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Review article

Insight into Bio-Advancement of Dental Implants

***Abdul Habeeb Bin Mohsin* [1], *Sarah Samee* [2], Mohammed Ayaz** [3]

[1] *Assistant Professor, Department of Prosthodontics, Sri Sai College of Dental Surgery, Vikarabad, Hyderabad*
[2] *Post Graduate Student, Department of Oral and Maxillofacial Pathology, Sri Sai College of Dental Surgery, Vikarabad, Hyderabad*
[3] *Department of Orthodontics and Dentofacial Orthopaedics, School of International Education, Zhengzhou University.*

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ABSTRACT

Implant companies has developed the anatomic implant, a CAD/CAM (computer aided design / computer aided manufacturing) Zirconium implant used in immediate placement. The hopeless tooth is extracted atraumatically to avoid any damage to the extraction socket, which is to be used as implant site. Particular care has to be taken to preserve the buccal cortical bone. The root or an impression of the extraction socket serves the purpose for production of the individualized immediate implant. The prepared root/impression is then scanned and the implant milled from a medical-grade Zirconia block, the surface is roughened by sandblasting and sintered to achieve the desired mechanical properties. Thereafter the implant is sterilized. Within few hours the customized implant is ready for use.

Introduction

Dental implantology has expanded rapidly from clinical advancement stand-point since its introduction by Branemark.[1] With the introduction of capable technologies in design, manufacturing, and testing, the dental implant advanced to its dominant design driven by clinical research and trends of success and failure by patient monitoring feedback.

The loading prevention period which was discussed in several previous studies concluded that the amount of motion provoked at the implant/alveolar bone interface in early stages of implantation strongly affects the implantations success.

Several alternative rationales were prescribed along the years, which deal with shortcomings found in different protocols. Hodosh et al[2] introduced the concept of root-analogous implants, which enables insertion right after extraction. Some in-vivo testing proved to provide some initial success, however portrayed poor success results (48%) 9 months after implantation. Kohal, et al[3] rendering the concept as unattractive. More recent by Pirker et al[4] employs CAD/CAM (computer aided design / computer aided manufacturing) techniques to produce root-analogous zirconia implants with macro-retention on the surface. A main improvement is the reduction of the implant size where it comes in contact with the brittle crestal bone, which was one main factors affecting the poor success rates of older versions of the concept.

* *Corresponding author:* ***Dr. Abdul Habeeb Bin Mohsin, 23-2-360/3, Moghal Pura, Hyderabad, Telangana, India, 500002. Email: doc.habeeb@gmail.com, Ph +91 9849990569***

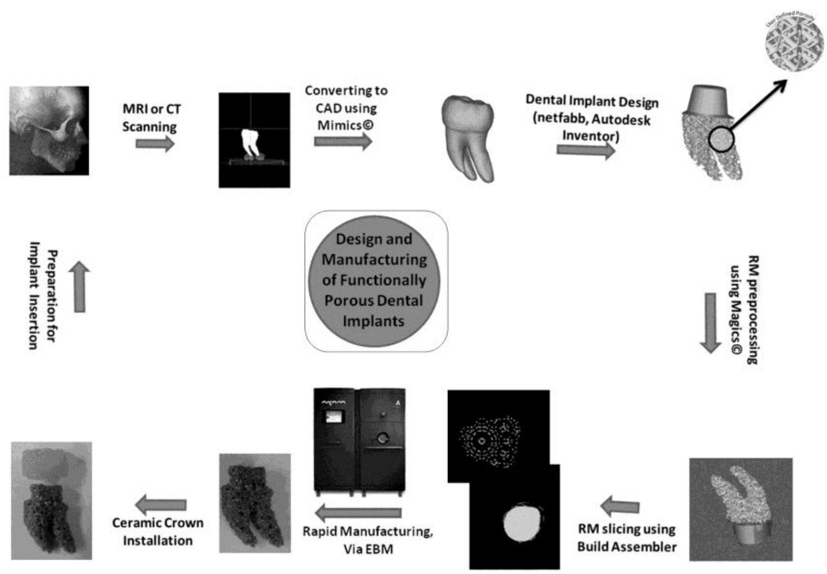

Fig. 1

Modern Concept (Fig.1)

Production of application-specific parts, a cost and time effective track of designing and producing customized dental implants was devised with the advantage of modern computed tomography (CT) techniques and the subsequent analysis capabilities of the scan data and the generation of three-dimensional computer models, in addition to additive manufacturing (AM).

1. This concept helps in treatment of compromised teeth by means of immediate placement of implant after extraction. Patient's CT scan is sufficient to provide enough geometrical data to produce a CAD (computer aided design) model of the tooth to be replaced. Subsequently scanned model is used to generate an identical root design along with two characteristics: functionally graded porosity (FGP) and advanced abutment design (AAD). The design is then prepared for additive manufacturing (AM) and manufactured. Before being sent to the dentist's office the implant undergoes post-manufacture processing steps before extraction of natural tooth. Entire processing takes around 24 to 48 hours, enabling the bio-device to be produced in time and cost-effective manner.
2. There are several advantages of bio-adaptable dental implant treatment protocol when compared to the traditional approach. The implant placement is done in one single visit in contrast to the three-visit protocol. The bio-adaptable implant is customized according to the patient and clinical situation; resultantly it provides optimal function and superior esthetics when compared to stock manufactured implants. In case of pre-stored CT scan in CT scan banks if available, the implant can be ready upon the initial dental visit of the patient

where the dentist can atraumatically remove the damaged tooth and insert the implant with minimal to no site preparation. Minimizing trauma will provide with faster healing of the surrounding bone.[5] In addition, the immediate placement can provide immediate esthetics and function.

