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December 2020

Full mouth rehabilitation using a complete digital workflow: a case report

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Sammy S. Noumbissi, DDS MS

Dear Colleagues,

I first want to thank the authors who despite the difficult times were willing and able to contribute significantly and to make this issue a reality. Since the release of our first issue the world has changed a lot and we are all facing multiple challenges.

Whatever the situation, the patients we serve still have needs and desires and continue to call upon us to continue to deliver the highest level of care. As a matter of fact, the COVID-19 pandemic news coverage and the limited movement imposed have given patients a lot of time and opportunity to think about their lifestyle, health, and treatment modalities they are willing to consider. Being confined for many weeks they had time to perform all types of searches on health and other topics. As a result, many practices have seen reluctant or on-the-fence patients calling offices making specific requests in terms of therapeutic modalities and techniques; implant dentistry has not been an exception to this trend.

This issue contains clinical articles by members of the academy who are sharing their clinical techniques, protocols, work, and experience with ceramic implants. Our contributors are a combination of academics and clinicians who are based in North America, Brazil and Europe. Of note and for the first time we have a publication submitted by a faculty and resident from New York University's Oral and Maxillofacial Surgery department on the increasingly growing concerns with titanium intolerance. We are very encouraged and honored by this contribution because the mission of the academy has always been to spread knowledge, understanding and the rationale behind ceramic implants beyond the academy's membership and followers.

The topics included in this issue are a clear indication of how far and how fast ceramic implants are establishing themselves in implant dentistry. Two-piece ceramic implants, full arch rehabilitation, aesthetic zone rehabilitation, guided surgery, immediate placement, immediate loading just to name a few are some of the many aspect of ceramic implantology presented.

I hope you enjoy this issue which by its content and the level of expertise of its contributors is contributing to making metal free ceramic implants a more widely accepted form of tooth replacement modality.

Cheers and Be Safe,

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Full mouth rehabilitation using a complete digital workflow: a case report

Schestatsky, R; Pohlmann, R; Finco CF; Noumbissi, S; Dutra, V;Beltrão, RG.

ABSTRACT

The use of digital tools for diagnosis, planning and execution of rehabilitative cases is a reality and is gradually moving conventional treatment planning steps to the digital environment. As these digital techniques emerge and improve, there are no well-established and standardized digital workflow protocols for dentists, radiologists, and dental technicians to achieve more predictable and optimized results, especially in complex cases which involve major dental and bone modifications. Therefore, the objective of this case report is to describe a consistent digital workflow, performed from one single consult where radiological examinations, images and intraoral scanning were obtained to a complete digital treatment planning performance on specific softwares. In this paper is presented a complete complex treatment where just one preoperative consult is necessary before surgical procedure.

Introduction

Implant rehabilitation is currently focused on the development of more predictable and resolutive protocols, seeking for a faster, more accurate and less invasive surgical intervention. The precision in the treatment planning and execution of implant surgery with immediate prosthodontic provisional loading leads to an effectively reduction of errors and clinical adjustment time during and after the surgical procedure. Thus, technology has become an indispensable ally in the planning of implant dentistry cases, allowing multidisciplinary planning among rehabilitators, surgeons, radiologists and laboratory technicians. Implantology has come to refine surgical and prosthetic techniques that allow the treatment of patients in varying degrees of complexity and, with the advent of digital planning platforms, the challenge is to reach a "stage of art" between all stages of digital planning and clinical execution.

Digital tools for planning, execution and design of surgical guides and dental restorations is an established reality well documented in the literature[9]. DSD planning, digital superimposing on computerized tomography (CT), 3D printing and CAD/CAM techniques are examples of tools that enable full digital workflow in implant rehabilitative treatments, as opposed to conventional techniques, like manual impressing and waxing[13,14]. Scanning techniques, dental software, and the CAD/CAM system have been reported in the literature to be effective[7] so the current challenge is to integrate all digital tools into a specific workflow by integrating all the factors that effectively could influence in achieving perfection on the clinical results.

Once these technological resources are constantly being introduced into implant dentistry, it is important for the clinician to dominate the digital planning/ execution workflow. The absence of established protocols and consensus regarding the application of these techniques can still generate errors or lack of precision in any of the digital workflow steps. Thus, this case report aims to present how a sequence of work using digital planning softwares can interact in the diagnosis, planning and execution of complex cases, and generate high predictability and accuracy.

Case report

The 63-year-old female patient sought care with aesthetic and functional complaints and the intention to replace her missing teeth from the upper arch (Figure 1).

After anamnesis and physical examination, imaging (tomography and intra-oral scanning) were performed. Digital photographs were taken for analyze the case on the DSD platform in a presentation software (Microsoft Power Point) to view a near-optimal two-dimensional dental configuration (Figure 2). This analysis evidenced a poor dental and alveolar position which, combined with the clinical conditions of the upper teeth, led to the decision for a treatment plan with full arch rehabilitation using dental implants.

Thus, the dental configuration obtained in 2D served as the basis for a specific software (Exocad) to design a dental and gingival arrangement in 3D, obtained on the patient's initial virtual models, properly aligned and superimposed. (Figure 3).

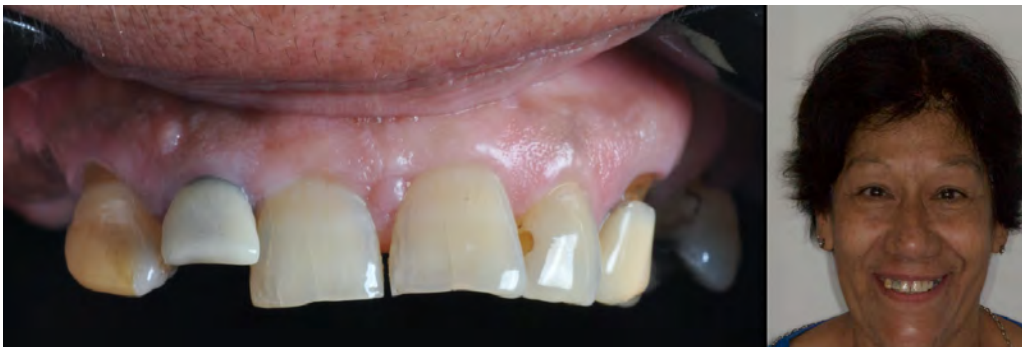

Figure 1:
Intra and extraoral initial condition.

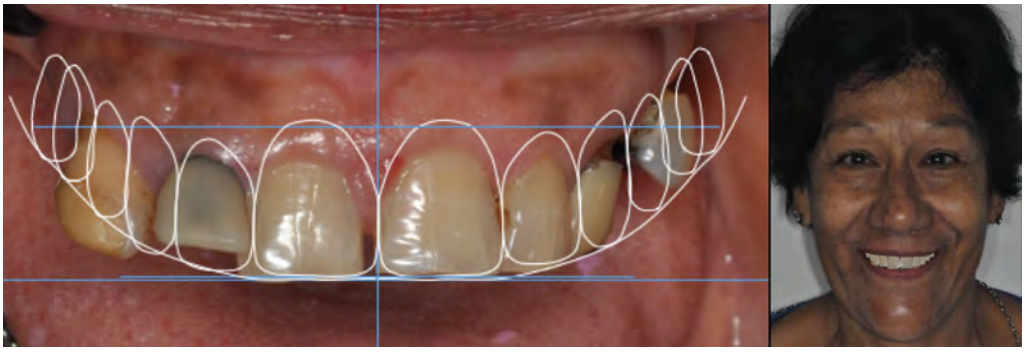

Figure 2:
2D planning in Microsoft Power Point program.

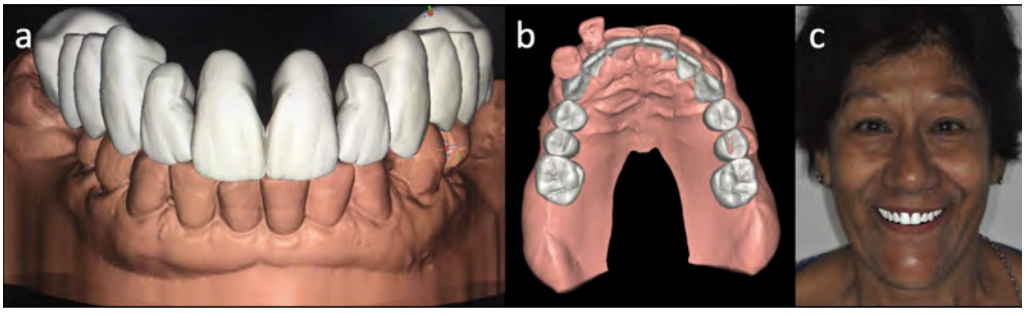

Figure 3:
a) teeth virtual design obtained from the 2D configuration;
b) obtained 3D design (white) superimposed on the initial model (pink);
c) simulation with extraoral photography.

This virtual dental model was then aligned on the tomography DICOM file (coDiagnostiX, Dentalwings, Montreal, Canada) for surgical planning of implant placement. At this stage it was found that, in order to arrive at the pre-established final prosthetic design, in addition to the installation of implants, considerable changes in the alveolar bone ridge would be necessary through osteotomies. Thus, the virtual models were manipulated in the software simulating the teeth extractions and osteotomies, transferring these bone reduction parameters to the generation of an Alveolar Reduction Guide (ARG) to guide the amount of alveolar bone tissue removal required for the installation of implants with a correct three-dimensional positioning. The ARG will contain fixation points for the next guide, designed for implant milling and installation called the Guide for Implant Milling (GIM) to be installed over the ARG, following the digitally produced model of the planned position of the future prosthesis. The GIM will be fully supported in the ARG and fixed with screws printed at the points in common between the two guides (Figure 3) and contains the metal sleeves of the chosen implant system (Straumann PURE Ceramic, Institute Straumann AG, Basel, Switzerland) with height H6.

Finally, the software also designed a guide for the installation of 4 anchor pins for positioning both ARG and GIM (Figure 4). This guide will be the first to be used and will only have the milling sleeves for the anchor pins of the next guides and, being supported by teeth, will provide greater accuracy for subsequent steps as the other guides will be installed after mucoperiosteal detachment of the alveolar ridge. Thus, 3 guides were designed to be used in sequence.

Upon completion of the guide designs, a provisional prosthesis was designed with virtual perforations of the implant positions determined in its structure. The guides were printed in SLA resin, and the provisional prosthesis milled in PMMA.

So, with the patient's written consent, surgery was performed to install the first guide for marking the anchor pin attachment points (Figure 5). After tooth extraction and mucoperiosteal detachment, the second guide for alveolar ridge reduction (ARG) was fixed at the bone marking position of the anchor pins previously established. With the help of drills, the alveolar ridge osteotomy was performed (Figure 6).

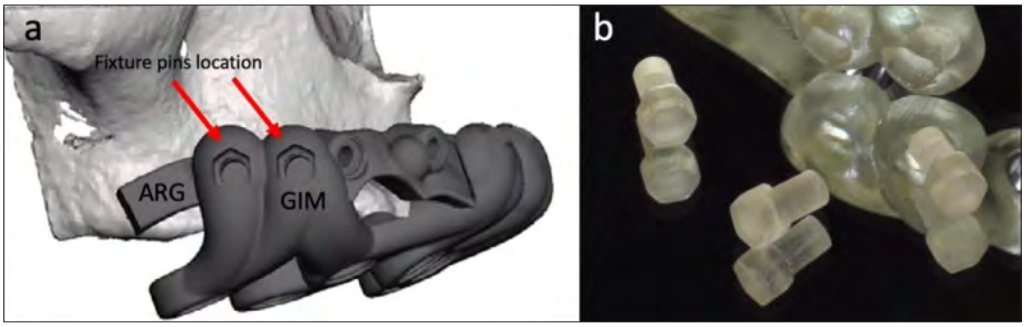

Figure 4:
a) overlapping ARG and GIM drawing;
b) printed fixing pins

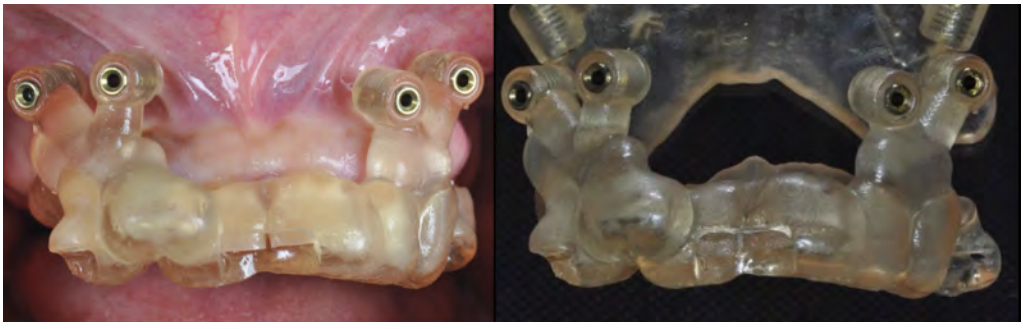

Figure 5:
Teeth supported Anchor Pin Guide

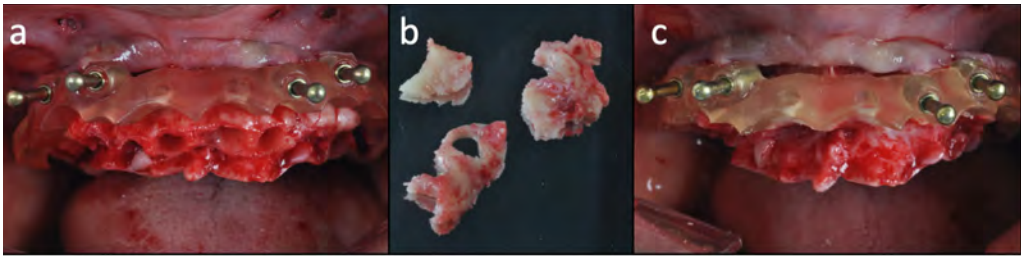

Figure 6:
a) Installation of the Alveolar Reduction Guide (ARG) following the position of the anchor pins;
b) and c) Osteotomy performed

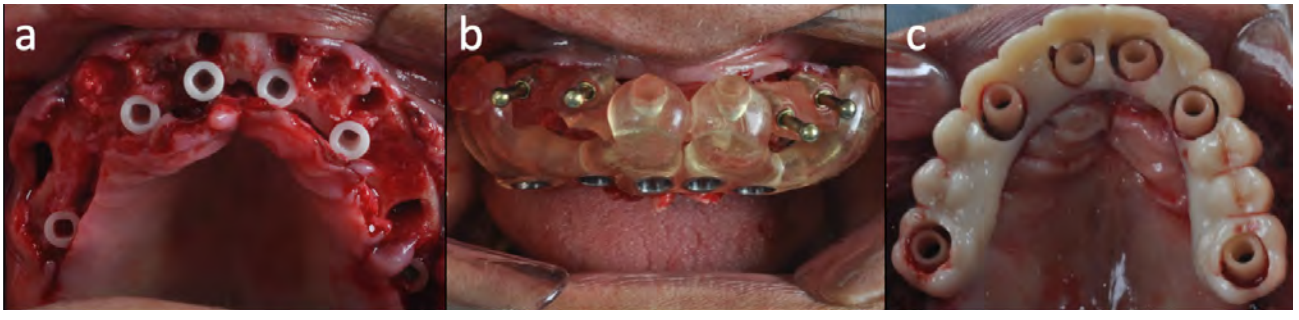

Figure 7: a) Guide for Implant Milling (GIM) positioned over the ARG;
b) Zirconia implants installed. Note the difference in implant positioning in relation to the pre-existing teeth alveoli;
c) PMMA temporary prosthesis precisely positioned over the temporary cylinders.

