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Are We Entering The New Era Of Zirconia Implants? – Review

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Abstract:
Background*: Though titanium is considered as the best for the rehabilitation of edentulous space TITANIUM based implant systems have been condemn for many disadvantages. The onset of hypersensitive reactions, incompatibility, and an unaesthetic gray discoloration raised the demand` for alternative material with more aesthetically appealing, natural, and tissue compatibility for fabrication of implants[18].*
Subsequently, Zirconia (ZrO2) with its physical and mechanical properties like high corrosion resistance, hardness, low thermal conduction, high flexure strength, and a low tendency for the build-up of bio film and microorganisms made it a good alternative material. Aesthetics, today in its prime position in dentistry diverged people to tooth-colored (ivory white) materials for good marginal aesthetics. This article opens up the idea of a newer metal-free implant material with improved aesthetics and biocompatibility. It shows the increased demand among the general population for non- mental implant materials.

Materials and Methods*: The literature search was performed on the Google scholar and Pub Med database using the keywords: 'zirconia,' 'zirconia implant,' 'zirconia and its biocompatibility,' 'zirconia and its marginal esthetics', 'zirconia and its bone-implant contact (BIC)/osseointegration,' and 'zirconia and its plaque.' (1990-2020). The searches were limited to articles only in English and those with an associated abstract. (Studies on materials coated with zirconium compounds were not included.)*
Literature was reviewed under the following groups:
• In vitro studies on the mechanical properties of zirconia implants.
• In vitro and in vivo studies on osseointegration of zirconia implants.
• In vivo studies on peri-implant/hard and soft tissue response and plaque accumulation around zirconia implants.

Results and conclusion*: The review on both zirconia and titanium implants shows both are better implants till date and zirconia is found to be better than titanium in terms of marginal aesthetics biocompatibility, osseo integeration, bone implant contact.*

Key Word*:'zirconia,' 'zirconia implant,' 'zirconia and its biocompatibility,' 'zirconia and its marginal esthetics', 'zirconia and its bone-implant contact (BIC)/osseointegration,' and 'zirconia and its plaque.'*

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I. Introduction

Dental implants are artificial tooth root which are inserted in the alveolar bone to bear a replaced tooth or bridge. It is an rehabilitatory option for people who have lost a tooth or teeth due to periodontal destructive diseases, injury, or other dental diseases. Dental implants are marked as the new standard in tooth replacement. The dark greyish coloured titanium is often apparently seen through marginal peri-implant mucosa, therefore compromising marginal aesthetics in patients with thin mucosal biotype and in gingival recession. Whereas the marginal aesthetics are greatly improved in zirconia.[26,36]

It has also been found that metals in certain conditions may induce nonspecific immune modulation and autoimmunity. It may also lead to galvanic side effects when it comes in contact with oral fluids and fluoride. Allergic reactions to titanium may be few but cellular sensitization has been demonstrated. Recent years have paved way for zirconia as a new material for dental implants. [27] They are completely inert in the oral environment and exhibit slightest ion release when compared to metallic implants. zirconia is also known for their higher flexural strength and higher resilience. [28] Zirconia with its tooth-like colour and mechanical properties is a suitable dental implant material and is also biocompatible.

Gingival recession around the metal implant often reveal a 'bluish discolouration' over the marginal gingival, compromising the aesthetics. Zirconia also has better strength, fracture toughness and biocompatability. Zirconia has lesser inflammatory response and bone resorption when compared to those induced by titanium, indicating the bio-compatibility of ceramics.

II. Materials and Methods:

The literature search was performed on the Google scholar and Pub Med database using the keywords: 'zirconia,' 'zirconia implant,' 'zirconia and its biocompatibility,' 'zirconia and its marginal esthetics', 'zirconia and its bone-implant contact (BIC)/osseointegration,' and 'zirconia and its plaque.' (1990-2020). The searches were limited to articles only in English and those with an associated abstract. (Studies on materials coated with zirconium compounds were not included.)

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Fracture toughness:

Yilmaz et al. [1] came up with a conclusion that zirconia has the highest fracture toughness, after evaluating different implant materials based on their strength and fracture resistance.