Imaging Analysis

3. Scan analysis techniques and software allows surgical pre-planning and enhances the ability of surgeon to visualize and predict the surgical outcome.[6] Imaging data obtained from computed tomography (CT) or magnetic resonance imaging (MRI) analyzed and geometrical models of different organs can be generated and used for a wide range of potential numerical simulation of bi-mechanical and biological response. CAD models of the different bio-components are produced by extracting partial geometry of a patient's jaw by CT scan analysis using Mimics, software developed by Materialise (Belgium), where grayscale analysis is employed at every image to separate the different biomaterials (cortical bone, alveolar bone, dentition, & periodontal ligament).

Also the grayscale analysis enables the detection of the anisotropic material properties of the different components. Grayscale analysis contributes to more realistic point of interest by mapping the grayscale distribution within a component, a distribution of the local material properties can be generated like elasticity and density.

Design Tool

4. Finite element method (FEM) is a numerical simulation technique which accurately represents complex geometry. FEM is used to solve equations that govern thermal, mechanical, and flow phenomena. The main idea of executing FEM into the design of a bio-adaptable dental implant is to deal with customizing the mechanical properties of different elements of the bio-device, in order to satisfy certain conditions inflicted by the implantation. ANSYS Workbench is a comprehensive and integrated simulation system used to solve for the stress and strain distribution along the geometrical domain.

DISCUSSION

Zirconia is a strong biomaterial and is a unique dental ceramic due to its ability to undergo transformation toughening.[7] The mechanical properties with high-fracture resistance and the elastic modulus of Zirconia might also contribute to the bone healing and provide mechanical stability. Moreover, this material is highly radiopaque.[8,9]

Since Zirconia implants are one-piece implants that can be left to heal submerged and can be easily provisionalised after their placement, it would be interesting to understand whether it is preferable to keep them out of occlusion during the osseointegration phase or if it is possible to immediately put them into function without an increased risk of failure. While there is abundant literature on titanium implant,[10] little is known about the outcome of Zirconia implants.[10,4]

Presently, pure titanium is the material of choice for dental implants. This material has been used for about

30 years as an implant substrate and has shown high rates of success. However, there is the disadvantage of grey metallic components showing through the mucosa or becoming visible in cases of soft tissue recession and an increasing number of patients are asking for metal-free treatment options. One of the possible solutions would be to make implants from tooth-colored materials, such as ceramics. Favorable mechanical, biological, esthetic properties, potential for osseointegration and the ability to customize it and place it immediately following extraction make zirconia material of choice for dental implants in recent times.

There are various recommendations regarding timing of implant placement after tooth extraction. The implant can be placed, immediately following the extraction during the same surgical procedure (Immediate implant placement) following a delay of 2-6 weeks (late implant placement). Other is following a delay of 3-6 months (delayed implant placement) to allow bone healing months or years following the tooth loss.[11] The predictability of aesthetic success depends on the tissue loss present at the initiation of treatment. The greater the amount of bone and soft tissue loss, the more difficult it becomes to produce an ideal aesthetic result.[12]

In 2004, Kohal and Klaus[10] reported the first clinical case report of placement of zirconia implant immediately after extraction. They presented a case in which an all ceramic custom made zirconia implant system was used as the replacement for a single tooth. They extracted a maxillary central incisor and immediately implanted a zirconia implant with successful outcomes. Pirkar et al[4] demonstrated the successful clinical use of a modified root analogue zirconia implant for immediate single tooth replacement. A right maxillary premolar was removed and a custom-made, root analogue, roughened zirconia implant with macro - retentions in the interdental space was fabricated and placed into the extraction socket 4 days later. No complications occurred during the healing period. An excellent esthetic and functional result was achieved. Pirkar et al[13] conducted the study for two rooted tooth describes the successful clinical use of an immediate, single stage, truly anatomical root-analogue zirconia implant for replacement of a two-rooted tooth. Significant modifications such as macro-retentions yielded primary stability and excellent osseointegration. This novel approach is minimally invasive respect the underlying anatomy, aids socket prevention, its time and cost saving with good patient acceptance as there is no need for bone drilling, like bone augmentation or other traumatic procedures. W. Pirker & A. Kocher[13] conducted a clinical case study for replacement of true anatomical Zirconia implants for molar replacement.

In a recently developed root analogue implant system, CAD/CAM was used for the fabrication of the root analogue which allowed the immediate replacement of teeth which had to be extracted.[3,14] Lundgren in 1992 concluded that this system osseointegrated with a high degree of predictability and the quality of bone-to-implant contact was high enough to function well. However; long surgical time was needed in immediate replacement with this system.[15] Today the combination of anatomically oriented implant designs, new biomaterials such as zirconia ceramics, and surface technologies has resulted in dental implants that are specially designed to replace each individual tooth.[8]

Conclusion

This concept restores immediate function and esthetics and reduces treatment time. Minimal invasive procedure & enhanced bone response makes bite feel better due to micromotion capabilities. Overall improved patient satisfaction and reduced cost of treatment.

This concept studies a new trend in implantology, where the implant matches the patient, instead of the contrary. This is only possible due to the emergence of digital dental engineering and the ability of producing customized bio-device which is economically attractive, due to its cost and time efficiency.

Future prospect includes in-vivo testing of bio-implants. More defined features can be designed and produced at a higher degree with the progression in CT scan and additive manufacturing resolution.

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