconia implants

titanium implants at a 24-month follow-up. Similar values have also been reported by Cionca et al., (17) which showed a survival rate of 87% just for zirconia on patients monitored for 588±174 days.

The clinical success of two-piece zirconia implants was also evaluated in a retrospective survey conducted by Jank et al. (18), in which they examined the data for implant replacement under guarantee by a well-known implant brand. The period investigated, between 2010 and 2014, examined three generations of two-piece implants. The results of this study reveal that two-piece zirconia implants have competitive success rates. The success rate has progressively increased, with initial levels higher than 96.7% in the first generations, up to levels exceeding 98.5% in the latest generations.

Implant designs

As with titanium implants, the same implant morphological principles apply to implants in zirconia. The ideal shape for an implant is cylindrical (Figure 5) or slightly conical (Figure 6) and it must also have a thread along its surface to distribute the axial load at the implant head along the entire thread. Thus, each thread contributes to resisting and supporting the occlusal load while the apex is orthogonally opposed to it. The implant's ability to withstand occlusal load enables its long-term survival without loss of osseointegration. This implant shape, however, does not dissipate well the oblique forces that are concentrated at the implant apex and neck. In fact, it is necessary to ensure prosthetic designs that redirect occlusal forces in a vertical/axial direction.

Two-piece zirconia implants are available in both

Figure 5 Cylindrical zirconia implant

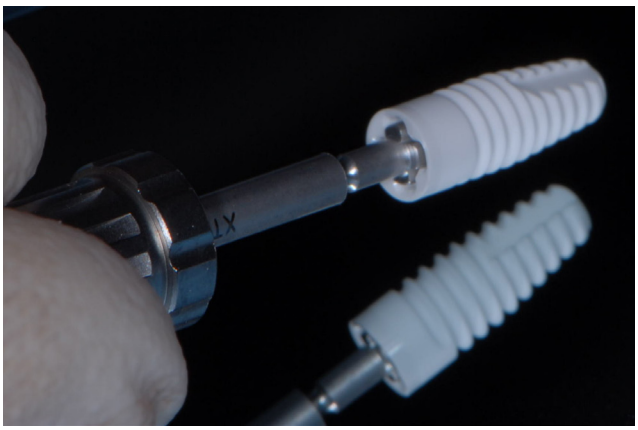

Figure 6 Conical zirconia implant

the cylindrical version (Straumann® Pure Ceramic, Straumann AG, Basel, Switzerland; Z3c/Z3s Z-Systems AG, Oensingen, Switzerland; Zeramex® P6, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland; TAV Zirconia two-piece implant, TAV Dental Germany GmbH, Hamburg, Germany) and conical (Ceralog® Hexalobe, Camlog Biotechnologies AG, Basel, Switzerland) and are threaded along the entire submergeable surface.

Some commercially available implants also have cylindrical-conical models (Zeramex® XT, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland; NobelPearl, Nobel®, Nobel Biocare Italiana, Vimercate; SDS 2.0, SDS Swiss Dental Solutions AG, Kreuzlingen, Switzerland).

Screw or cement-retained abutment?

As already mentioned, in the two-piece system, the implant can be connected to the abutment in two different ways: screwed or cemented. The screwed connection method involves a connection screw between the implant and the abutment that can be made of titanium, gold, PEEK or carbon-PEEK.

Gold and titanium screws are found in some types of two-piece zirconia systems (Ceralog®, Camlog Biotechnologies AG, Basel, Switzerland; TAV Zirconia two-piece implant, TAV Dental Germany GmbH, Hamburg, Germany; Z3s Z-Systems AG, Oensingen, Switzerland). Using implants with these screws means that the restoration cannot be defined as completely metal-free, although it should be specified that the metal connection screw is not in direct contact with the patient's tissues.

The carbon-PEEK screws (Figure 7) are made of carbon fibre reinforced PEEK (Vicarbo®, Dentalpoint AG, Spreitenbach, Switzerland). This material is not radiopaque, with an elastic modulus >160 GPa, flexural strength >1100 MPa, tensile strength 2000 MPa and is biocompatible according to ISO10993. Its specific feature is in its intrinsic structure as the carbon fibres are continuous and go in a longitudinal direction (60% CF) and are held in a matrix of PEEK (Polyetheretherketone 40%). This provides a significant clinical advantage in the tightening of the screw which, thanks to the presence of longitudinal and continuous carbon fibres, adapts to the internal thread of the implant and significantly contribute to dissipate stresses and tension forces.

However, such adaptability comes with the disadvantage of the carbon-PEEK screws being indicated only for single use therefore they are guaranteed by the manufacturer only for a one-time tightening of the screw. The recommended maximum tightening torque is not to exceed 25 Ncm and, as previously stated, it is recommended to use the screw only once.

Several two-piece systems involve the use of carbon-PEEK connection screws (Zeramex® P6 and XT, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland; NobelPearl, Nobel®, Nobel Biocare Italiana srl, Vimercate, Italy).