The third guide (GIM) was immediately positioned and fixed with the printed pins on the anterior guide, being used for the milling and installation of six 2-piece zirconia implants (Straumann PURE Ceramic, Institut Straumann AG, Basel, Switzerland) following surgical protocol established by the coDiagnostiX software and the manufacturer. The excellent primary stability obtained (greater than 45 Ncm) allowed the installation of the previously made immediate provisional prosthesis. The connection to the implants was made with the use of temporary PEEK cylinders, with bisacrylic resin (Protemp 4, 3M, São Paulo, Brazil) (Figure 7).

After suturing, occlusal adjustments were made, the medication and postoperative recommendations were passed, and the patient was released. The review appointment was made in 11 days, where it was found a great tissue response of the covered areas, as well as a total patient adaptation and satisfaction with the aesthetic result (Figure 8). After 60 days of gingival conditioning, the final aesthetic result is shown on Figure 9.

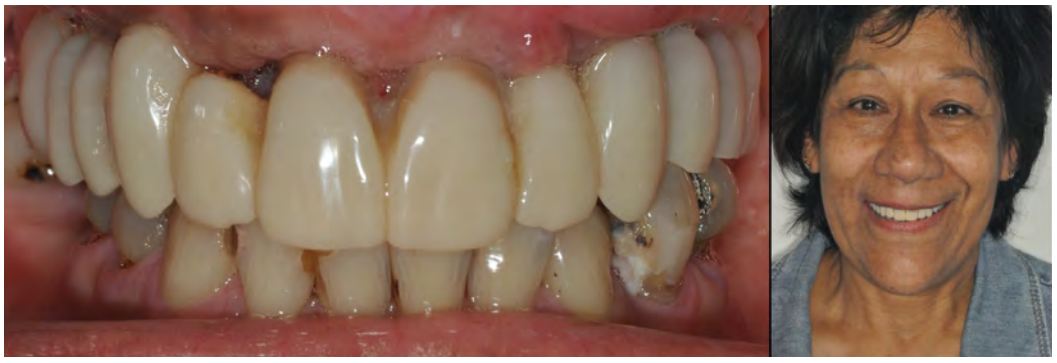

Figure 8:
a) Intraoral clinical appearance showing optimal tissue response at 11 days; b) Extraoral aspect of the provisional prosthesis accurately reproducing the virtual drawing of the teeth previously obtained in the planning software.

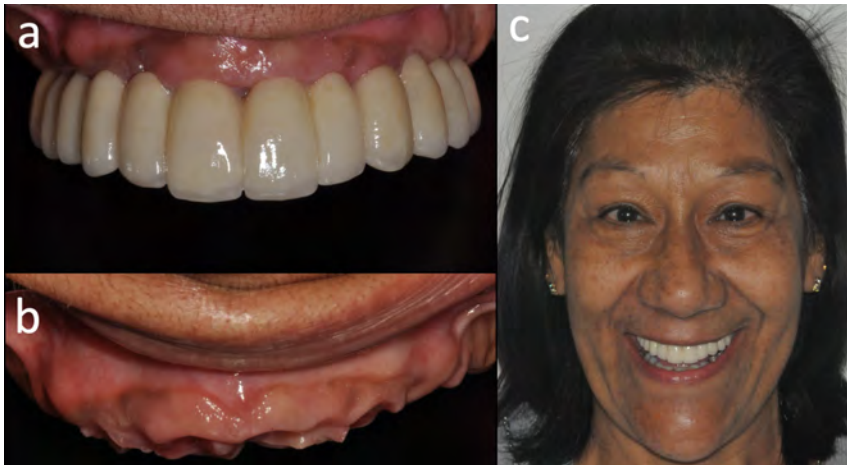

Figure 9:
a) Intra-oral aspect of the final full-zirconia prothesis and b) the gingival condition result; c) Extra-oral result of the treatment.

Discussion

Guided surgery for osseointegrated implant placement is already a reality in the clinical routines of many professionals, even those who do not follow a complete digital flow. This number of users has increased due to the advantages of guided surgery protocol such as: shorter surgical time, trans and postoperative comfort and precision in implant placing[1,6,21]. Even so, several factors have been listed in the literature with potential to influence the results, such as the quality of the 3D data, precision of the records, the correct positioning of the implants during the planning, the accuracy in processing the temporary guides and prostheses and even surgeon and prosthesis experience during planning execution17,20.

The basis for the use of partially or fully guided surgery protocols is digital reverse planning[4]. Thus, the ideal dental format is provided to guide the sequence of procedures that will culminate in the final functional and aesthetic result[10]. In the case report presented, the entire planning sequence was initially based on a simple drawing of dental contours superimposed on intra and extraoral photographs, aligned and calibrated with each other, following Digital Smile Design protocols, developed by Coachman[5]. Therefore, the author himself emphasizes the importance of the clinician's knowledge of the basic aesthetic and functional parameters, so that they are predominant in the clinical decisions adopted and not fully delegated to the technicians of the planning centers.

In this context, there are cases where the discrepancy between the position of the remaining teeth and the planned implant position is of such magnitude that bone ridge corrections are imperative for a successful treatment. There are descriptions of techniques that help this procedure, which use CTs performed with radiopaque radiographic guides in position16, use of conventional impressions[2] or direct measurements in the mouth[19]. Here, this step was eliminated, and a guide for alveolar bone reduction was developed based only on digital simulations, and resulted in a highly accurate surgical guide, which notably provided favorable aesthetic and tissue response.

The accuracy of implants installed in digital workflow is no longer questioned[3,9]. Although differences in positioning and angulation are found[4], these differences have been reduced to levels of virtual perfection[18]. This is the result of the constant development and improvement of protocols in digital workflow as well as the creativity, experience and curiosity of dentists, radiologists and laboratory technicians in working new possibilities, always aiming to achieve excellence of results[20]. However, there have been reported difference in the accuracy of muco/bone supported and tooth-supported guides based on digital STL file images, which are more accurate and this is due to the fact that the teeth are rigid structures that allow a fixed, passive and secure guide support[14,15]. Even with dental support, there may be dimensional variations in implant position, depending on the number and position of teeth and edentulous spaces[8]. Thus, the use of anchor pins for

extra stability of the guides in the bone tissue is a strategy that allows greater safety and precision in the implant milling and installation[2]. In this case, this stabilization was provided by the presence of the remaining teeth, which ensured initial fixation and remained so even after extraction, detachment and osteotomy. Another important point regarding these guides is that digital files are obtained from direct intraoral scanning and not from model scanners that can generate distortions due to the molding and pouring stone cast models[3,12,14]. This guarantee of accuracy is especially important when using zirconia implants as despite their well-known and documented biocompatibility[11]. They do not have the same prosthetic versatility compared to titanium implant systems in terms of their inclination or height eventual correction needs.

This paper aims to contribute to the introduction of a sequential implant surgery guide system based on a totally virtual planning, showing that this approach is safe and reliable. Thus, the protocol presented in this article is based on these principles in order to maintain the accuracy in the milling and installation of implants even after teeth removal and alveolar ridge reduction. By fixing the anchor pins guide over the remaining teeth prior to extraction, it is possible to have an accurate installation of the guides in bone tissue for the entire treatment sequence. The advantage of fully planned digital flow in a virtual environment allows for reduced preoperative consultations as well as the cost of printing models and/or mockups, especially in substrate cases where physical mockup is not possible. It is important to notify that the virtual planning work should always be checked by the professionals involved and if the team decides that there is inconsistency in the scans or doubts on the patient planning, a new appointment may be required before printing the guides and provisional prosthesis. It is noteworthy that the digital flow presented was performed by professionals with relevant clinical experience and, therefore, easily transmitting this real information to the virtual environment. The ability to visualize and interpret real clinical situations in a virtual environment is gained from the experience and understanding that this workflow model facilitates safer, more accurate, interdisciplinary, and cost-effective planning. ■

- Conflicts of Interest: The authors declare no conflict of interest.

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SBH All in One Concept, Metal removal, Presurgical preparation and Bolstering of Immune system prior to surgery, SDS Zirconia Implants and surgical process, SDS Restorative, Khoury Technique.

Dr. Corbin Popp, Biological Dentist, Denver, CO, USA, Dr. Rebekka Hueber, Leader department of biological dentistry, Swiss Biohealth Clinic, Kreuzlingen, Switzerland, Dr. Ulrich Volz, Founder and Leader of the Swiss Biohealth Clinic, Swiss Biohealth Clinic, Kreuzlingen, Switzerland

72 year old female presented on referral for a comprehensive biological approach to restore her failing prosthetic dental work composed of porcelain-fused to metal crowns and bridges. (Figure 1) Her motivations were to maintain overall health and to have lasting dental work with biocompatible materials. She had a history of trauma and multiple missing teeth plus multiple root canal therapies,a history of recurrent decay and periodontal disease. Her occlusion appeared to have a Mandible to Cranial Base discrepancy with significant first touch and slide coupled with multiple posterior interferences. She reported previous migraine headaches and clenching at times. The long spanning PFM bridge from #14-24 was class 1 mobile. Additional PFM crowns 16, 17, 25, 26, 36, 44, 46. Multiple failing root canal treated teeth #15, 14, 25 and questionable prognosis #24 with periodontal bone loss. She had slight mobile lower incisors with moderate recession and subsequent black triangles were apparent with moderate crowding. Esthetically, the patient was unhappy with the shape of her current teeth, stating: "my teeth have a large overbite" After complete examination and presentation of our findings the patient expressed interest in a comprehensive program to restore her bite using non-metal materials. In our initial plan, we discussed treatment of worn restorative work and to address the harmony of her bite for optimal lasting dentistry. We discussed the All-In-One concept of the Swiss Biohealth method to utilize immediate implantation using SDS ceramic implants and long-term fixed temporaries. She liked the biological approach and was referred to Swiss Biohealth Clinic for planning of this surgical phase in conjunction with our pre-surgical site work to remove metal PFM restorations and mercury fillings.

She began treatment at the end of October 2019, completed the site work following SMART protocols of the IAOMT and placement of composite core build ups with Luxatemp provisional crowns. (figure 2) She and her husband flew to Switzerland and arrived at the Swiss Biohealth Clinic in Kreuzlingen a few days prior to her surgical visit on December 11 2019.

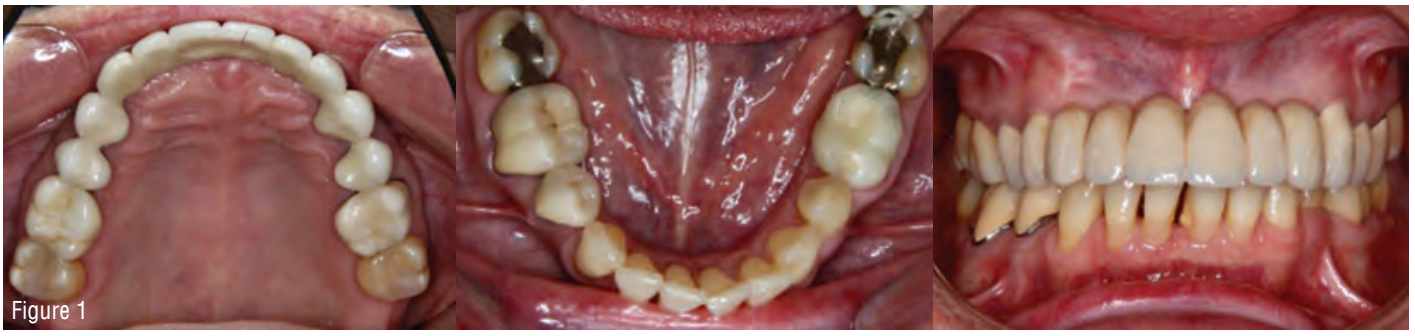
Preoperative measurements

The patient introduced herself for the first time at the beginning of December 2019 in the Swiss Biohealth Clinic and was kindly referred to by Dr. Corbin Popp. The clinical examination revealed that teeth 5, 6, 12 and 13 were not worth preserving. Horizontal and vertical bone loss occurred in the maxillary anterior region due to long-standing edentulism. In the CBCT-scan taken on site, ischemic osteonecrosis in the sense of FDOJ could be diagnosed. Due to the SAC Assessment classification tool, that is a guideline in order to graduate the difficulty of a surgical implant case we were facing a complex situation, in terms of aesthetic, surgical and restorative evaluations.

