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FEM ANALYSIS FOR STRESS DISTRIBUTION OF ROOT ANALOGUE ZIRCONIA DENTAL IMPLANT: A REVIEW

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Abstract: Dental implants constitute a well-established approach for substitute of lost teeth with titanium being the most preferential material for implantation. However, titanium has its confines in esthetically demanding cases and neither the form nor material of such implants has changed much over the past 40 years. Immediate implantation is used to overcome the disadvantages of conventional implantation which in turn has many disadvantages owing to the incongruence of the implant to the extraction socket. Today, there is scientific evidence that Zirconia dental implants osseointegrate well and offer many advantages over titanium implants. The successful use of Zirconia ceramics in orthopedic surgery has led to a demand for dental zirconium-based implant systems. Because of its excellent biomechanical characteristics, biocompatibility, and bright tooth-like color, Zirconia (zirconium dioxide, ZrO2) has the potential to become a substitute for titanium as dental implant material. In addition, there are previous reports on the successful use of Zirconia as root-analogue implants by reproducing the contours of the extracted toot.

No complications occurred during the healing period. An excellent aesthetic and functional result was achieved with the composite crown. Significant modifications such as macro retentions seem to indicate that primary stability and excellent osseointegration of immediate root-analogue Zirconia implants can be achieved. The macro-retentions must be limited to the interdental space to avoid fracture of the thin buccal cortex.

Keyword: dental implant, immediate implantation, osseointegration, biocompatibility.

I.INTRODUCTION

Ceramic materials are best able to mimic the appearance of natural teeth. dental implant is used to anchor the artificial tooth and hence support it in same manner as that of natural anatomical root (fig 1) as a result of the good properties of dental ceramics, such as esthetics, chemical resistance, hardness, compression resistance and biocompatibility, a significant effort has been made over the years to improve their weak points which include brittleness and low tensile strength.[1],[2].

A progressive improvement in the mechanical properties of dental ceramic has led to an increase in Metal free restorations. The Zirconia systems currently available for use in dentistry include ceramics with a 90% or higher content zirconium dioxide, which is the yttrium, stabilized tetragonal Zirconia (Y-TZP). Mostly titanium implants are widely used because of advantageous mechanical properties [1]. The process and resultant apparent direct connection of an exogenous materials' surface and the host bone tissues, without intervening fibrous Connective tissue present or Dental implant integrates with surrounding bone, the phenomenon is called Osseointegration and it is very important consideration for success of dental implant. The conventional two piece implant comes across many problems like abutment screw loosening and abutment screw fracture occur after the prosthetic phase. Simon

[2] determined the success rate of implant restored as single molar and premolar crowns and reported that the dental implant failure rate was 4.6%; of which abutment screw loosening occurred in 7%. Hence it is need for some other types of implant having several good properties.

Replacement of lost teeth using oral implants is an accepted treatment modality with well documented, high long-term success rates of up to between 90% and 100% at 10-year follow up [2]. Titanium and titanium alloys are widely used for fabrication of dental implants [3]. With titanium it is difficult to manufacture to have anatomical root structured implant along with esthetics look like natural tooth. Expectations regarding esthetics in dentistry are growing and research in the field of all ceramic materials for restoration of natural dentition and dental implants has intensified. To improve the esthetic aspect of dental implants, a ceramic material, Zirconia, was introduced [4]. Zirconia provides greater machinability over titanium alloy implant with good esthetic look. It is possible to have immediate implant placement has its own advantages and the problem of incongruence associated with it can be rectified by employing a novel approach using custom-made root analogue implants placed into the ex-traction socket. By adapting the root to the extraction socket instead of adapting the bone to a preformed standardized implant they reduced the bone and soft tissue trauma [5]. Zirconia-based implants were introduced into dental implantology as an alternative to titanium implants. Owing its ability to be milled into the shape of the natural tooth root and be placed immediately following extraction, excellent biomechanical characteristics, biocompatibility, and bright tooth-like color, Zirconia has the potential to become a substitute for titanium as dental implant material [3]. Stadlinger B, et al [6]observed that osseointegration of Zirconia implant is 80% and titanium74% .The success rate of Zirconia implant is more as compared to titanium implant.

II.IMMEDIATE PLACEMENT OF ZIRCONIA IMPLANTS

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).Following a delay of 3-6 months (delayed implant placement) to allow bone healing. Months or years following the tooth loss [7]. 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 [8]. In 2004, Kohal and Klaus 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 crown 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 [9]. Pirkar et al [10] demonstrates 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 (As shown in fig. 2) 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 [11] conducted the study for two rooted tooth report 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. Refer fig 3. This novel approach is minimally, invasive, respect the underlying anatomy, aids socket prevention, is time and cost saving with good patient acceptance as there is no need for bone drilling. Since like bone augmentation or other traumatic procedures. Fig .2. Custom-made Zirconia implant with the mesial root slightly modified for ease of implant placement compared with a conventional titanium implant buccal view W. Pirker & A. Kocher [11] conducted a clinical case study for replacement of true anatomical Zirconia implants for molar replacement.

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Fig. 1 Implant before insertion, and a copy of the extracted tooth with macro-retentions.