The use of screws in a material different from zirconia can be a critical point of implant restoration, since stress areas can be concentrated in the connection point with the screw. Carbon-PEEK connection screws have proven to be able to better withstand the tension forces thanks to their intrinsic adaptation capacity.

A study conducted by Spies et al. (19) corroborates the stability under stress of the carbon-PEEK connection screw. In this article, systems with a carbon-PEEK connection screw were evaluated together with control groups subjected to cycles of hydrothermal aging (85° for 60 days) and to dynamic load cycles (for 107 days). The results of this work showed that the carbon-PEEK screw has a good clinical reliability, even under stress.

Another common problem of all the systems that involve a connection screw is the possibility that it can become unscrewed. In order to avert this risk, some two-piece zirconia implants have a pre-mounted clamp wedge that is located inside the

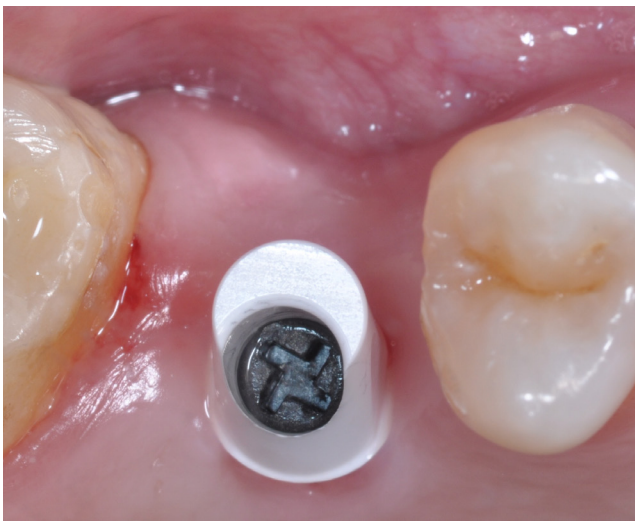

Figure 7 Abutment with carbon-peek screw

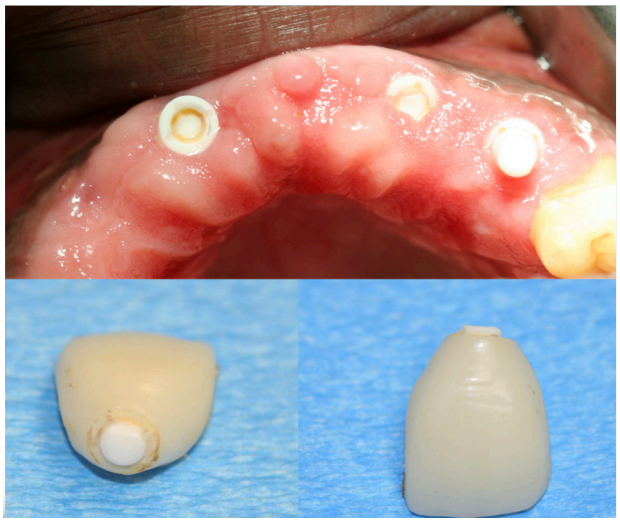

Figure 8 Fractured cemented abutments

implant and keeps the screw fixed to the abutment. In this type of implant, the manufacturer claims a lesser risk of screw loosening (Z3s Z-SYSTEMS AG, Oensingen, Switzerland).

With regards to abutment-implants connections by means of luting cements for two-piece zirconia implants, joining the abutment to the implant require the use of a resin modified glass ionomer cement preceded by decontamination and priming of the surfaces. This implant type allows the two-piece to be treated in a similar way to the one-piece type. Cements recommended for luting differ according to the manufacturer's indications but generally belong to two categories: glass ionomer cements (KetacTM Cem, 3MTM Espe, 3M Italia S.p.a, Pioltello, Italy) and resin cements (PanaviaTM 2.0, Kuraray, Kuraray Europe GmbH, Hattersheim, Germany; RelyXTM Unicem, 3MTM Espe, 3M Italia S.p.a, Pioltello, Italy; Els cem, Saremco Dental, Saremco Dental AG, Rebstein, Switzerland).

The operative phases concerning the cementation are very simple, which means it can be used even by less experienced operators. However, this type of connection has some disadvantages, specifically because of cementation. One of the main disadvantages is the risk of excess cement which can be very difficult, especially if it is subgingival. In addition, the use of cements introduces critical issues related to the type of material used (product characteristics) and its clinical duration.

Since the decementation of an implant is a not infrequent complication, even for two-piece implants, the abutment may become detached from the implant owing to decementation.

Besides the detachment of the abutment, the greater problem lies in the fact that, in the initial phases of decementation, there are micro-movements of the structure. These, by creating areas of stress, can lead to fractures in the implant structures and/or the abutment (Figure 8).

There are no reports available in the literature on the loss of retention of the abutment for two-piece implants with cemented abutments using self-curing resin cements (16,17). However the authors have observed the above-mentioned incidents clinically in private practice. In addition, in order to increase the stability of the connection, abutments have recently been introduced that have a ring in PEEK at the base (Zeralock™ PEEK ring, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland). These abutments used on two-piece implants with dedicated internal morphology (Zeramex® T Zeralock™, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland) enable mechanical fixing by a rotational movement of 60°.

