Review article:

Computer aided design of customized zirconia dental implants with macro retentions: A review

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Abstract:

Background: The history of dental implants can be dated back to 600 AD in Mayan civilization. Dentistry science took huge leap when Swedish surgeon, Branemark, introduced threaded titanium implants in 1952. Now-a-days zirconia is used as biomaterial for root analogous zirconia dental implants. This study signifies that significantly modified zirconia dental implants is a better alternative for conventional immediate implants.

Methodology: The Google Scholar, Researchgate, Science Direct, PubMed database was searched electronically with the use of keywords like titanium vs zirconia, zirconia dental implants, surface topographies of dental implants & root analogous zirconia dental implants & zirconia implants. Available articles were obtained & whenever possible unavailable articles were requested from the corresponding authors. After studying the research papers their references were also searched & requested.

Results: The specified search ended with around 260 articles. Most of which were review articles, clinical trials, in vitro and in vivo studies. On careful review, 23 of which were found to lie within the criteria specified. Out of which 5 were related to titanium vs zirconia dental implants, 4 emphasized zirconia as a biomaterial, 9 articles presented different surface topographies of dental implants, 5 were clinical studies enlightening clinical success of root analogous zirconia dental implants & 2 other dental studies.

Conclusion: Based on the review it can be conclude that zirconia ceramics are the much better alternative for gold standard dental biomaterial, titanium. Zirconia shows.

Keywords: Titanium vs Zirconia, Dental Implants, Surface Topographies, Root Analogous Zirconia Dental Implants, Macro Retentions.

Introduction

The history of dental implants can be dated back to 600 AD in Mayan civilization. Archeologists also discovered the roots of dentistry in Greek & Egyptian history. The different archeological surveys showed that the dental materials include carved stones, fragments of sea shell, elephant tusk, wood & various metals also.¹¹

Maggito² inserted gold roots in tooth sockets around early nineteenth century (1809). Dentistry science took huge leap when Branemark, introduced threaded titanium implants in 1969. Since then titanium has
been the most preferred dental material for over 4 decades.

Zirconia began its role as biomaterial in 1969 when Hekmer & Driskell[^3] described biomedical applications of zirconia. Also the materials such as Tetragonal Zirconia Polymers (TZP or Y-TZP), polycrystalline alumina, and glass ceramics marked their baby steps in dentistry around last one & half decade[^4]. Last decade also witnessed the introduction of newer processing technologies like CAD, CAM, and Rapid Prototyping etc.

Now a days zirconia is used as biomaterial of uttermost choice in the field of immediate implantation i.e. - for root analogous zirconia dental implants. Researchers & practitioners have shown that significantly modified root identical zirconia dental implants is an better alternative for conventional immediate implants, i.e.- root analogous titanium implants.

This review is an attempt to throw some more light upon 1) titanium vs zirconia dental implants, 2) zirconia as a biomaterial, 3) surface topographies of implants & 4) clinical success of root analogous zirconia dental implants.

**Material & Method**

The Google Scholar, Researchgate, Science Direct, PubMed database was searched electronically with the use of keywords like titanium vs zirconia, zirconia dental implants, surface topographies of dental implants & root analogous zirconia dental implants & zirconia implants. Available articles were obtained & whenever possible unavailable articles were requested from the corresponding authors. After studying the research papers their references were also searched & requested.

The articles found were included in study on the basis of following criteria:

1) studies related to comparison of titanium and zirconia as dental implant materials,
2) studies and clinical trials enlightening advantages of zirconia as biomaterial,
3) studies focused on dental implant surface roughness/topographies and macro/micro retention patterns,
4) clinical trials of root analogous zirconia dental implants placed into humans.

**Results**

The specified search ended with around 260 articles. Most of which were review articles, clinical trials, in vitro and in vivo studies. On careful review, 23 of which were found to lie within the criteria specified. Out of which 5 were related to titanium vs zirconia dental implants, 4 emphasized zirconia as a biomaterial, 9 articles presented different surface topographies of dental implants, 5 were clinical studies enlightening clinical success of root analogous zirconia dental implants.