An important part of our SWISS BIOHEALTH CONCEPT is to strengthen and optimally prepare the immune system of our patients in order to achieve the best possible bone healing. Four weeks before the surgery, our patients start to supplement the BASIC IMMUNE mixture, formulated by Dr. Klinghardt and Dr. Volz, that not only contains every necessary micronutrient for an optimal support of the body's own regeneration but also works as a pre-biotic due to the cellulose sponges it contains. It is taken for another four weeks after the surgery. Through this intervention we are able to lift the vitamin-D-level 70 ng/ml or higher in order to reach optimal bone growth.

On the day before the surgery the patient got an infusion consisting of Vitamin C (15g), Vitamin B12, Natrium bicarbonate, magnesium sulfate, procaine and ringers solution. On the next day the surgery was performed after the All-in-one-concept in one day.

During the whole treatment, the patient receives the so-called BTPII-infusion, which contains 15g vitamin C, procaine, Mg-sulfate, sodium carbonate and vitamin B12, bear the end of treatment, the high-dosage vitamin C infusion is replaced with a pain-relief infusion. It is of great importance not to activate the sympathetic nervous system as this would impair the immune system and healing mechanisms.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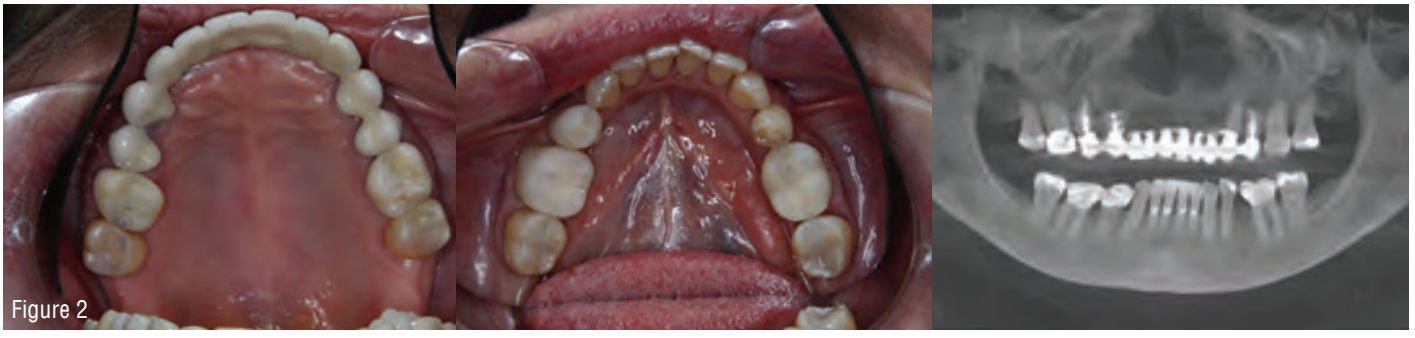
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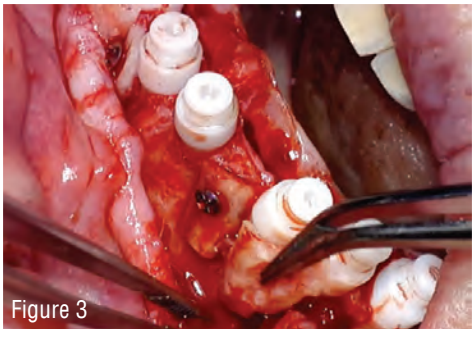
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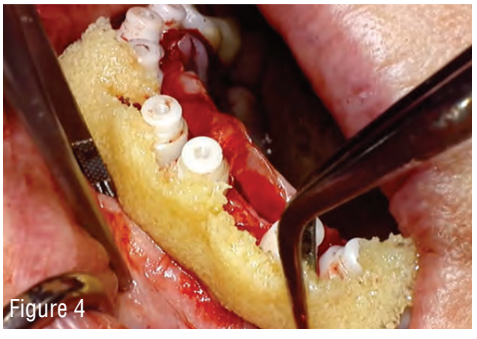
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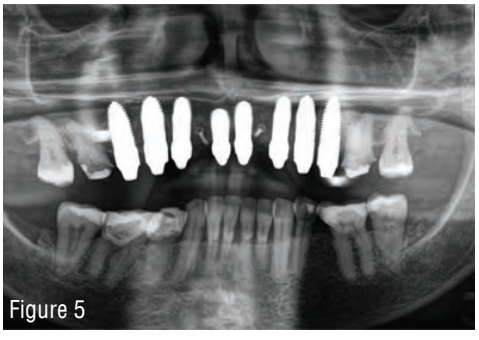
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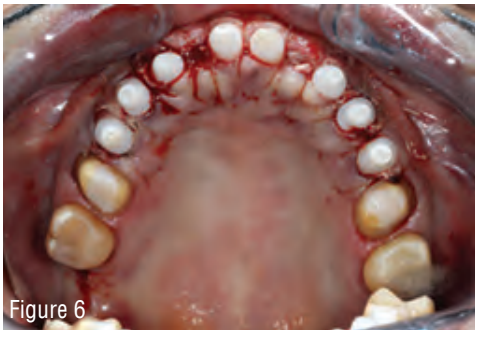


Figure 6

Surgical intervention

In all four wisdom tooth regions, both the ischemic and degenerative bone material was removed with piezo surgery and autologous bone chips were obtained after a minimally invasive approach. In regions 38 and 48, bone windows were lifted for subsequent bone augmentation in the maxillary anterior region. The areas were treated with ozone DTA and closed after insertion of PRF (platelet rich fibrin) matrices.

The teeth 5, 6, 12 and 13 were extracted under local anesthesia with a minimal and gentle procedure aiming to save as much bone as possible. The inflamed tissue was carefully cleaned and removed. It is inevitable to thoroughly clean the alveolus and disinfect it, as ceramic implants only osseointegrate in healthy bone. For cleaning additionally the ozone DTA 60 was used seconds on level 6.

Implantation and bone augmentation

It is highly important to follow a drilling protocol that considers the biology of the bone. The drills for the implantation are made of ATZ ceramic and by combining different protocols that vary based on bone class and appropriately adapted form drills, the implants gained an excellent primary stability. In the region of the compacta, the preservation of the blood flow was achieved through an oversized drilling and therefore zero compression on the bone. The stability of the implant was gained on the tip through an aggressive „Macro-Thread", that works simultaneously as a bone condenser on the spongiosa.

Ceramic implants were placed in regions 4, 5, 6, 8, 9, 11, 12 and 13.

Due to the pronounced resorption in regions 6 to 11, a solid sticky bone was created using an allogenic augmentation material and the low-speed centrifugation concept according to Prof. Dr. Ghanaathi (University of Frankfurt, Germany). A-PRF and i-PRF were centrifuged (Mectron) for 8 minutes at 1200 revolutions per minute. The augmentation material was then sprinkled with the injectable PRF and additionally activated with the exsudate from the pressed PRF matrices of the A-PRF tubes. Autologous bone collected during the operation was added and fixed with two osteosynthesis screws in the region 7 and 10 on the buccal site (Ustomed). The region was then covered by sticky bone and PRF matrices.

The mucoperiosteal flap, which had previously been opened by a marginal incision, was sutured again after gentle brushing (Brushing System, Dr. Choukroun) with deep apical mattress sutures and papillary sutures.

The implants were immediately provided with a long-term provisional restoration (Luxatemp, Durelon TM).

The healing phase at the SWISS BIOHEALTH CLINIC is supported by the SWISS BIOHEALTH WEEK, in which the patients are looked after by our medical team and get treatments that keep them in parasympathetic mode. The


Figure 8

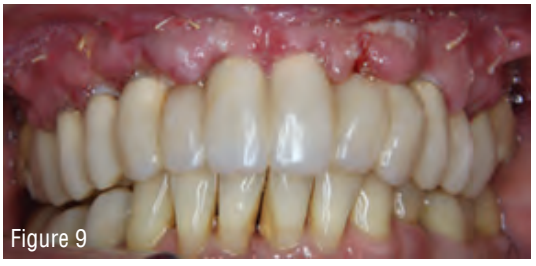
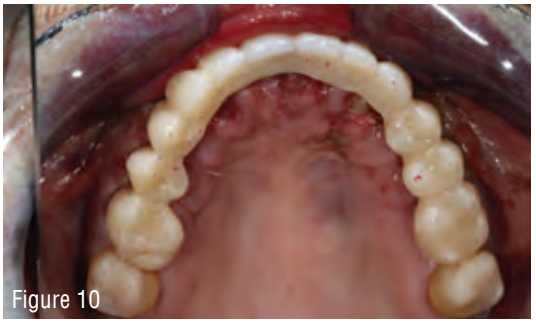


Figure 9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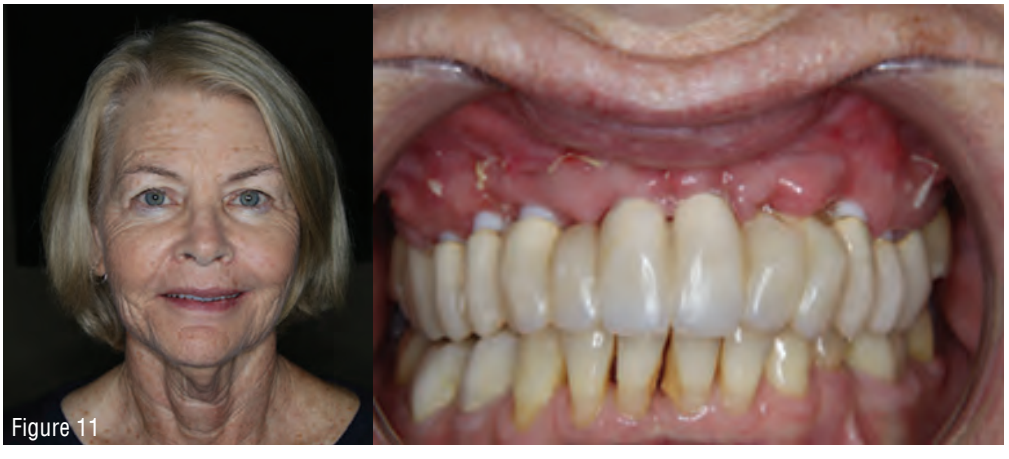
Figure 11

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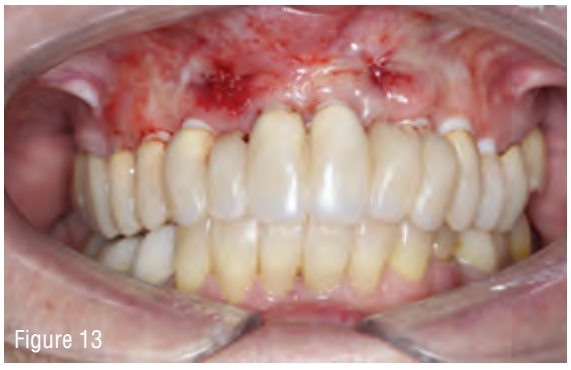

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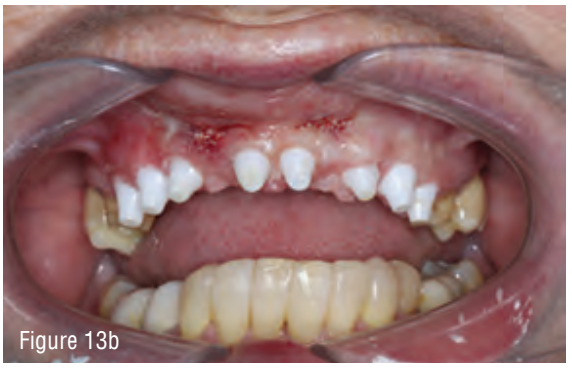


Figure 13b

Figure 14

patient experienced no swelling on the surgical site and an instant relief of most of her symptoms. After a few days, she was able to fly home to the United States. In only one minimally invasive and biological intervention her chronic inflammation and the causing teeth were removed.

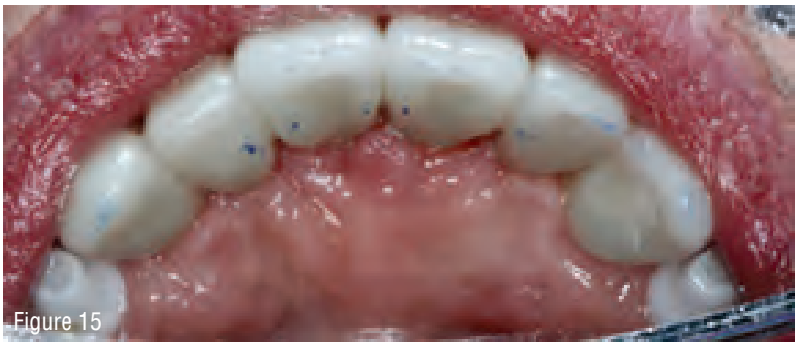
Post–Operative measurements

The patient returned to Denver and was seen by Dr. Popp two weeks post-operative PO. (figure 8-10) The patient reported mild swelling and no pain 0/10. She was taking 400mg ibuprofen q 8hrs as needed to manage her pain. She was concerned with some recession in the upper area palatal area of 13/14 (#5/6). The tissue exhibited slight recession but was healing very well without redness or drainage and only with very mild swelling. The patient was reassured she was healing normally. We infiltrated near the surgical sites 2ccs procaine 2% w/o epinephrine then 1cc Vit B12, 2cc Trameel, and 1cc lymphomyosot followed by 11gamma ozone injections five minutes following the procaine anesthetic. Her healing was unremarkable over the next couple weeks.