Of particular interest are the systems that involve a combination of the two connection techniques, as they require both a micro clamping screw and cementation (SDS2.0, SDS Swiss Dental Solutions AG, Kreuzlingen, Switzerland). These micro screws can be made of titanium, gold or PEEK (in the case of patients with metal allergies). The tightening for the titanium and gold micro-screws must not exceed 15 Ncm, while for the PEEK micro-screws it must not exceed 5 Ncm.

Every effort is made to avoid a micro-gap during cementation of the abutment, but it is not always achieved. To reduce the presence of a micro-gap, some implants have a designed space at the implant-abutment juncture which is created to form a hermetic seal. This is brought about by inserting the cement of the fixed prosthesis, which combines with the cement of the abutment and creates a seal that according to the manufacturer is supposed to limit

Figure 9 Two-piece zirconia implant with quadrilobate internal connection

bacterial infiltration (Z3c Z-SystemS AG, Oensingen, Switzerland).

With regard to abutment fractures, the fracturing of the abutment has been recorded in only a few clinical studies (17, 20,) and, when it occurred, the fracture line was located at the base of the connection (17). Unfortunately, in some of cemented abutment cases the fracture takes place at the base of the abutment as it transitions into the implant. The cemented portion of the abutment remains cemented within the implant and removal often leads to destruction of the internal connection portion of the implant.

Implant connections

The abutment-implant connection is an important variable in the distribution of mastication loads from the prosthesis to the bone-implant interface (Figure 9). Unfortunately, the connection is a point of discontinuity and weakness in the system. Ideally, a connection should be:

- precise (to guarantee the maximum possible seal between abutment and implant in order to minimize the possibility of bacterial adhesion and proliferation);
- stable (to ensure adequate resistance to mastication stresses, the two connected components must not be allowed to move against each other, whether these are rotary torsion or bending movements);
- simple (to ensure maximum practicality of use for the clinician both during surgery and when loading the prosthesis).

The implant connections for zirconia implants, like for titanium implants, are currently divided into the following types.

- External hex connections (Zeramex® P6, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland).
- Internal hex connections (Ceralog® Hexalobe, Camlog Biotechnologies AG, Basel, Switzerland; W Zirconia two-piece implant, TAV Dental Germany GmbH, Hamburg, Germany).
- Internal multi-lobe connection (NobelPearl, Nobel®, Nobel Biocare Services AG, Kloten, Switzerland; Zeramex® XT, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland).
- Internal cone connection (Z3c Z-Systems AG, Oensingen, Switzerland; SDS® 2.0, SDS Swiss Dental Solutions AG, Kreuzlingen, Switzerland).
- Internal square connection with parallel sides (Straumann® Pure Ceramic, Straumann AG, Basel, Switzerland).

The external hex connections have an external hexagon at the neck of the implant with an anti-rotational function. The cylindrical base of the abutment rests on the edge of the implant. Hexagonal indexing guarantees a solid anti-rotational protection and a safe and simple positioning of the abutment.

External connections allow in some cases the simplified engagement of the implant in several possible positions (Zeramex® P6, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland) and also, for the prosthetic stages, they allow an indirect capture of the impression free of tension.

In the connections with internal hexagon, the walls of the implant neck are flared towards the inside and end with an anti-rotational hexagon. The internal hexagon allows the diffusion of the forces tangentially and provides good anti-rotational stability (Ceralog® Hexalobe, Camlog Biotechnologies AG, Basel, Switzerland).

The internal four-lobed connections facilitate the correct positioning of the implant as the four retention elements in conjunction with the four abutment hooks enable the abutment to be easily positioned (NobelPearl, Nobel®, Nobel Biocare Services AG, Kloten, Switzerland; Zeramex XT, Zeramex®, Dentalpoint AG, Spreitenbach, Switzerland).

In the internal cone connections (Z-System® Z3c, Z-Systems AG, Oensingen, Switzerland; SDS® 2.0, SDS Swiss Dental Solutions AG, Kreuzlingen, Switzerland) the abutment, whose profile is tapered, is inserted into the housing inside the implant, becoming an integral part of the implant by means of a conical coupling. However, it does not have an anti-rotational function and can lead to serious complications in the event of fracture.

In the internal square connections, there is a flat-to-flat connection, which increases its stability at the expense of prosthetic flexibility. They are also characterised by the presence of a rotational block and an internal thread for fixing the provisional and final components (Straumann® pure Ceramic, Straumann AG, Basel, Switzerland).