Case presentation

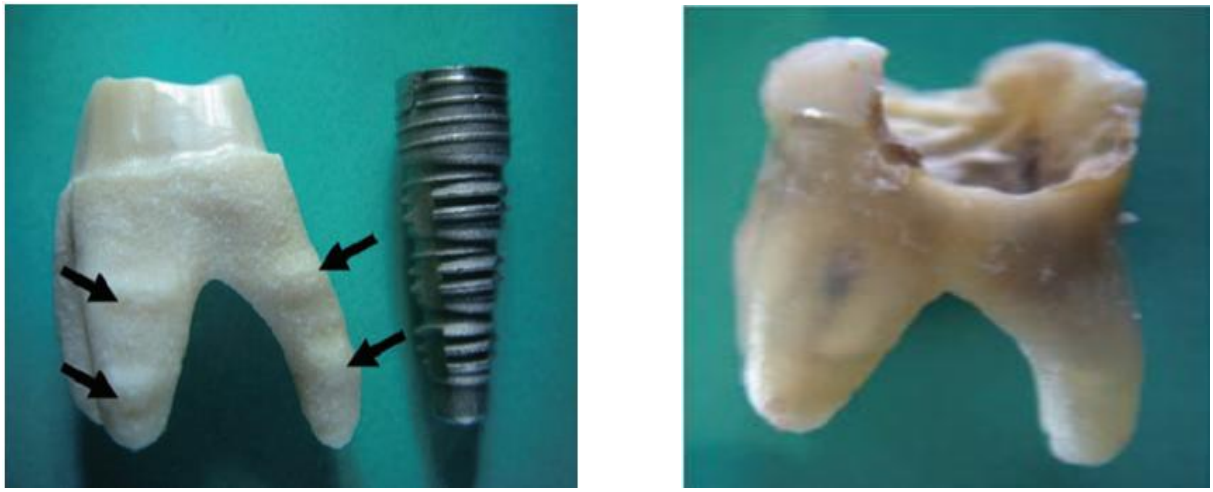

Fig.2. Anatomical Zirconia implant compared with conventional titanium implant.

Zirconia a root analogue custom implant material

In immediate implantation of Zirconia, following tooth extraction, however, a socket often presents dimensions that may be considerably greater than the diameter of a conventional implant. Hence, after implant installation a gap may occur in the marginal part of the recipient site [11]. 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 [10,11]. Lundgren 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 [12]. 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 [13]. It is observed that during above investigation the stress distribution for root analogue in Zirconia implant for various root surface pattern are not studied. Various surface patterns can be used like elliptical oval shape pattern, rectangular horizontal pattern, rectangular vertical pattern, micro porous texture and different serrations for retention and stability of implants.

Properties of Zirconia

Partially stabilized Zirconia, which is comparable to the highest values for oxide ceramics, has been introduced as a new ceramic implant material [14]. Yttria–stabilized tetragonal Zirconia polycrystal (YTZP)

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exhibits a very high flexural strength (900 to 1,200 MPa), a favorable fracture toughness (KIC7 to 1 MPam–1), and a suitable Young's modulus (210 GPA) [10]. Zirconia is a strong biomaterial and is a unique dental ceramic due to its ability to undergo transformation toughening [15]. 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 [16],[17].

Properties of some materials for biomedical applications

Property	Units	Ti 6Al 4V	316 SS	CoCr Alloy	TZP	Alumina
Young's modulus	GPa	110	200	230	210	380
Strength	MPa	800	650	700	900–1200	>500
Hardness	HV	100	190	300	1200	2200

Davies emphasized the importance of implant surface design and micro topography to achieve what he called "de novo bone formation" on the implant surface itself, in addition to the ingrowths of bone from adjacent bone surfaces. Roughened surfaces have been shown to support osteoconduction leading to bone formation on the implant surface [17]. Furthermore, Sennerby et al found that Y-TZP implants with a moderately roughened surface showed a fourfold to fivefold increase in resistance to torque forces compared with machined Y-TZP implants after 6 weeks of healing [18]. 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 [19, 20]. Lundgren 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 [12]. 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 [16].

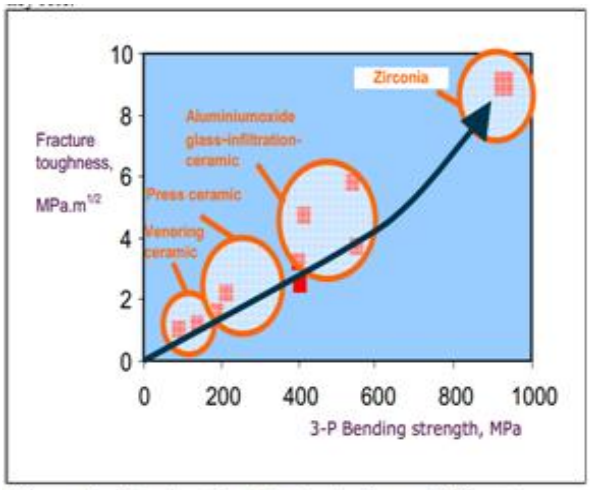

Figure **Bending strength vs. fracture toughness of different ceramic systems.**

III.DISCUSSION

Since Zirconia implants are one-piece implants that can-not 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 [9], little is known about the outcome

of Zirconia implants [9, 10]. 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 ex-traction make Zirconia, a ceramic material of choice for dental implants in recent times. It is found that there is gap between actual clinical study and the FEM analysis for the various root analog structure with different surface texture for minimum stress at crystal bone for the vitro study is not studied.

Zirconia implants are mainly manufactured in one piece. So the problem like abutment loosening, fracture and metal look never arises. Advantage of one piece implant is time and cost saving. However further study are needed about this type of root analogue implants provide with different patterns on root surface of implant.

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