At one month post-operative she returned removing the remaining sutures (figure 11). All sites were healing well however she mentioned her migraine headaches had been periodically returning and was concerned that it may be from clenching. We discussed the Foundation for Bioesthetic Dentistry (OBI) method utilizing a bioesthetic Maxillary Anterior Guidance Orthotic, bMAGO to achieve the most stable condyle position and to simulate an increase in the vertical dimension of occlusion to expand our restorative rebuilding options. She also mentioned some esthetic concerns to improve the shape and proportions of her upper incisors.

At three months post-surgery her temporaries were still intact and we took alginate impressions (densply) to fabricate a maxillary orthotic. Following multiple adjustment visits to balance the orthotic as the condyles settle to the most stable condylar position SCP. The patient had significant improvement with headaches over three months time.

Challenges included hyper-eruption of the lower anteriors, mobile lower teeth with black triangles and recession, in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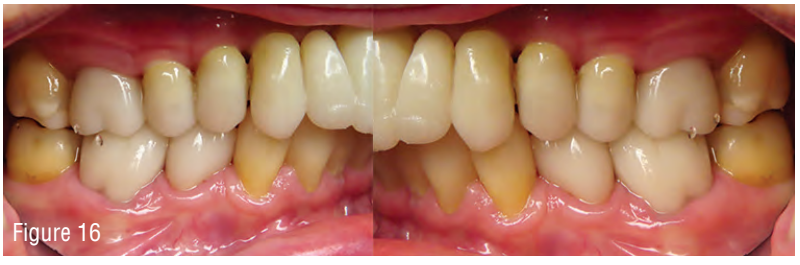
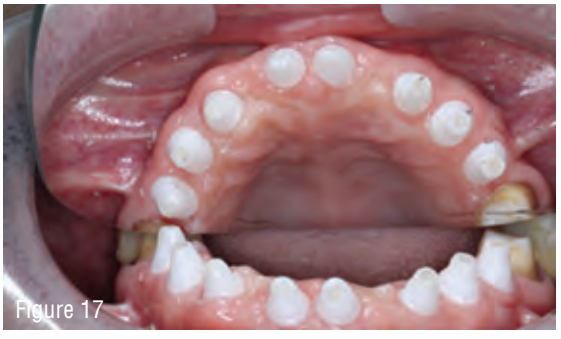


Figure 16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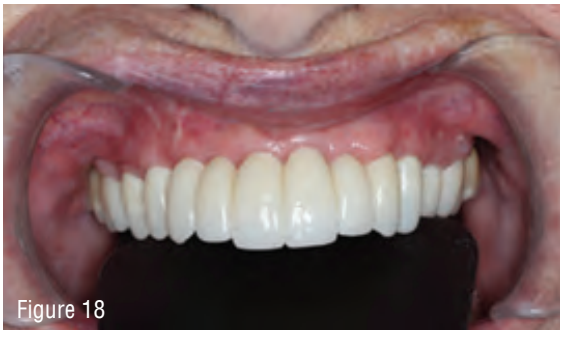
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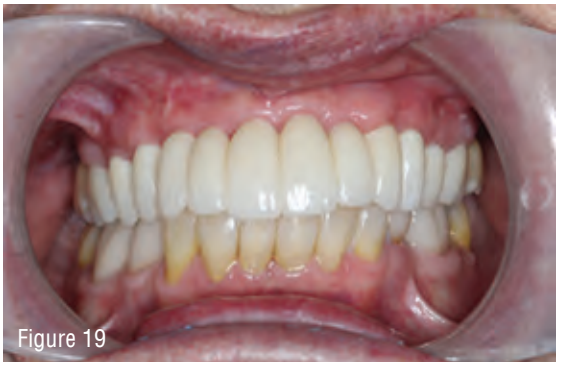
Figure 19

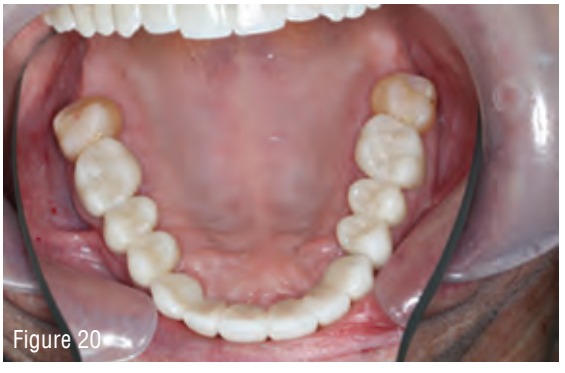
Figure 20

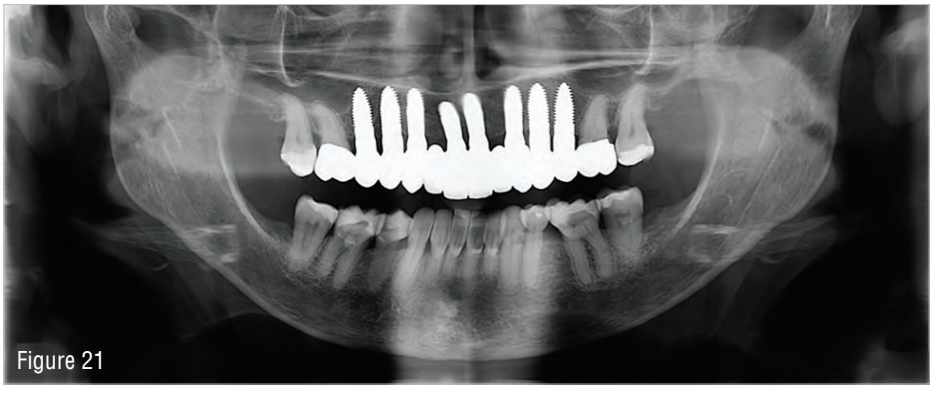
Figure 21

addition to lingual positioned lower canines. We restored the lower anteriors with resin (GC Universal flow A1) using a modified bioclear method to treat the black triangles and improve the mobility.

The titanium fixation screws were removed and new upper PMMA splinted partials were delivered in three sections #15-14, 13-23, 24-25. This sectioning avoids a bridge across cranial suture lines of the upper canines. (figure 12)

The upper implant SDS abutment was prepared with a red stripe diamond football bur (Brassler) prepared down to the gingiva per SDS protocol. We relined and recemented with a darker temp CEM (Telio A3) as she was unhappy with the opaque look of the PMMA crowns. (figure 13, 13b) We bonded the lower permanent crowns (Activa) (figure 14) (figure 16) and continued to refine to a balanced occlusion following OBI occlusal design. (figure 15).

Last we completed the upper arch removing the provisional in sections from anterior to posterior and fabrication of anterior jig (clear triad sheet) preserving the bite in a tripod fashion. The upper SDS implant abutments were prepared and finalized again using red strip diamond burs with chamfer margin at or slightly below the gingiva. Final Records sent to Andres Dental Studio requesting slight modifications and fabrication of splinted porcelain fused to Zirconia (PFZ) sections. Additional crowns on remaining natural teeth #16, 26. The Perio M testing for implant integration were as follows: #4 -5.2; #5 -4.5; #6-4.5; #8 -3.4 ; #9 -2.5; #11 -4.8; #12 -2.1; #13 -3.0. All implants appeared well integrated and were ready for loading. The permanent prosthesis was delivered with Ketac CEM per SDS protocol. (figure 17-21). A final protective maxillary orthotic was fabricated for long term protection and potential clenching.

Conclusion

This case offers a great example of the Swiss Biohealth Concept removing all failing dentistry and potential inflammatory sites and placement of immediate Zirconia SDS implants; and the final rehabilitation utilizing multiple sets of Interim prosthesis. of a long standing partial edentulism. The Swiss Biohealth Concept is a fantastic option for patients seeking a non metal biocompatable solution for partial or complete edentulism.■

The Author

Dr. Corbin Popp was born in Lincoln, Nebraska and is a graduate of the University of Nebraska. He obtained his dental degree from the Arizona School of Dentistry and Oral Health, then went on to earn resident of the year from the Graduate Practice Residency at the University of Colorado Anschutz. Dr. Popp's hunger for knowledge and his passion for exceptional outcomes drives his continued research. With extensive training in oral surgery, sedation, bioesthetics, ceramic implants, and biological dentistry, Dr. Popp is ardent advocate of the Swiss Biohealth Concept, The Foundation for Bioesthetics (OBI), and ceramic implantology.

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MODULE 1

Periodontal disease

- Diagnosis of periodontal diseases and conditions using the new classification system
- Treatment planning
- Non-surgical and surgical treatment options
- Periodontal maintenance program

Hands-On component:

- Suturing techniques
- Open Flap debridement and distal wedge
- Crown lengthening

MODULE 2

Soft tissue grafting:

- Biologic principles
- Classification, Goals and Objectives
- Indications and Risk Factors
- Instrumentation and materials
- Complications

Hands-On component:

- Free gingival grafting
- Connective tissue grafting
- Tissue guided regeneration for soft tissue grafting

MODULE 3

Hard tissue grafting:

- Biologic principles
- Predictability, Goals and Objectives
- Indications
- Bone grafts and membranes and their indications of use
- Management of the complications

Hands-On component:

- Socket preservation
- Ridge augmentation
- Guided bone regeneration for treating periodontal bony defects

Dr. Parvaneh Bahrami obtained her first degree in Dentistry (DDS) in Iran in 1992. At the University of Toronto, she completed the Qualifying program with honors in 2004 and a Master of Science in Specialty Training in Periodontology and Implant Surgery in 2012.

More than a decade of experience in general dentistry before becoming a specialist has been an invaluable asset in her understanding and treating patients and working with referring dentists. Dr. Bahrami is board-certified and a Diplomat at several institutions, a clinical instructor at the University of Toronto and practices as a periodontist and implant surgeon at Prosthodontics Associates.

Contact: p_bahrami@yahoo.ca

LOCATION

Courtyard by Marriott Toronto Northeast/Markham
7095 Woodbine Avenue, Markham,
ON L3R-1A3

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CERAMIC TWO-PIECE IMPLANTS

FOR THE REPLACEMENT OF MISSING MANDIBULAR MOLARS

VARO BOYER, DDS, FICOI

INTRODUCTION

Titanium implants have long been used as an excellent option for replacement of missing teeth for more than 4 decades. Both long term clinical success and also years of research show that dental implants are one of the most predictable treatment options in dentistry with the success rate of titanium implants being well over 90%[1,2].

In recent years, however, a need has risen for an alternative to titanium as a material for dental implants. Studies have shown that a small fraction of the population (0.6%) has sensitivity to titanium[3] and allergic type of reactions that require the removal of the titanium implant. In addition to this, with titanium being a dark colored material, esthetics becomes an issue where the patient biotype is thin. There is also demand from patients for metal free solutions and a more holistic approach. Recent literature shows evidence of titanium corrosion in the mouth and release of titanium particles into the soft tissue[4,5], which contributes to a reaction from the body and could be one of the reasons for peri-implant inflammation.

Dental implants made from zirconia (zirconium dioxide) have been shown to have great biocompatibility, since the new material is a ceramic now and loses the metallic properties. Multiple authors have shown for zirconia implants to have equal BIC (bone to implant contact) and osseointegration rates when compared to titanium implants[6,7,8]. Zirconia has shown adequate strength to be used in anterior and posterior tooth replacements, and superior aesthetics in the anterior zone[9]. Zirconia also exhibits less plaque accumulation10, thus allowing for healthier peri-implant tissues.

Currently there are one-piece and two-piece zirconia implants commercially available. One-piece implants present a surgical and prosthetic challenge, since they require high levels of precision during placement and do not allow for submerged healing when needed. This could result in loading of the implant during the healing phase and also present prosthetic challenges if not ideally positioned.

Two-piece ceramic implants allow for prosthetic corrections, a better way to manage the soft tissue around implants, and most importantly to have a true screw-retained restoration, which will minimize biological complications and allow for the retrievablity of the restoration.

This case report describes two instances where missing mandibular molars were replaced by two-piece ceramic implants and restored with screw-retained implant crowns.

CASE 1: Clinical situation

A 62 year old otherwise healthy patient presented to us with missing lower left second mandibular molar. The tooth had had gross decay and was extracted seven years prior, and the extraction socket was augmented using xenograft. Clinical examination showed adequate bone volume (2-dimensionally), interocclusal space and keratinized tissue. Due to the proximity of vital anatomic structures, a CBCT scan was also taken to evaluate the three dimensional shape and quantity of the bone. The CBCT revealed a pronounced lingual concavity (Figure 1), therefore a shorter, 8mm length implant was selected.

Surgical Procedure

Prior to the procedure, patient rinsed with Chlorhexidine oral rinse. Inferior alveolar, long buccal and lingual nerve block was administered with 2% Lidocaine, lingualized crestal incision with a small distobuccal release was done to expose the bone, and manufacturer osteotomy protocols with copious irrigation and radiographic controls were performed.

A 4.1 x 8mm Straumann Pure 2-piece tissue level ceramic implant (Figure 2) was inserted with final torque of 35 N/cm and a 3mm healing abutment was placed finger-tight (Figure 3).

ISQ measurements were taken with Penguin RFA, showing values of 69 in buccolingual and 71 in mesio-distal directions. Surgery site was closed with 4.0 chromic gut single interrupted sutures, hemostasis a chieved and usual post-operative instructions given. Patient would take 800mg of Ibuprofen as necessary for pain. Two weeks after placement surgery, patient returned for a follow-up. Clinical examination showed no sutures, healing abutment in place and excellent recovery of the soft tissue around the implant (Figure 4).

16 weeks after surgical placement, patient returned to initiate prosthodontic steps (Figure 5). ISQ measurements were taken with values of 73 and 81 respectively. An open tray impression coping was used

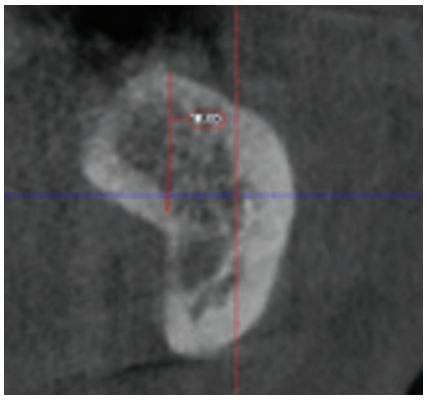

Figure 1: A coronal section of the CBCT in the area of tooth #18 showing a large lingual concavity.