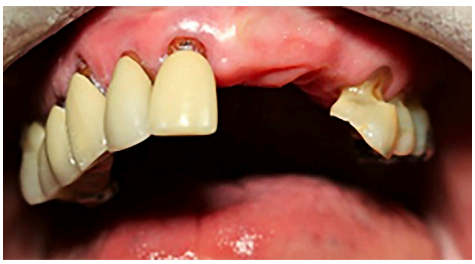

Figure 10 Initial situation

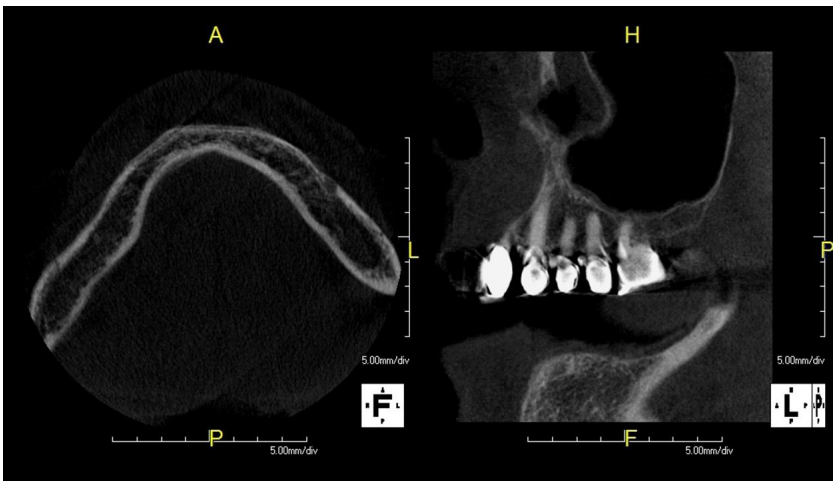

Figure 11 Cone beam CT scan

Implant surfaces

The surfaces of ceramic implants have been constantly evolving over the years, which has been necessary to achieve higher performance characteristics for improved osseointegration.

It is known that osseointegration of titanium implants is increased by altering their surface, and therefore it has been hypothesised, tested and proven that this effect could also occur on zirconia implants.

The first in vivo and in vitro trials (21,22) took into consideration the surface changes of zirconia in order to evaluate their effect on the osseointegration ability and on the mechanical characteristics of the biomaterial.

The most frequently used zirconia surface treatments involve mechanical and chemical subtractive processes. Mechanical modifications include machining processes and sandblasting processes, while chemical ones include etching processes. In general, chemical treatments lead to an improvement of the morphological alterations since, in topographic terms, they create a more uniform surface than just sandblasting. Sandblasting processes can be performed using different materials; currently the material most used is aluminium oxide. Sandblasting with aluminium oxide in Y-TZP implants, performed before the sintering process, this manufacturing sequence protects the zirconia from transforming from the tetragonal phase to the monoclinic phase therefore avoiding to undermine its physical properties. In their guidelines, Wennerberg and Albrektsson stressed the importance of using several parameters to increase the roughness of an implant (23,24). This aspect is justified by the fact that using only one parameter fails to guarantee an adequate spatial distribution in the surface topography. For this reason, it has been noted that the use of both processes (chemical and mechanical) provides a greater increase in the bone adhesion and proliferation on the implant surface. In detail, sandblasting ensures an adequate bone adhesion, while acid etching evens out the topography of the implant, smoothing the peaks. In fact, a recent study has observed a superior bone bonding around sandblasted and etched implants compared to those that had undergone sandblasting treatment only (25). However, it is important to underline that while both treatments improve the maintenance of osseointegration they do not increase its speed: it is not possible to establish which of the two treatments has a greater effect on bone growth.

The growth of osteoblasts on these implant surfaces treated both chemically and mechanically has been widely documented (18).

A study conducted by Gahlert et al. (6) confirmed that the increase in the rough surface of sandblasted and etched zirconia implants has an important influence on bone integration and bone stability. A greater torsion strength during removal was also noticed.

The latest generations of systems have seen the entry of LASER technology among surface treatments. The results of these treatments not only determine a rough thread, but also allow to achieve an optimal degree of roughness at microscopic and macroscopic level (2-3 μ) (26).

Of the various types of laser usable for this treatment, a study conducted by Delgado-Ruíz et al. proposed the use of femtosecond laser as a valid alternative (27). However laser surface treatment of zirconia is known to adversely compromise the structural stability and integrity of zirconia by accelerating the transition of the materials from tetragonal to monoclinic.

Full-arch restoration with two-piece zirconia implants

When dentists perform implant therapy for teeth replacement in full-arch indications, not only do they restore form and function, but also improve the quality of life for the patient. Full-arch implant rehabilitation techniques use a minimum of four implants per arch to treat complete edentulism. The