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Comparison of Titanium and Zirconia Implants

Hans J Wenz et al[5] evaluated osseointegration & clinical success of zirconia implants. On peer review of 96 articles related to clinical & animal studies, he found that osseointegration of Y-TZP (zirconia) implants is as high as that of titanium implants. Also surface modifications can lead to enhanced bone healing. It was concluded that zirconia has ability to act as replacement for titanium implants.

Rehman B Osman et al[6] studied various dental implant materials. They assessed various properties of implant materials and problems associated with them. They observed that titanium fails under high cyclic loading and on the other hand similar or even better bone growth of zirconia surface compared to titanium surface. So conclusion was, fabrication of dental implants can be governed by zirconia implants.

Rahul Patil[7] in 2015 concluded that although titanium has success and survival rate, its corrosiveness and individual sensitivities to it makes it less popular. On the other hand zirconia success rate and aesthetics proves zirconia, a viable alternative.

Gabrial Marques et al[8] inserted titanium and zirconia implants into right and left tibia of 15 rabbits for up to 60 days. They found that, up to 30 days bone healing was same but after 45 days early bone maturation takes place. So they concluded that zirconia and titanium has comparable bone healing.

In an in vivo comparison of osseointegration of zirconia and titanium implants, Rita Depprich et al[9] introduced a total of 48 implants in 12 minipigs. Out of 48, 24 were screw type zirconia implants and 24 were pure titanium implants. Although BIC was higher for titanium implants, it was concluded from the histological results that modified zirconia implants has osseointegration comparable with titanium-implants.

Advantages of zirconia as biomaterial

C Piconi[3] et al in 1997 reviewed the various properties of zirconia based on the articles published. They studied microstructural properties, mechanical properties, wear, biological safety etc. Upon study among zirconia ceramics Tetragonal Zirconia Ceramics (TZPs) can be preferred as biomaterial of choice for dental implants.

Zeynep Ozkurt et al[10] in 2011 worked on zirconia dental implants (TZP). The study of articles related to Bone to Implant Contact (BIC), surface analysis, removal torque study (RTQ), mechanical strength and stress analysis concluded that osseointegration of zirconia dental implants may be comparable with that of titanium implants. They also have low, well distributed and similar stress distribution compared with titanium implants.

Xavi Oliva et al[11] in 2013 during histomorphometric study in sheep inserted eight zirconia implants (Y-TZP) into hip of an adult sheep. After 2 months BIC was observed to be 75.6 to 79.9%. It was concluded on from the results that zirconia has excellent biocompatibility and osseointegration. Also RTQ test demonstrated rigid fixation between implant and bone.

Scarano et al[12] experimented on rabbits in order to study bone response to zirconia ceramic implants(Y-TZP). The experiment included 5 rabbits each with 4 implants, 2 in left tibia & 2 in right tibia. The BIC was found to be 68.4% ± 2.4%. No gaps, fibrous tissue and infiltrate were observed at bone implant contact.
Surface roughness/topographies and macro/micro retention patterns

Isabel de Monserrat et al\cite{13} studied the implant surface roughness and different topographies. They reviewed about 30 articles consisting of in vivo studies in human, in vivo studies in animals and in vitro studies. The average success rate observed for rough surfaced implants was 93.48% & 83.42% for implants with other than rough surfaces.

Rama Krishna Alla et al\cite{1} in their article presented the surface roughness characteristics and their effect on osseointegration of dental implants. Their study showed that response of the tissues to the implant is largely controlled by the nature and texture of the surface of the implant. Compared to smooth surfaces, textured implants surfaces exhibit more surface area for integrating with bone via osseointegration process.

Also various in vivo studies by Buser D et al\cite{14}, Gotfredson K et al\cite{15}, Puleo D A et al\cite{16} demonstrated that enhanced surface area of the implant improves BIC after the implant placement.