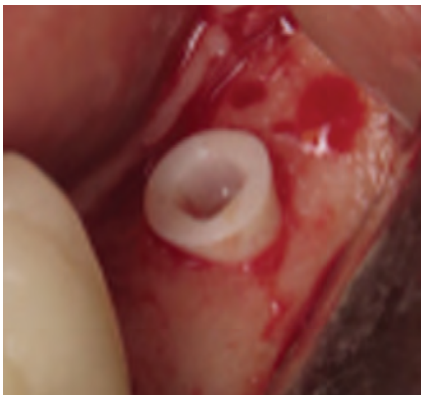

Figure 2: The tissue level ceramic implant has a smooth collar and should be placed 1.6-1.8mm supracrestal.

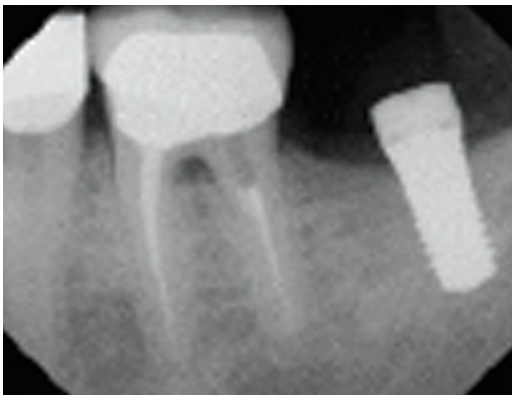

Figure 3: Final periapical radiograph showing the implant position in bone and the healing abutment after placement.

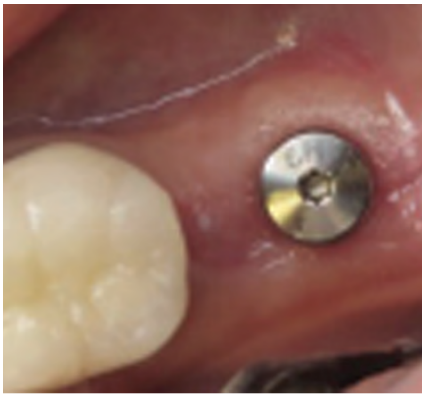

Figure 4: At two weeks after implant placement, clinical examination reveals excellent soft tissue healing around the neck of the ceramic implant and the healing abutment.

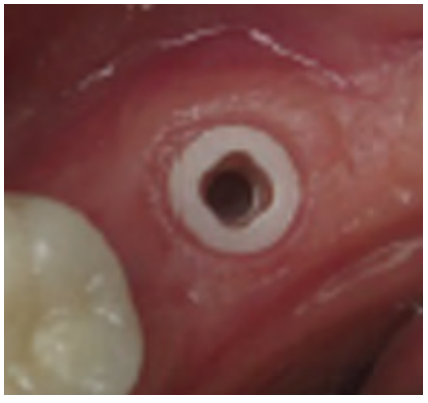

Figure 5: Clinical photograph showing pink and healthy keratinized tissue around the implant, ready for restoration.

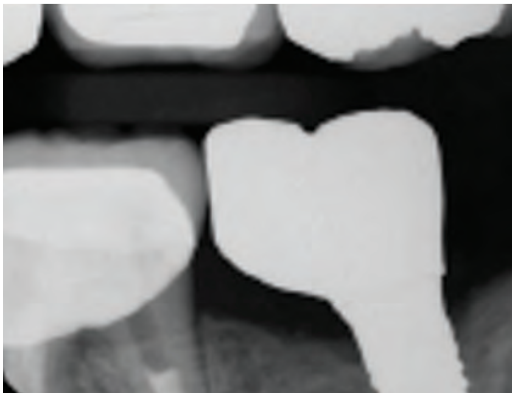

Figure 6: Bitewing radiograph to confirm full seat of the crown before torquing it to 35 N/cm2.

to take full arch impression after confirming radiographic seat, bite registration and opposing dentition impressions were also taken.

A screw-retained monolithic zirconia crown was fabricated over a PureBase abutment (Figure 6). The implant crown was delivered using standard procedures (Figure 7), and care was taken to establish adequate occlusal scheme (light centric contact, no excursive contacts, keeping centric contacts over the implant body and away from cusp tips and marginal ridges). Patient was placed on a hygiene recall protocol and thoroughly educated on regular and implant hygiene.

CASE 2: Clinical situation

A 39 year old patient had presented to with pain in lower left and a failing root canal treatment on lower left first molar. Large periapical radiolucency, mobility of grade II, and loss of buccal plate were found.

Tooth was extracted, the socket was carefully and thoroughly degranulated, grafted using xenograft with PRF and sticky bone protocol, and covered by a resorbable collagen membrane.

Implant surgical procedure

20 weeks after the extraction and grafting, patient presented with a healed site (Figure 8) and implant placement was initiated. Patient rinsed with Chlorhexidine rinse before the procedure; inferior alveolar nerve, long buccal and lingual nerve blocks were achieved using 2% Lidocaine. A lingualized crestal incision was made and an envelope flap was elevated. Manufacturer protocol and copious irrigation were used to create the osteotomy and implant was inserted with 25N/cm final torque (Figure 9). The defective amalgam on #20 and chronic endodontic lesion on #18 were both addressed before #19 was restored.

ISQ values were 58 bucco-lingually, and 60 mesio-distally. A cover screw was placed, and site was sutured with 4.0 chromic gut interrupted single sutures. Post-operative instructions were given, and over the counter anti-inflammatory medications were prescribed.

20 weeks after implant placement the patient presented for stage 2 surgery. Implant was uncovered, ISQ's were taken (73 and 87). A 3 mm healing abutment was placed, and tissue was left to heal for 3 weeks (Figure 10).

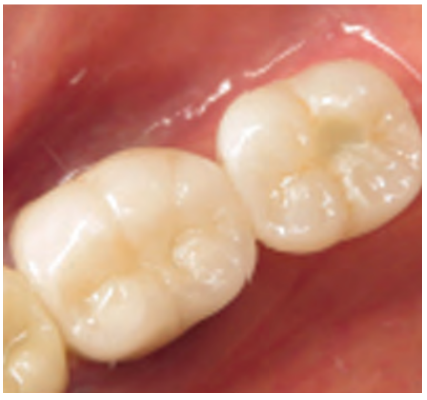

Figure 7: Screw-retained implant crown was fabricated over a titanium base called Straumann PureBase, and delivered. Screw-access is covered with PTFE tape, opaquer and composite material.

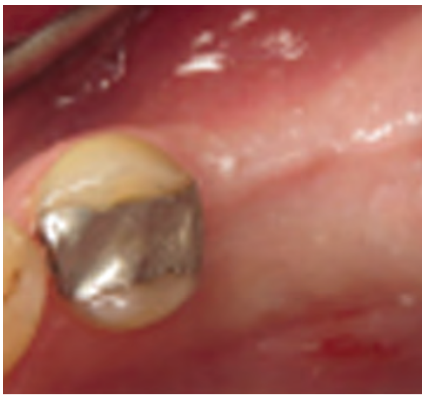

Figure 8: Clinical view of the implant site preoperatively.

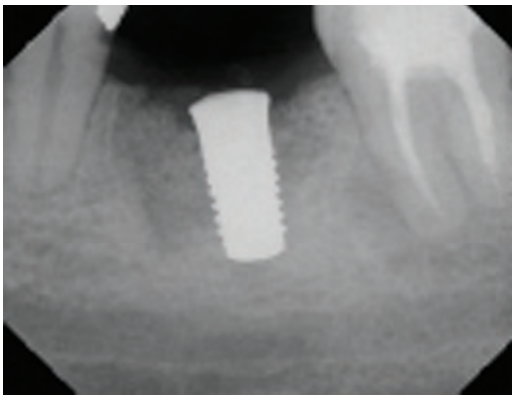

Figure 9: Periapical radiograph showing the position of the ceramic Straumann Pure implant immediately after placement.

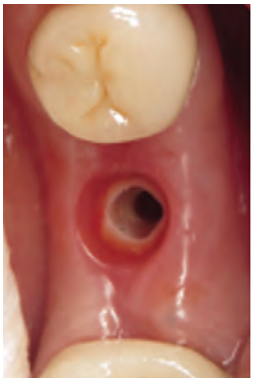

Figure 10: Pink and healthy soft tissue around the implant three weeks after stage II.

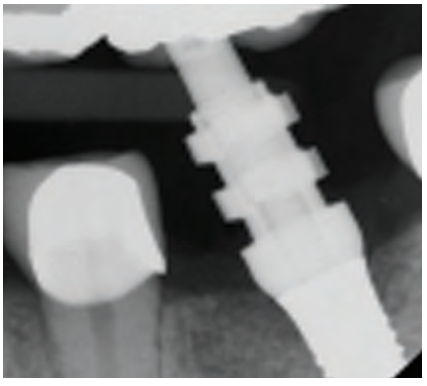

Figure 11: A bitewing radiograph showing the open tray coping fully seated onto the implant.

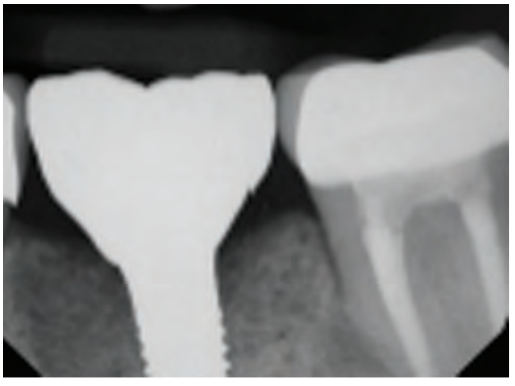

Figure 12: Bitewing radiograph of the screw-retained crown during delivery, before final torque.

Prosthodontic Steps

The same prosthodontic steps were followed to fabricate the final restoration - open tray impression (Figure 11) and delivery of a screw-retained zirconia crown over Straumann PureBase (Figure 12). Access was obturated with PTFE and composite (Figure 13); proper occlusal scheme was developed and maintained throughout every recall visit.

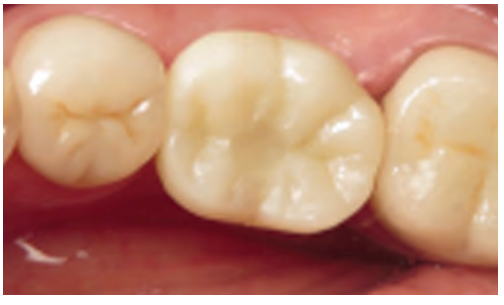

Figure 13: Clinical photo of the final restoration after access obturation.

Figure 14: The Zirconia crown over PureBase abutment sits directly onto the shoulder of the Straumann Pure implant.

DISCUSSION

When zirconia implants were first introduced, their strength to withstand masticatory forces was questioned. However, in the last decade, multiple treatment modalities have been introduced that increase the toughness and fracture resistance of zirconia11 (addition of Yttria or Alumina, hot isostatic pressing, etc). Therefore, currently commercially available zirconia implants have adequate strength and can be used both in aesthetic areas and also in molar areas where the occlusal load is higher. As you can see in Figure 6, implant #18 in the first case report was placed too distal, which resulted in a mesial cantilever. This case shows that even in non-ideal placement situations and with the risk of increased nonaxial loading, this two piece implant has performed well and been able to demonstrate adequate strength and stability. In addition, in Case 1, the tissue level implant was placed only 1mm supra-crestal (Figure 2).

As expected, bone will not integrate to the smooth neck of the implant, and therefore on the final bitewing you can see natural bone remodeling up the the first thread of the implant (Figure 6). Two-piece ceramic implants have less long-term research available compared to their titanium counterparts,

and also one-piece implants12. The aim of this paper was to present the use of two-piece implants in mandibular molar replacement. One shortcoming of the current Straumann Pure system is the lack of different diameter implants (the two-piece implant currently available only in 4.1mm diameter). Given that molars usually have 9-11mm mesio-distal and 8-11 mm bucco-lingual dimensions, this can lead to increased cantilever and non-axial loading of the implant. That is why in these cases control of occlusion is paramount (for example, not using these implants in patients who are missing multiple teeth or do not have a stable occlusion).

The Straumann Pure two-piece implant features a titanium base called PureBase and uses a titanium screw that can be tightened to 35 N/cm and be used and tightened multiple times. In contrast to the standard VarioBase, the PureBase is not in contact with patient tissues and is fully surrounded by the implant neck and crown (Figure 14). Therefore, soft and hard tissues are never exposed to metal and are always in contact only with the ceramic/zirconia material.

Another advantage of two-piece implants is the ability to use resonance frequency analysis to determine the stability of the implants at placement, loading and during follow-up visits if necessary13. Since implant #19 in the second case report had low initial torque and ISQ's of <60, it was planned for submerged healing. In contrast, implant #18 in the first case report had good insertion torque and ISQ's > 69, it was done in a one-stage fashion to avoid a second surgery to expose the implant. There is research that recommends an ISQ value of > 66 at the time of implant placement for one-stage protocol. The same study14 also showed a cut off ISQ value of > 67 to determine that the implant is ready for loading. Research has also shown, both in RCT's and systematic reviews/meta-analyses, that ceramic implants have comparable short and long term survival and success rates[15, 16, 17,18].