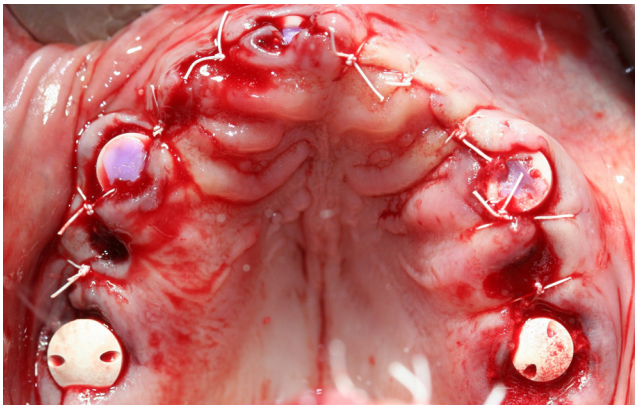

Figure 12 Surgical phase

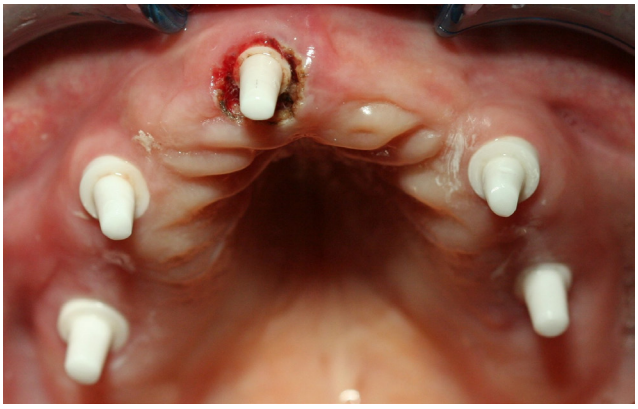

Figure 13 Cemented abutments

full-arch restoration treatment concept was pioneered by Malo and colleagues. (28,29,30). For a rapidly aging and health-conscious population, the need for replacement solutions of missing teeth is growing as well as the request for alternative methods and materials that are more flexible and safer (31,32). By providing a fixed implant prosthesis, we can positively impact these patients' lives (33) with a restoration that mimics the appearance and function of natural teeth while avoiding the morbidity of bone loss and poor nutrition. Whether they are requesting treatment for ill-fitting, poorly functioning removable prosthetics or a long-term solution for terminal dentition, these patients experience discomfort, diminished chewing capability (34), suffer from digestive problems, malnutrition and low self-esteem as a result of their condition. After decades of successful (35,36,37,38,39) single implant to full arch rehabilitations with titanium implants, there is scientific evidence that they are prone to corrosion which results in the release metal ions in peri-implant tissues and are now seen as a significant contributor to the occurrence of peri-implantitis (40, 41) There are also increased reports of titanium sensitivity and the mechanism of its occurrence (42).

This paper is to show two case reports that demonstrates the possibility and feasibility of full-arch implant restorations with two-piece zirconia implants. All cases were treated with a traditional approach were no immediate loading of the implants was done. Patients received soft-relined immediate dentures which were relined periodically during the osseointegration period. Once the permanent prosthetics phase started, the removable dentures were either duplicated or new teeth set ups and wax try-ins were done in order to improve aesthetics, occlusion and fit. The zirconia frameworks and permanent prosthetics were designed and milled based on the wax teeth set up.

Case report 1 had a three-year follow-up, while the second case was evaluated up until 18 months.

Case report 1
Cemented two-piece zirconia ceramic implants for full mouth rehabilitation

An 82 years old female presented partially edentulous maxilla and a fully edentulous mandible. She stated that she tried to wear removable partial and full dentures over the years, but they made it difficult for her to sing at church and socialize confidently. Furthermore, a few years earlier she had poor response to her hip and knee replacement implants, her preference was to have her teeth replaced with ceramic implants and a metal free hybrid prosthesis. The remaining maxillary teeth were non-restorable (Figure 10) and the mandibular ridge presented moderate resorption of bone. A cone beam CT scan was obtained and reviewed to assess bone levels and anatomy as well as critical anatomical structures such as maxillary sinuses, mandibular canal and nerve (Figure 11). Alternative treatment options were presented however she opted for fixed maxillary and mandibular full arch reconstruction on ceramic implants. Immediate dentures were fabricated and duplicated to make a surgical guide. A two-phased treatment plan was put in place with extractions of the remaining maxillary teeth, immediate implant placement in both arches and soft reline both maxillary and mandibular immediate dentures. Surgical planning was done on a computer using the native software of the Prexion 3D CBCT scanner. The patient returned for surgery, a consent form was obtained, local anaesthesia was administered across the maxillary arch by infiltration and bilateral posterior superior alveolar blocks. Local infiltration was the method used for cross-arch local anaesthesia of the mandible. Cross-arch and intra-sulcular incisions were made in the maxilla and mandible with a midline release. Alveolar bone was exposed, and extractions of all remaining teeth were done sequentially from the left to the right in the maxilla and moderate alveoloplasty of the mandibular bone.

Five two-piece ceramic implants were placed in the maxilla according to the manufacturer surgical protocol

and under profuse irrigation (figure 12). Insertion torque value for all implants was in the range of 20 to 25 Ncm and all implants showed good clinical primary stability. The same protocol was followed for the mandibular implants and four implants were placed with similar insertion torques and primary stability observations. The patient was followed up after two weeks for suture removal and periodically for sixteen weeks.