Arthur Belem Novaes Jr. et al\cite{17} in 2010 reviewed the quantitative and qualitative results on the analysis of bone-implant interface using micro and nano surface topographies. They concluded that the implant surfaces with micro and sub micro (nano) topography bring forward benefits to the process of interaction between bone cells and implant surfaces, accelerating and increasing the quality of BIC.

Rafael Arcesio Delgade-Ruiz et al\cite{18} within their study concluded that addition of microgrooves on the surface of zirconia dental implants enhances primary and secondary implant stability, promotes bone tissue ingrowth and preserves crestal bone level.

Radhika B Parekh et al\cite{19}in their study, on peer review, stated that surface composition, surface topography, surface roughness and surface energy affects the mechanical stability of implants and osseointegration.

Kishorkumar Khandare et al\cite{20}; in 2013 analyzed the different micro retention patterns for root analogous zirconia dental implants. They found the stress values for horizontal rectangular, vertical rectangular, horizontal oval, vertical oval shaped micro retentions in canine and also premolar teeth. On the basis of analysis performed they concluded that the stress distribution in canine teeth is minimum for vertical oval retentions and for premolar vertical rectangular retentions produces minimum stress.

Root analogous zirconia dental implants

In 2008 W Pirker et al\cite{21} first attempted to use root analogous zirconia implants for tooth replacement. They replaced the first maxillary right premolar of a 63 year old patient with an immediate, non-submerged, root analogous zirconia implant. This study demonstrated that prior to root analogous titanium implants, zirconia implants yields excellent results

**FIGURE 1 – RIGHT MAXILLIARY PREMOLAR TEETH**

A. Kocher et al\cite{22} studied the behavior of root analogous zirconia implant with two different surfaces. After extraction the root was laser scanned and one-piece root analogue zirconia dental implants with one or two different surfaces were manufactured. On the clinical study of the implants
they found that implants with retentions has higher survival rate than roughened implants.

W. Priker et al\textsuperscript{23} described the procedure for immediate, truly analogous, zirconia implant placed into right lateral maxillary incisor. The surface was roughened by sandblast & macro retentions were provided on interdental spaces, and was placed into socket, 7 days after extraction. The modifications indicated primary stability & excellent osseointegration.

FIGURE 2 – RIGHT LATERAL MAXILLIARY INCISOR TEETH

W. Priker et al\textsuperscript{24} in 2009 modified the extracted root of right maxillary molar tooth of a female patient by application of micro & macro retentions. The behavior of the same was studied over 2 years after placement in the tooth socket. This research was first evidence of successful use of root analogous zirconia implants for a three rooted tooth.

FIGURE 3 – RIGHT MAXILLIARY MOLAR TEETH

D. Wiedemann et al\textsuperscript{25} analyzed the use root analogous zirconia implants for first mandibular left molar teeth. The tooth was extracted from a fifty year old female patient and a root analogous zirconia implant with micro retentions was placed into the socket. On two year follow up authors concluded that root analogous zirconia can be used for molar teeth replacement.

FIGURE 4 – LEFT MANDIBULAR MOLAR TEETH

Conclusion

Based on the review it can be concluded that

1. Tetragonal Zirconia Polycrystals (TZP) are better alternative for gold standard titanium implants. They provide better aesthetic results and biosafety.

2. Among zirconia ceramics Tetragonal Zirconia Poly-crystals proved better as a biomaterial. The BIC (bone-implant contact) values are very much similar to that of titanium implants.

3. Surface roughness must be provided in order to increase implant success rate newer macro retention patterns can enhance BIC and stress distribution.

4. Root analogous zirconia is an excellent option for replacement of lost teeth with almost 100% success rate.

This reveals that further research work need to be done on the macro/micro retention patterns of root analogous zirconia dental implants. Analysis and
clinical trials has to be done in order to increase the efficiency of the implants and to decrease stress distribution.

References