In summary, the advantages of two-piece ceramic implants are multi-fold. They allow for a screw-retained two-piece metal-free solution, they can be tested for RFA at every step of the way and finally that they have not only adequate strength for the molar areas, but they also have superior aesthetics and biology around the implant. Both surgical and prosthodontic practitioners using a two-piece ceramic implants have the flexibility during surgery to do submerged or one stage healing, the options to do cement retained or screw retained restorations, and also the ability to ISQ test the implants and better communication with the patient during the whole process. ■

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One Piece Zirconia Implant Primary Stability Evaluation with Periotest

Dr. Sammy Noumbissi
Rodrigo Gomes Beltrao, DDS, PhD – IMED School of Dentistry – Brazil
Fernando Rios, DDS, PhD – Sobracid – Brazil
Cristine Faria Finco, DDS, MsC – Sobracid – Brazil

INTRODUCTION

As a result of the studies by Branemark [7], the use of osseointegrated implants for the replacement of lost teeth and rehabilitation of masticatory functions has been a reality and met with great success. Over the years, several modifications to the structure, material composition, macroscopic and microscopic design of titanium implants have been made to improve their properties[41, 42]. However, reports of undesirable immunological events[18], osteolysis[8, 12], cell sensitization to metal alloys [28, 39], galvanic current formation [10] and mixed aesthetic results, the search and demand for more aesthetic and biocompatible implant material [4, 22, 46] than titanium alloys has been active for decades. Furthermore regulatory agencies have increasingly been scrutinizing and reevaluating the biocompatibility and the impact on human health of alloys used for implant materials. [45]

Zirconia is rapidly establishing itself as a viable alternative to the conventional titanium-based implant systems for oral rehabilitation. Zirconia presents with superior biological [35, 36], aesthetic, mechanical and optical properties [2, 16, 40, 46]. The white and opaque color of zirconia, together with the first reports of good biocompatibility and low affinity for plaque [36], make it a suitable material in the biomedical sciences. In vitro experiments with zirconia have not provided evidence of mutagenic or carcinogenic effects [9]. Zirconia also exhibits unique physical and mechanical properties, including low thermal conductivity, high flexural strength, good fracture resistance, as well as wear and corrosion resistance [37].

Currently, most of the commercially available zirconia implants are one-piece or monobloc[31, 32]. The monobloc configuration gives them advantage of not having a microgap between the implant and the abutment [17]. However, these systems have several limitations starting with the surgical positioning of the implant which may not always meet the prosthetic requirements. Furthermore there are no angled abutments to correct the possible misalignment. In addition, immediately after placement, one-piece implants are immediately submitted to tongue and chewing forces. Another disadvantage may be the fact that cementation is the only option for connecting these implants to their prosthetic components. According to a recent systematic review [48], technical and biological complications are significantly more frequent if the prostheses are cemented as opposed to being screwed.

The stability of the implants can be considered as a lack of clinically detectable mobility[38] and defined as the ability to support different loads[30]. Implant stability, either immediately after surgery primary stability or during and after the healing process also known as secondary stability is an important parameter in assessing the status of osseointegrated implants [25, 26, 29]. Acceptable primary stability is a key factor to be considered before immediate implant loading [14] but also a reliable predictor of implant successful osseointegration. As such, reliable numerical or quantifiable data on the stability level are extremely important because they are objective information that will directly influence the clinician's decision with regards to the loading protocol and timing be it immediate or delayed [3, 15, 32].

The method or technology used to measure implant stability must be accurate, repeatable, non-invasive and reliable [5]. There are several techniques to measure the stability of dental implants[11, 30, 43, 44]. Among them, Periotest® is considered a non-invasive stability testing modality and not disruptive or destructive to the bone-implant interface[38]. In addition, it has an important advantage over others which is that it can be applied directly to the implant superstructure. Periotest® was initially designed to test natural teeth 'degree of movement, it functions by measuring the damping capacity of the implant. In other words the Periotest measuring procedure is electromechanical. An electrically driven and electronically monitored tapping head percusses the implant 16 times for 4 seconds during which the tapping head records the duration of contact with the implant. The longer the

contact time between the tapping head and the implant the higher the Periotest values (PTV) as opposed to stable well osseointegrated implants where the contact time is brief and the results recorded are lower. The Periotest is a commonly used device, and there is evidence of its reproducibility and reliability [23, 24]. The more negative the PTV the greater the stability up to a maximum value of -8.

Evaluating the stability of one-piece or monoblock zirconia ceramic implants, which are identified in the literature as quite promising, using Periotest®, a modern and reliable method, was the focus of this study.

The objectives of this study was to Measure the stability of single-body zirconia implants, compare the Periotest® values obtained in this survey with results described in the literature and other stability measuring instruments such as the Resonance Frequency Analysis (RFA) from Osstell, assess possible clinical modifying factors in the stability of single-body zirconia implants. to determine if implant length, diameter, location would yield different values and rates of implant stability and stabilization.

METHODOLOGY

The present work was an observational cross-sectional study. The study was a double center study carried out at Washington, DC - USA and Porto Alegre, RS, Brazil. The implants observed in the USa were all Z-systems ceramic implants (Oesingen, Switzerland) and the ones tested in Brazil were the Straumann Pure ceramic implants from Straumann Group, Switzerland. A total of 78 zirconia implants placed were analyzed based on the periotest values at the time of implant placement.

Inclusion Criteria was Individuals who had single-body zirconia implants, having signed the free and informed consent form, were considered eligible to be included in the sample of the present study. Patients included were in a broad range of rehabilitation situations ranging from single missing tooth to full mouth edentulism and rehabilitation. Medically they had to be ASA I in order to be included in the study. Heavy smokers, diabetic, immune deficiency, high cholesterol or unwilling to participate in the study were excluded from this study sample.

The measurements on the implants were made only immediately after placement at buccal aspect of the implant prosthetic post three consecutive times and a mean value was determined.

The clinical data variables were as follows: Immediate primary stability, Implant site with or without previous bone graft, Implant-related factors such as diameter, length and platform were noted. Anatomical considerations such as maxilla vs mandible or anterior vs posterior location referring to the sites corresponding to where the implant were placed. The Periotest was used according to the manufacturer's instructions. It was positioned perpendicular to the implant abutment and the values were measured from the buccal side of the implant abutment. The measurements were repeated three times for each implant by tapping sixteen times for 4 seconds each time. A pause of 10 seconds was taken between each measurement.

The main outcome of the present study was the Periotest® value obtained immediately after the surgery. Position, diameter, length and use of graft were analyzed as possible risk indicators for Periotest® positive values. Position was dichotomized into anterior (incisors or canines) and posterior (premolars or molars); diameter into narrow (3.3 - 3.6mm) and wide (≥4.0mm); length into short (8.0 – 10.0mm) and long (11.0 – 14.0mm); and use of graft into yes and no. The Periotest® data were categorized in negative and positive, associated to success or failure, respectively.

The association of the measured values in the Periotest® with the other variables was verified through univariate analysis. The chi-square test was performed at a significance level of 5%. The SPSS 18 software was used in the analysis.

		Periotest value		Total	p*
		Negative	Positive		
Position	Anterior	20 (71.4%)	8 (28.6%)	28 (100%)	
	Posterior	45 (76.3%)	14 (23.7%)	59 (100%)	0.627
Diameter	Narrow	14 (73.7%)	5 (26.3%)	19 (100%)	
	Wide	51 (75.0%)	17 (25%)	68 (100%)	0.907
Length	Short	37 (69.8%)	16 (30.2%)	53 (100%)	
	Long	28 (82.4%)	6 (17.6%)	34 (100%)	0.189
Graft	No	23 (82.1%)	5 (17.9%)	28 (100%)	
	Yes	42 (71.2%)	17 (28.8%)	59 (100%)	0.272
Total n(%)		65 (74.7%)	22 (25.3%)	87 (100%)	

*Chi-square test

Table 1. Univariate analysis of possible clinical modifying factors for Periotest values.

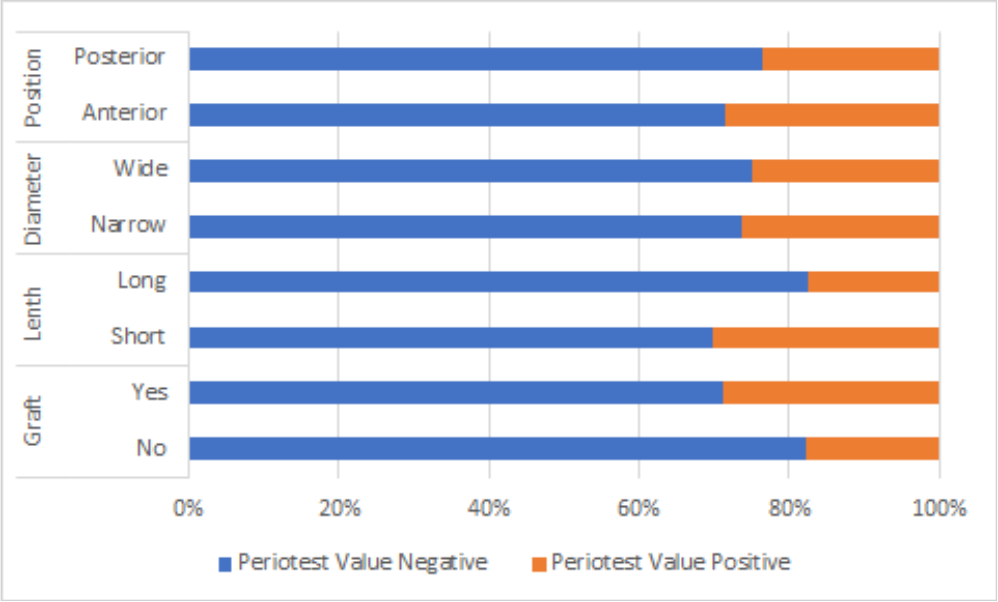

Figure 1:
Percentage of implants with negative and cording to clinical variables.

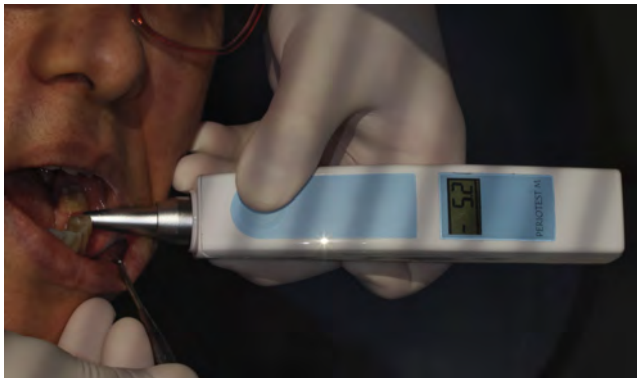

Figure 2: Periotest Positioning

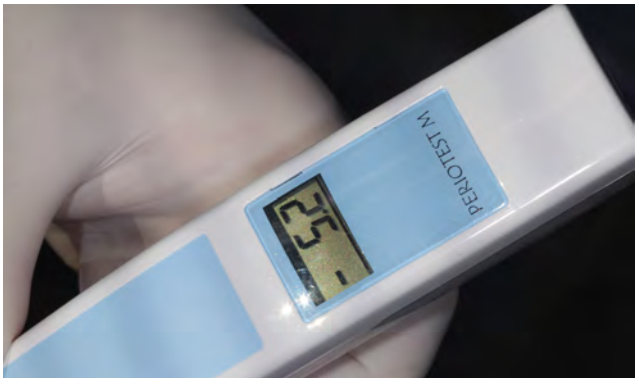

Figure 3:Periotest Reading

RESULTS

The results showed that there is no correlation between implant length, implant diameter, surgical site and bone grafting with regards to Periotest values observed. That means that Periotest values are only dependent on the implant stability itself and any other variable does not interfere with the clinical measurements.

Therefore the graphic shows a pattern regarding Periotest readings for primary stability. Even though the measurement values are negative or positive, the pattern remains the same for all clinical variables.

DISCUSSION

Zirconia has become attractive as a new material for dental implants, due to its tooth-like color and mechanical properties. In addition, it is known to be inert in the body and does not exhibit ion release like metal alloy implants. The release of ions from metal implants induce an inflammatory response which results in osteolysis and bone resorption.This is one of the main factors that have been used to look at zirconia as a material with higher biocompatibility than metal alloys. Crestal bone loss and gingival recession associated with implants generally exhibit portions of the metallic implant, revealing a bluish tinge to the overlying gum. The use of zirconia implants avoids this complication and meets the requirements and wishes of many patients who chose to be treated with ceramic implants (34).

Given the fact the one body zirconia implants needs to be perfectly placed since there's no angle abutments or any other option besides small adjustments by preparing the abutment (not recommendable by some Companies) there are many variables that interfere with the primary stability of the implants. Therefore, implant design and precise surgical technique can lead clinicians to achieve proper primary stability based on insertion torque. Although insertion torque correlates to primary stability, zirconia Implants are sensitive to high insertion torques and require a pre-insertion tapping of the bone.

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The primary stability of the implant is an important indicator for timing to apply load to the implant and secondary stability is an important parameter in the evaluation of osseointegration [25, 26, 38]. It should be noted however that the Periotest does not directly measure the osseointegration of the implant but it does so indirectly by assessing and quantifying the stability of the implants at the time of testing. In this study, Periotest® showed excellent stability values. The observations of the stability patterns were very similar to those observed with other implant stability measuring devices with titanium alloy implants. These observations lead us to believe that the osseointegration and biological stabilisation process is somewhat identical to what has been extensively observed with metal implants.

The variables evaluated in this study, which were related to implant measurements, graft utilization and anatomical site of installation, do not have an impact on the stability values of single-body zirconia implants. When searching the literature, we found similar analyzes only when titanium implants were evaluated it was showed results similar to the observations made in the present analysis: titanium implants installed in a region with a graft showed stability similar to that found in implants installed without a graft [1]. However, other study showed different results from those obtained in our analysis regarding the anatomical location of installation. The authors have found that titanium implants installed in the mandible showed greater stability than implants installed in the maxilla [27]. These findings are probably due to the fact that pre-implantation tapping procedures are not always necessary with titanium implants in dense bone as opposed to one-piece zirconia Implants.

Therefore a reliable measurement device such as resonance frequency analysis (RFA) is important to make it possible to measure implant primary stability of two-piece ceramic implants is mandatory for one-piece implants as well. Periotest readings are not influenced by any clinical variables studied and can accurately define and quantify implant stability at different stages starting from the time of placement. Objective and accurate implant stability assessment is critical in the decision making with regards to implant loading.