Five months post implant placement the implants were uncovered with a diode laser where needed. Implant stability had to be subjectively evaluated since there is no device designed to measure the stability of two-piece ceramic implants with cementable abutments. After thorough cleaning, decontamination and priming of the abutment and abutment space of the implant, both maxillary and mandibular abutments were cemented to the implants with a resin modified glass ionomer cement (Fuji GC cement). (figure 13) Conventional impressions were made using polyvinylsiloxane heavy and light body with the closed tray technique and sent to the dental laboratory where they were digitized. The temporary prosthesis was designed and milled in PMMA material. The PMMA temporary prostheses were provisionally installed on both arches after fit and occlusal adjustments were made. (Figure 14)

The patient wore the provisional prosthetics for four months during which aesthetic and occlusal adjustments were made. Once it was determined that the patient had adjusted to and was comfortable with the provisionals, they were scanned and duplicated in a zirconia framework which was manufactured with CAD/CAM milling technology. Only the anterior teeth areas from Canine to canine were cutback for subsequent application of lithium disilicate porcelain. The posterior areas of the prosthesis were full contour. A try-in of the framework was done to verify and confirm passive fit to the implant abutments on both arches. The frameworks were returned to the laboratory for overlay of pressed ceramic on the anterior section of both prostheses. After minor occlusal adjustments, the all-ceramic porcelain fused to zirconia cementable hybrid bridges were bonded to the implant-abutment assemblies following the previously described cementation protocol (Figure 15). The patient has been followed up for the last three years and there have been no complications to date.

Case report 2

Screw-retained full mouth rehabilitation with hybrid: two-piece ceramic implants

A 59-year-old male presented partially edentulous with severe collapse in the vertical dimension of occlusion. Most teeth were periodontally involved or fractured