FINAL CONSIDERATIONS

The single-body zirconia implant achieved excellent stability values. The Periotest values for primary stability were not affected by any of the clinical variables. Therefore, Periotest clinical readings are only dependent on the implant stability itself. We can conclude from this study that the Periotest is a reliable and accurate device for the assessment of implant stability at the time of placement. ■

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Titanium Intolerance and its Relevance in Clinical Practice

Thomas G. Wiedemann MD, PhD, DDS, FEBOMFS, DICOI
Marco Bergamini DDS, FICOI

ABSTRACT

Despite the high biocompatibility and resistance to disintegration, corrosion of titanium dental implants has been reported in the oral environment. The aim of the ongoing review is to discuss the properties and biological behavior of titanium implants and particles, diagnostic techniques, and recommendations in the management of titanium hypersensitivity or intolerance.

An electronic literature review was performed through different databases including Pubmed, Cochrane and Scopus.

Studies showed that titanium dioxide may cause the immune system of an individual to elicit a type IV hypersensitivity reaction which is basically defined by two phases: an initial sensitization phase upon exposure, followed by an immune response to subsequent exposures of a sufficient concentration of Titanium ions. Studies have revealed that an idiopathic and rapid marginal bone loss around a titanium implant surface might be related to hypersensitivity reactions to the material in a subgroup of patients. This reaction is exacerbated by the unavoidable chronic nature of the exposure through constant direct bone to implant contact.

MELISA Test is considered to be the most appropriate diagnostic tool to determine titanium intolerance and to measure the relative severity. However, this diagnostic tool is yet incapable of predicting a possible implant failure preoperatively without primary Titanium exposure.

INTRODUCTION

Titanium is considered to be one of the most biocompatible metals and is FDA - approved for implantation into human bodies. Therefore, the use of titanium for orthopedic and dental implants has markedly increased in recent decades. Titanium and its alloys are traditionally the gold standard materials for endo-osseous integrated dental implants. [2,3] On the other hand, like all metals, titanium is not completely inert; biocorrosion may occur with titanium implants and, with it, the potential to elicit an immune reaction.

Although the failure of implants has been widely studied some failures are difficult to explain, such as spontaneous rapid exfoliation of the implant, or the successive and multilocular failure of implants in the same patients, known as "cluster phenomenon", without any infection or overload risk factors identified.[4] [5] Many clinicians agree that in these cases, there must be a systemic determinant of failure that has not been identified or fully understood.[6] Titanium intolerance or hypersensitivity is barely recognized in the dental field, but some articles have suggested that this could just be the very tip of the iceberg and advocate further awareness. Although we know that titanium intolerance is uncommon and that not all patients sensitized to a certain metal display complications following an endosseous implant [7], the appearance of significant complications in particularly sensitive patients cannot be disregarded [7,8]. Researchers have reported a higher prevalence of titanium hypersensitivity among patients sensitive to other metals [8,9].

When looking into orthopedic research, aseptic loosening of an orthopedic titanium implant is a well-known complication and was first introduced by Harris et al. Aseptic loosening is described as osteolysis around an implant by the activation and secretion of pro-inflammatory cytokines (eg, interleukin IL-1β, IL- 6, TNF-α and PGE-2 caused by wear debris and nanoparticles from the implant itself. In contrast to an orthopedic implant installed in a sterile environment, a dental implant is connected to the oral cavity through the peri- implant mucosa and is exposed to microorganisms and chemical products.[10] This chemical exposure of the dental implant can further enhance Titanium release from the implant by corrosion. It has also been proven that titanium ions concentrate in tissues surrounding dental and orthopedic implants, as well as in regional lymph nodes and pulmonary tissue.

Titanium particles and ions leaked from dental implants are not bio-inert with even an immunogenic potential acting as secondary stimuli for the inflammatory process which may enhance bone resorption. Numerous recent articles suggest that titanium hypersensitivity or titanium intolerance may lead to adverse reactions including failure of osseointegration of the implanted material [11,12,13].

The aim of this review is to discuss the properties and biological behavior of titanium implants and particles, incidence, diagnostic techniques, and provide recommendations for clinicians in the clinical management of titanium hypersensitivity.

MATERIALS AND METHODS

The search strategy was conducted analyzing electronic databases including Pubmed/Medline, EMBASE, Scopus and the Cochrane Library from 1990 to September 2020. The following key words were selected: "titanium intolerance", "titanium hypersensitivity", "titanium allergy", "dental implants intolerance" "titanium corrosion" "titanium release". The selected inclusion criteria were publications as systematic reviews, meta-analyses, randomized controlled trials, reviews, in vivo and in vitro studies. The exclusion criteria consisted in preclinical studies, reports based on questionnaires and studies not available in English. A comprehensive literature review was conducted until January 2020. No limitations in time were imposed in the search protocol. An initial screening yielded a total of 708 articles obtained through an electronic research in the different databases such as Pubmed/Medline, EMBASE, Scopus and the Cochrane Library.

RESULTS AND DISCUSSION

1. Allergy or Hypersensitivity: a traditional classification:

According to the Coombs and Gell classification, hypersensitivity reactions can commonly be classified into four categories depending on their pathophysiology. Type I hypersensitivity include immediate allergic reactions, type II hypersensitivity is defined as a cytotoxic response, type III hypersensitivity reactions are immune complex-mediated and finally type IV hypersensitivity reactions are delayed and cell-mediated. [14]

Type IV reactions are the only hypersensitivity reactions that involve sensitized T-lymphocytes rather than antibodies. A classical example of a type IV reaction is contact dermatitis causing a cutaneous rash by an allergen such as nickel. The development of symptoms in a type IV hypersensitivity could take only days or even take years after the initial sensitization. As nickel, titanium intolerance is characterized by the local presence of abundant macrophages and T- lymphocytes, indicating a true Type 4 hypersensitivity. These T-lymphocytes or "memory lymphocytes" are able to recognize the antigen even after years of the primary sensitization and release proinflammatory cytokines inducing several symptoms on the affected individuals (15,16). It has also been reported that titanium reactions are most often characterized as a type IV-hypersensitivity but in sporadic cases, a Type 1 allergic sensitivity reaction could be elicited [16,17].

2. Incidence

Titanium intolerance appears to be exceptionally rare, but some dental experts believe that oral-implant related titanium hypersensitivity is currently underreported because of failure to recognize it as a potential etiological factor [51,52]. To the author's knowledge there is only one demographic study reporting the incidence of titanium hypersensitivity. This value was reported by Sicilia et al. where the patients have been analyzed through an Epicutaneous Patch Test (EPT). The authors describe titanium hypersensitivity to have an overall incidence of approximately 0.6%. [18]

In general, EPT is an effective tool to diagnose a sensitization and explains certain adverse reactions in conditions like food allergy or metallic allergy including nickel. It consists in a cutaneous application of an allergen for 3-4 days to determine its sensitivity. An erythematous reaction is normally considered to be a positive association with the antigen.

Nevertheless, this testing procedure is of little use in the assessment of titanium hypersensitivity. The probability of a positive patch test reaction is extremely rare for a subject experiencing titanium hypersensitivity since titanium particles have a different reaction compared to other metals in testing due to the low epidermal penetration of Titanium salts. [19] Titanium-dioxide has been determined to not infiltrate in healthy and erythematous epidermis due to the increased reactivity for oxygen and due to the fact that it cannot exist in a free cationic form. [20] Hence, the conventional EPT is not a recommended tool to validate this problem. Due to the above-mentioned reasons, it is not possible to determine a true incidence value for titanium intolerance. At this point, the literature is lacking adequate data to determine a true incidence or prevalence of Titanium hypersensitivity reactions in a population.

3. Etiology: Concept of Implant Corrosion and Immune response to Titanium

Current literature shows that dental or endo-prosthetic implants can induce a clinically relevant hypersensitivity in a small and specific subgroup of recipients. Contrary to the past reputation of titanium as an "inert" metal, it is now well accepted that no metal is completely inert. As reported by Noumbissi et al., this could be a "silent inflammation factor," and its etiology may be behind the pathogenesis of implant pathology and failure [21].

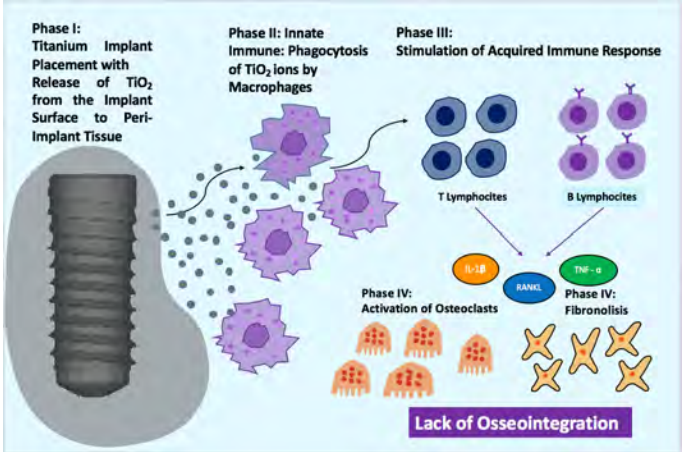

Figure 1: Schematic Diagram showing the Pathophysiology of Titanium Hypersensitivity.

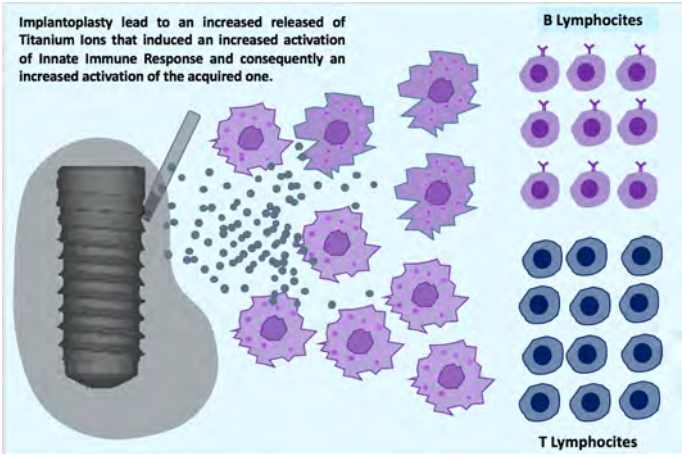

Figure 2: Schematic Diagram showing the effect of implantoplasty in patients with titanium hypersensitivity.

The release of Titanium particles into the peri-implant tissue is one of the key factors in the pathogenesis of Titanium intolerance. Corrosion is attributed to this presence of metal particles originated from the endosseous implant, in particular when excessive forces (pressure, torque) are applied during the surgical implant insertion or when friction occurs at the microgap between the implant neck and the abutment occurs[25, 29,30]. This also applies to certain treatment modalities such as implantoplasty which would significantly increase the release of titanium particles in the peri-implant tissue surfaces[25,30] [Figure 2].

Furthermore, Titanium alloy materials contain a small yet consistent percentage of detectable impurities, such as Al, Be, Cd, Co, Cr, Cu, Fe, Hf, Mn, Mo, Ni, Pd and V. The presence of these trace elements is believed to be negligible from a metallurgical standpoint but may potentially be significant enough to cause an allergic reaction in an already sensitized patient[20]. Therefore, impurities in certain circumstances could lead to adverse reactions and increase the release of titanium ions.[23,24]

Multiple types of intra-oral corrosion have been described in the literature, including uniform pitting, crevice, galvanic, stress, erosion and microbial corrosions [21,25]. The most common type of effect of degradation is termed as "tribocorrosion" which is a combination of the effect of friction, wear and corrosion [15,26]. The physico-chemical properties of the outer surface layer of a dental implant depend not only on the chemical composition of the implant bulk material but also on the solution chemistry[27] According to Revathi et al. titanium and its alloys spontaneously form an oxide layer on its external surface under typical physiological conditions.[12] The reviewed literature shows that the cascade of inflammation typically begins during the surgical implant placement and continues also during the osseointegration phase. As shown by microscopic evaluations, the first immuno-defensive cells to be affected are the macrophages that will phagocytize the titanium particles and stimulate the acquired immune response controlled by the T - lymphocytes. This will lead to a cascade of degenerative changes in different cells including macrophages and neutrophils which phagocytize titanium ions. As a consequence, proinflammatory cytokines, infiltration of inflammatory response cells and induction of osteoclast activity are stimulated and recruited locally to the peri-implant soft and hard tissues. Macrophages release pro-inflammatory cytokines, such as interleukin 1 (IL-1) and tumor necrosis factor alpha (TNF- α) mediating the inflammatory and osteolytic process of the peri-implant tissue [15,21,28]. This will ultimately break the biological stability and will induce an increase of osteoclastic activity in the peri-implant site. [Figure 1].

The role of cytokines in implant failure is meanwhile widely documented in the current literature. Vasconcelos et al. postulate that titanium particles induce cytokines activation of different proinflammatory factors such as RANKL, IL-1B, IL-6 IL10, TNF-α (33). A higher concentration of degradation products may directly increase the inflammatory mediators and therefore the osteolytic process though activation of RANKL, TNF-α and IL-6.

Furthermore, it was found that the presence of titanium dioxide is higher in sites immediately around failed implants and was also found systemically [34].

As previously described by Ghassib et al. in a systematic review and meta-analysis there is a statistically significant difference in biological markers between healthy implants, peri-implant mucositis and peri-implantitis being higher in two pathological groups (35). In this study, it is reported that IL-6 was higher in patient with peri-implantitis.

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In another study, it was found that Titanium - ions when eliciting an immune response were significantly higher ($p < 0.0001$) among patients with early compared to late implant loss [TNF- α: (256.89 pg/ml vs. 81.4 pg/ml) and IL-1b: (159.96 pg/ml vs. 54.01 pg/ml)][36]. Furthermore, an increased level of Titanium ions was found in subgingival plaque around implants with peri-implantitis compared with healthy implants [37].

In summary we can conclude that corrosion processes can lead to a cascade of alterations on the implant surface that include the disruption of the TiO2 layer and facilitate titanium dissolution into peri-implant soft and hard tissues.[25] These titanium particles and ions leaked from dental implants are vulnerable to corrosion attack in wet environments inducing an immunogenic potential and acting as secondary stimuli for the inflammatory process which may enhance bone lysis and resorption. Understandably, this proves to be an issue if the metal object is implanted into hard tissue [21,22,25].

4. Diagnosis of Titanium Hypersensitivity

When suspecting titanium intolerance, a proper medical examination with evaluation of potential metal allergies must be carried out in order to assess and determine a possible presence of Ti-hypersensitivity. A meticulous history of the implant history must be obtained consisting of the time of placement, type of implant, implanted materials, and previous unexplained implant failures. One of the most common pathognomonic factor of titanium hypersensitivity is early implant failure after implant placement with early bone loss and even lack of osseointegration of the implant fixture.

4.1 Medical and Implant History

Every clinician must evaluate and determine the cause of implant failures.

• Medical conditions: It is essential to assess, resolve and discard other well-established medical risks factors including smoking, elevated cholesterol, uncontrolled diabetes, bone pathologies, history of chemotherapy or radiation and previous history of periodontitis[21,28]. Certain nutrient deficiencies such as but not limited to Vitamin D3, Vitamin K2, Magnesium and Vitamin C need to be assessed and resolved when applicable.

• Implant surgery related factors: It is relevant as well to reject other implant risks factors including an improper surgical procedure, improper implant selection, placement in pathological sites or in non-healed grafted material. [13]

• Implant material related factors: Furthermore, a meticulous allergic history of the patient must be carried out. Wood et al. reported that if a patient who is considered to have implant placement presents with one or multiple adverse immune responses to a metal there is an increase chance to have an adverse event with the implanted material [20].

4.2. Clinical and Radiological exam:

A proper clinical examination along with a synergic radiological evaluation of the implant must be conducted.

• Intraoral Exam: Presentations of perioral stomatitis, peri-implant mucositis, unexplained pain on the implant site, oral edema, perioral erythema and hyperplasic tissues or a granulomatous reaction surrounding the implants are the most common intraoral manifestations. [17,20,38-43]

• Extraoral Exam: presence of lymphadenopathies or extraoral abnormalities including erythema, rashes, acne-like facial inflammation, psoriatic epidermis or facial swelling especially in sub-labial and sub-mental regions.

• Systemic Exam: The classical systemic reactions include urticaria, eczema, muscle and joint pain, hair loss, eczematous rashes, neurological symptoms, chronic fatigue syndrome and even episodes of memory loss [17,18,20,21]. In recent studies, it was suggested that titanium particles could travel through blood stream and reach organs like lungs, spleen, liver, or abdominal lymph nodes [19,33,44]. Furthermore, recent studies have demonstrated that there is growing evidence that titanium particles could even affect and produce mutagenesis of the DNA structure of the peri-implant microbiota [2, 34, 45].

• Radiological signs are rare but one of the possible signs of titanium intolerance is early osteolysis around the implant with failure of osseointegration [21,15,33].

4.3 Diagnostic Testing

Diagnostic testing for titanium intolerance has a longstanding, unreliable, and frustrating history. Currently, there is no gold standard diagnostic tool in place to assess titanium intolerance or hypersensitivity. Nevertheless, literature has identified different techniques such as the Epicutaneous Patch Test, Lymphocyte Transformation Test (LTT) and Memory Lymphocyte Immunostimulation Assay (MELISA).

• Epicutaneous Patch Test: EPT is an effective tool to diagnose other metal allergies (e.g. nickel, beryllium, cobalt, chromium). A patch test consists of the appliance of an allergen to skin for 3–4 days; for which development of an erythematous reaction is considered positive. As already mentioned above, compared to other metals, Titanium particles do not behave in the same manner due to the low capacity of penetration of Titanium

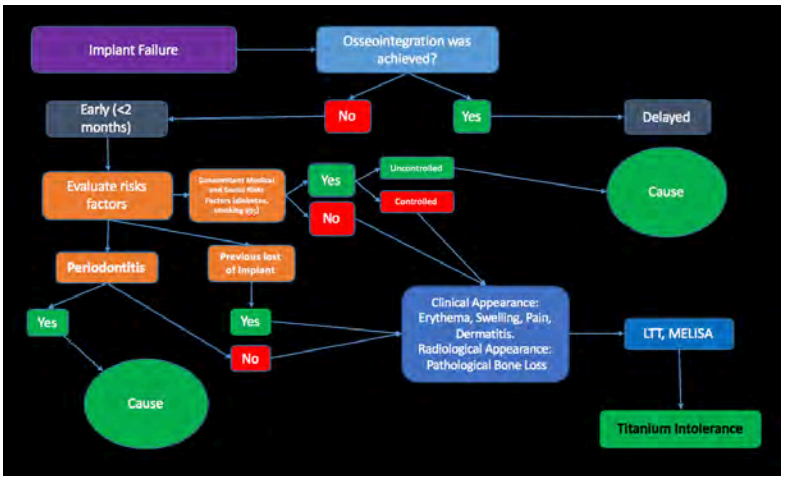

Figure 3: Algorithm to assess titanium intolerance.

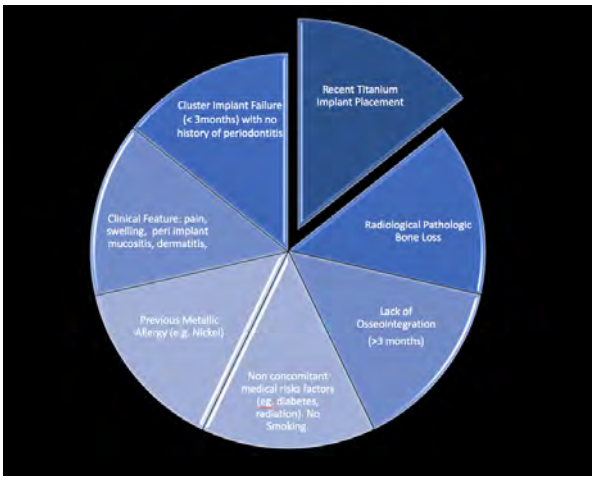

Figure 4: Risk Factors for Titanium Intolerance.

ions in the epidermis. Hence, a high percentage of false negatives or false positive test results tend to make EPT an unreliable diagnostic tool for Ti Hypersensitivity (19,20). Currently, there is no reliable patch test for titanium hypersensitivity.

- Lymphocyte Transformation Test: LTT an in vitro measurement of the proliferation response of lymphocytes following antigen-specific activation and aims to assess whether a patient has developed a specific T-cell sensitization. Unlike patch testing, LTT cannot induce sensitization. Studies show that LTT has a higher sensitivity compared to the regular EPT in detecting Type IV reactions [20]. Mueller and Valentine-Thon tested patients with various health problems after receiving titanium implants and observed that 37.5% of their patients tested positive to titanium on LTT, all of them patch tested negative. Removal of the implants resulted in dramatic improvement of clinical symptoms in almost all patients. Interestingly, they also observed normalization of LTT response following implant removal [54]. Nevertheless, the most important limitation of LTT is the frequent lack of clinical correlation in patients with and without metal sensitivity and the not widespread acceptance of this test by dermatologists. In general, only a handful of articles have been published with data on LTT testing for titanium allergy/intolerance.

- MELISA® - Test: MELISA is a clinically modified and updated version of the LTT and a validated blood test which can identify type-IV hypersensitivity reactions mediated by T-lymphocytes that have had prior contact with a given allergen. It uses defibrinated blood. Literature shows that MELISA is able to offer a sensitive result and can be able to decrease the number of false positive or false negative test results of LTT[46,47]. Although MELISA® is a widely published in vitro test, and a number of articles have suggested its clinical utility, it is not approved as a routine method for testing Titanium intolerance and is still under evaluation.

Owing to the suspected low specificity of MELISA to Titanium and its sensitivity also to other metals, an overestimation of the actual prevalence might be considered and is problematic.

In summary, generalized preoperative screening as a clinical standard protocol cannot be recommended at this time since MELISA® and LTT require a prior sensitization to indicate Titanium intolerance and should only be applied when a patient is suspected of having a Titanium intolerance condition.

4.4. Differential Diagnosis:

Sensitivity to other metals (nickel, vanadium) or materials (epoxy resin) may masquerade as titanium sensitivity (20). It is acknowledged, that a multitude of factors can be attributed to early implant failure including patient related factors and also overheating, overpressure or over-torque at the osteotomy site and a preoperative low plasma level of Vitamin D3, Vitamin C, Magnesium and other minerals and nutrients. An Algorithm that is applicable to every clinician in the assessment of titanium intolerance (Figure 3). A summary of all the indicating factors is described in Figure 4.

5. Treatment Options

If Titanium-hypersensitivity is confirmed, the only reasonable treatment is the removal of the implants as atraumatic as possible in order to minimize further release of titanium particles into the tissue. Hence, it is suggested to avoid surgical high-speed burs and only use counter torque or counter screw technique devices or trephine burs of wider size than the implant platform. After the removal, the authors suggest to copiously irrigate the socket with saline solution, chlorhexidine or ozone and let the surgical site to heal for a period of approximately 3-4 months without placement of a further Ti - implant. Literature shows that after the removal of the Ti - implant, oftentimes patient

reported resolution of the symptoms. [17,39,43] If the patient requests another implant fixed restoration in the previous failed implant site, clinicians should consider the use of zirconia ceramic implants.

Other treatment options and attempts to preserve a titanium implant such as an open flap debridement with curettage of the implant surface or implantoplasty, would instead rather lead to another titanium release into the peri-implant hard and soft tissue. Hence, the authors, do not recommend these techniques to be performed in patient experiencing symptoms of titanium hypersensitivity.

Medical management has also been reported but not for titanium hypersensitivity in dental implants. After 3 unsuccessful pacemaker implant attempts in a 10-year-old girl because of titanium hypersensitivity (including a failed attempt at coating the pacemaker case with silicone), the patient was managed medically with oral atropine sulfate every 6 hours with adequate control [53].

CONCLUSIONS

Concerns have been raised regarding titanium's potential to induce hypersensitivity or inflammatory reactions in host tissue. Titanium is still considered to be one of the most used material and biocompatible device for endosseous dental implants and for medical appliances. However, the current literature provides a proven evidence to sustain that titanium hypersensitivity is a fact and not a fiction. Titanium particles induce inflammation and osseo-disintegration in a minority but rapidly growing number of implant recipients and these reactions could lead to biological complications and even to the failure of dental implants. There is an established association between biocorrosion, presence of titanium particles and biological implant complications. A diagnostic test already exists to identify Ti-intolerance. However, this tool (MELISA) is yet incapable of predicting a possible implant failure preoperatively without primary titanium exposure. Therefore, further studies need to focus on developing a reliable and useful preoperative screening method to predict a potential hypersensitivity reaction to implanted titanium devices.

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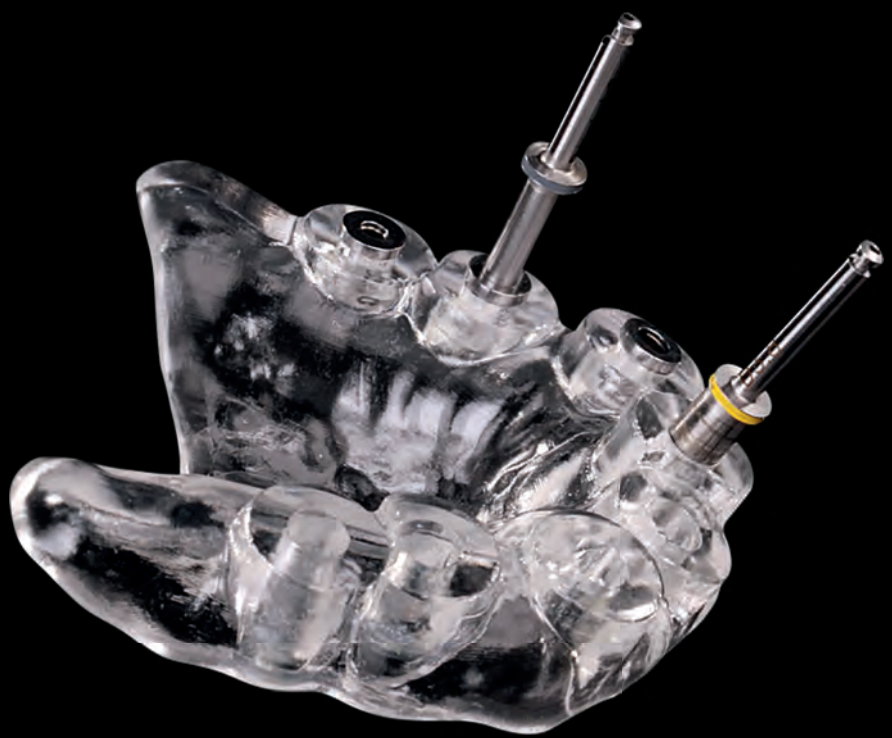

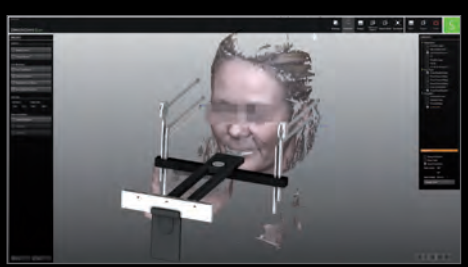

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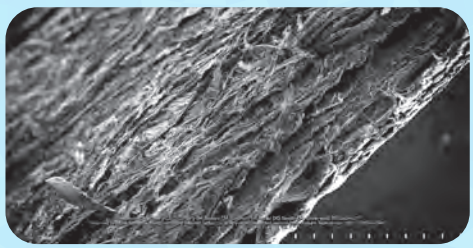

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