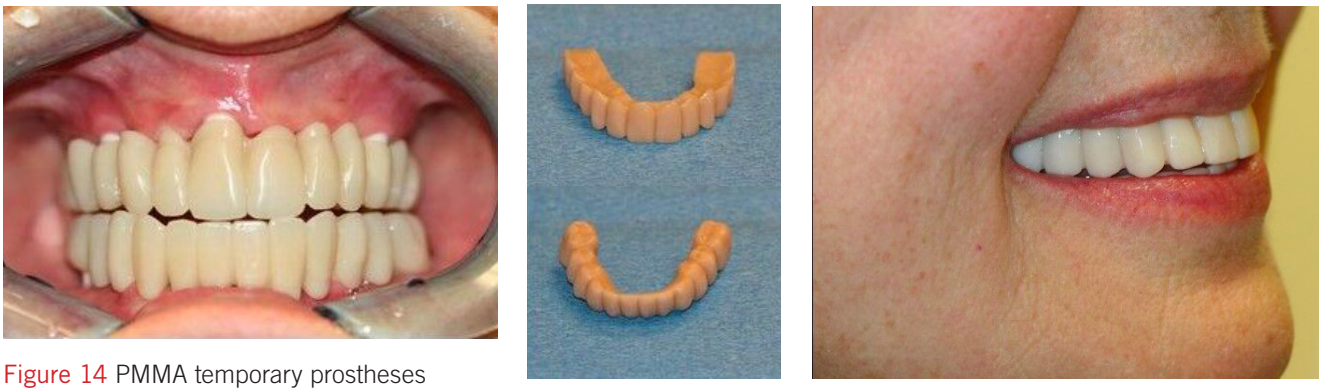

Figure 14 PMMA temporary prostheses

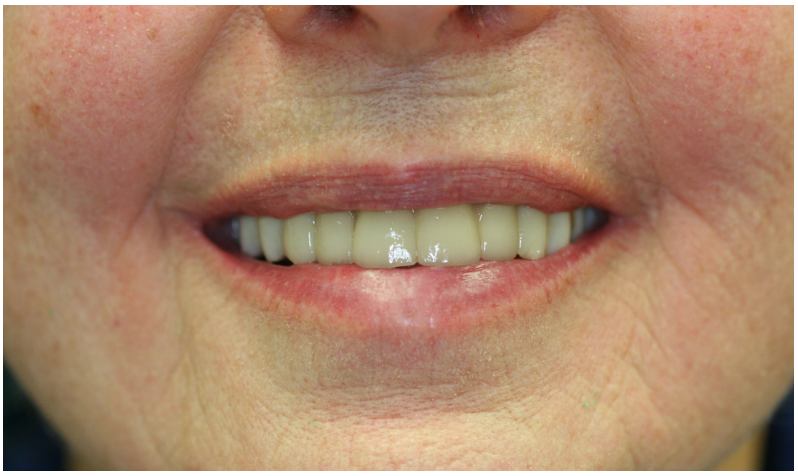

Figure 15 Final rehabilitation

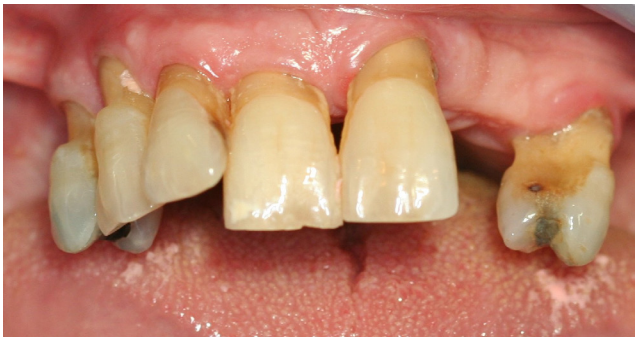

Figure 16 Clinical view of the upper arch

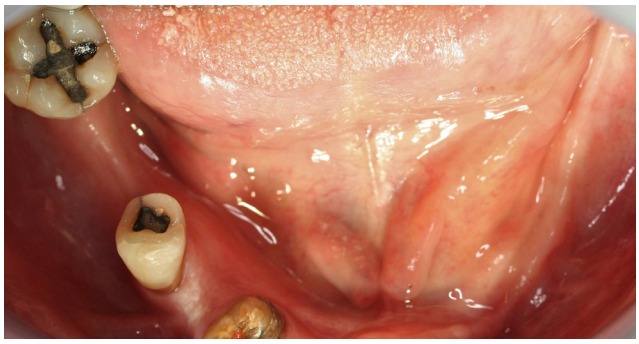

Figure 17 Clinical view of the lower arch

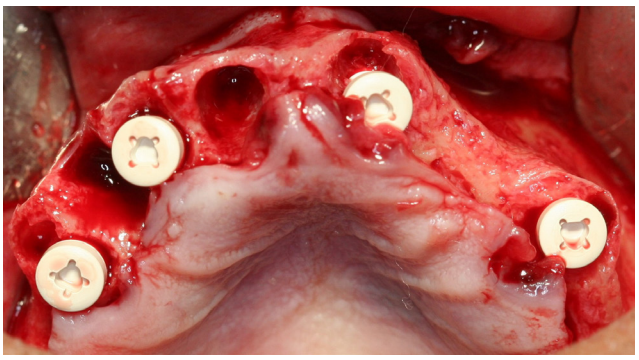

Figure 18 Intraoperative view of the maxilla after implant placement

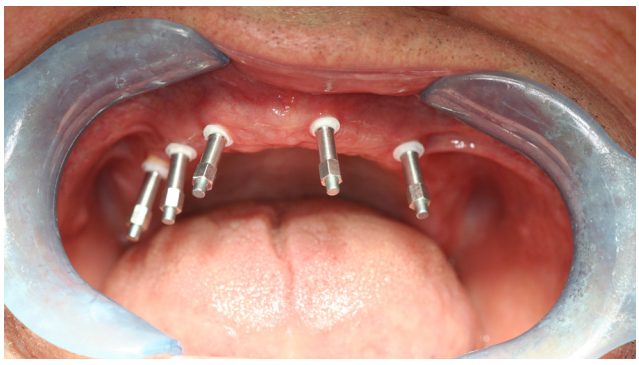

Figure 19 Implant stability measurements

at the gingival level. The periodontally involved teeth had mobility type II with moderate to advanced bone loss and gingival recession (Figure 16). Only three mandibular teeth were present (Figure 17) with no teeth remaining in the left quadrant and moderate to advanced vertical bone loss. A cone beam CT scan was obtained and reviewed to assess bone levels, anatomy as well as critical anatomical structures in the areas of planned implant placement. The patient had difficulty wearing removable appliances, has a severe gag reflex and requested a metal free fixed solution to replace his teeth. Alternative treatment options were presented including overdentures on four ceramic implants. The patient opted for maxillary and mandibular fixed full arch screw-retained prosthetics using zirconia ceramic implants. A two-phased treatment plan consisting initially of full arch extractions, immediate implant placement in both arches and soft reline immediate dentures for both arches. The patient returned for surgery, a consent form was obtained, local anaesthesia was administered across the maxillary arch by infiltration and bilateral posterior alveolar blocks. For the Mandible anaesthesia was administered by means of cross arch local infiltration. Extractions of all remaining teeth was done atraumatically using periotomes and taking care to preserve the buccal plates on both arches.

Five two-piece ceramic implants were placed in the maxilla as well as in the mandible (Figure 18). The manufacturer surgical protocol was closely followed. Insertion torque value for all implants was 25 Ncm and all implants showed good initial clinical primary stability. However, one of the mandibular implants failed to osseointegrate and was removed two months after placement. The patient elected not to have it replaced with another implant.

Four months post-surgery the implants were uncovered as the soft tissue above the implants cover screws was removed with a diode laser where needed. The smartpegs specifically designed for the implants were screwed into the implants and stability measurements were made using resonance frequency analysis technology (Figure 19) . This modality has been well proven and documented to assess implant stability and readiness to be restored. The Osstell device was used to measure the implant stability level for each implant after four months of healing time (Osstell, Integration Diagnostics, Gothenburg, Sweden)

All implants returned average Implant Stability Quotient Values (ISQ) values above 74. Given that the acceptable value range for safe loading of dental implants (43) is between 55 and 85, it was determined that the implants were ready for loading with permanent fixed prosthetics. Conventional Impressions were made using polyvinylsiloxane heavy and light body with the closed tray technique.

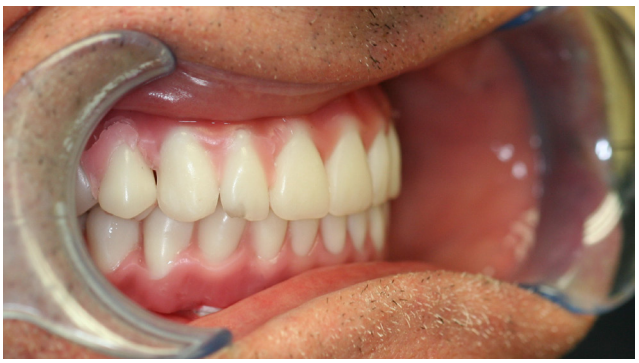

Figure 20 Wax try-in

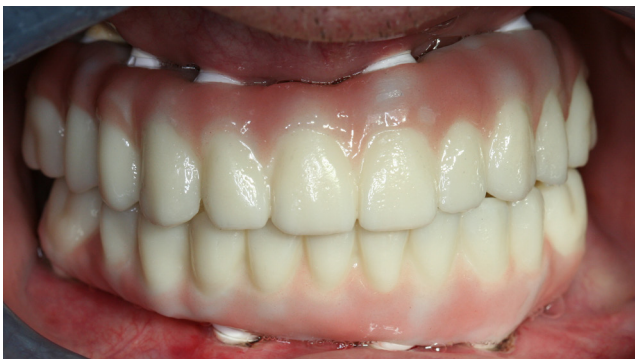

Figure 21 Final full mouth rehabilitation

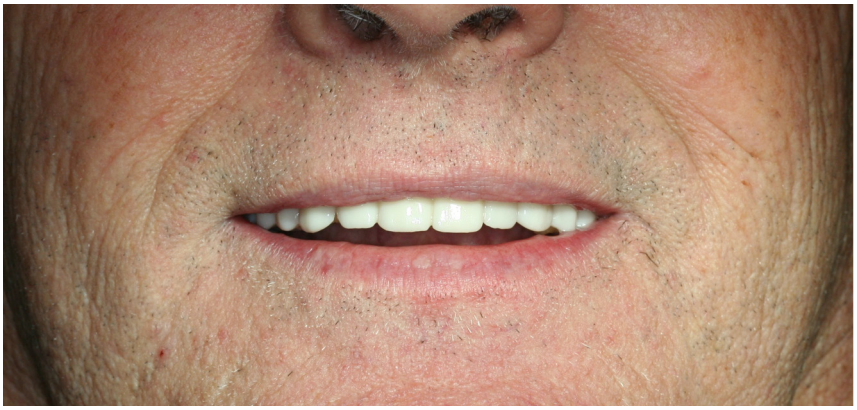

Figure 22 IFinal full mouth rehabilitation

The fabrication of a hybrid prosthesis was started by going through the process of making a conventional denture. Wax rims, wax try-in were done for space analysis, occlusion, speech and aesthetics (Figure 20). Once the waxed prototypes were approved, multiple clinical photographs and bite registration records were taken for effective transfer of information with the dental laboratory. The zirconia prosthesis framework was manufactured with CAD/CAM technology after scanning of the wax-up prosthesis. A try-in of the framework was done to verify and confirm passive fit to the implants on both arches. The frameworks were returned to the laboratory for overlay of pressed ceramic. The screw-retained all-ceramic porcelain fused to zirconia hybrid bridges were connected to the implants. The abutment screws were initially tightened to 15Ncm then after occlusion was checked and adjusted where needed they were all tightened up to a final torque of 25 Ncm. The patient has been followed up periodically for the last eighteen months and there have been no complications to date (Figure 21 and Figure 22).

Conclusion

Full mouth rehabilitation with two-piece screw-retained ceramic implants is an option. The evolution of ceramic implantology has led to the introduction of two-piece implants, in response to the growing demand for metal-free restorations and to the demand for an alternative that would allow its use in cases where single-piece types in zirconia were not suitable. For example, two-piece implants are indicated in cases where ideal implant parallelism is difficult to achieve, poor bone quality (bone type D3/D4), partial edentulism, restoration of the posterior quadrants, regenerative therapy, operative difficulties in implant insertion and in full-arch restoration of edentulous patients.

With the aging population, the reliability of dental implants, the comfort and convenience of oral rehabilitation with fixed prosthetics has led to an increase in requests by patients for full arch and full mouth rehabilitation on dental implants. As a result, clinical situations where patients want metal free teeth replacement are becoming more and more comprehensive and complex. Since patients have increasingly become knowledgeable, sophisticated and health conscious, there has been a rise in requests for metal free alternatives of teeth replacement. Ceramic implants which are well proven to be stable in the oral environment and highly biocompatible perform as well as their titanium counterparts. The two cases presented in this paper show that two-piece ceramic implants can

be implemented in complete arch and full mouth rehabilitations. However, it should be noted that case selection and rigorous treatment planning are crucial for the success of such rehabilitations.

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