Stress distribution:

Kohal et al. [2] to analyzed stress distribution patterns in implants, a 3D finite element analysis is made out of titanium and zirconia implants. It was found that both implants had a similar stress distribution.

Ozhurt and Kazazoglaund Wenz et al.[3] in their literature review and Bal et al. and Chang et al. in their in vitro experiences conclude that Zirconia and Titanium have a similar stress distribution to the surrounding bones. Whereas, Mobilio et al. results showed lower stress level by the Zirconia implant than that of the Titanium implant on the cortical bone .

Fuh et al[3]. Through his study states that the stress level around the zirconia implant is much lower when compared to the titanium implants. He also tried explaining the phenomenon of stress shielding effect by zirconia which is due to high elastic modulus of zirconia which is almost double of that of titanium.

AUTHORS	MATERIALS USED	SPECIMEN AND PARAMETER	RESULTS		
Yilmaz et al	6 ceramic core materials ' In- Ceram alumina' (ICA), 'In-Ceram Zirconia' (ICZ), 'Cercon Zirconia'(CZ)] (15 × 1.2 ± 0.2 mm) [Finesse (F), 'Cergo (C), IPS Empress (E)'	Indentation fracture Toughness		Biaxial flexural Strength	Weibull Modulus
			F: C: E: ICA: ICZ: CZ:	88.04(31.61) 94.97(13.62) 101.18(13.49) 341.80(61.13) 541.8(61.10) 1140.89(121.33)	3.17 7.94 10.13 6.96 10.17 13.26

Osseo integration And Biocompatibility:

Andreoitelli et al and cohort [8] performed a systematic review to study on the animal, on bone-implant contact (BIC), osseointegration, success rate and clinical acceptability and compatibility of zirconia. The study resulted in a final sample of '21 studies" showing similar rate of osseointegration between the materials of the various implant in animal tests. Zirconia may have the capability to be a ideal material for implants, though the supporting clinical investigations are not adequate.

Kohal et al [9] confered a study to understand the histological behaviour (osseointegration) of endosseous Zirconia and titanium implants in animal models. 5th month after extraction of upper anterior teeth, 12 custom-built zirconia and titanium implants were placed in the extraction sockets in six monkeys. The exterior surfaces of titanium implants were sand-blasted and acid etched with Al2O3. Whereas the zirconia implants were only sandblasted. 6 months after implant placement, impressions were taken for crown building. 3rd month non-precious metal crowns were placed. 5th month the implants with the surrounding hard and soft tissues were took for histological assessment.The dimension of peri-implant soft tissue and osseointegeration, bone-to-implant contact is checked under a light microscope. The results showed all implants were intact. The average height of the soft peri-implant tissue cuff was 4.5mm and 5mm around the Zirconia and titanium implants respectively. The extents of the soft tissue around the implants were similar. Through the animal

experiment, it was concluded that the customised titanium and Zirconia implants show similar peri-implant soft tissue dimensions.

According to Depprich et al., [4] rapid increase of osteoblasts were found around zirconia implants and lesser around titanium implants. Mosgau et al. [5] and Dubruille et al. [6] have found a higher bone-to-implant contact (BIC) with zirconia. The peri-implant bone density and volume were also superior in zirconia according to Gahlert et al. [7]

AUTHORS	MATERIALS USED	SPECIMEN AND PARAMETER	RESULTS
Schultze-Mosgau et al.	Y-PSZ cone (Friadent), (1.4 mm × 7 mm) Titanium cone (Straumann), (1.4 mm × 6.5 mm)	Bone implant Contact (BIC) and Bone–fibrous connective tissue contact (BFCC)	BIC:BFCC ratio Y-TZP: 1.47 ± 1.12 Titanium: 0.97 ± 1.10
Gahlert et al.[7]	zirconia implants(threaded+ acid etched) (Ti-SLA) Titanium implants (sandblasted and acid etched)	Osseointegration/Bone-implant contact (BIC) and bone-volume density (rBVD) at 4th week, 8th week, and 12th week	rBVD: 4 weeks 8 weeks 12 weeks Zr 42.3% 52.6% 54.6% Ti-SLA 29% 44.1% 51.6% BTC: Zr: 27.1%–51.1% Ti: 23.5%–58.5%
Dubruille et al	Y-TZP and titanium grade-I (each 6 implants)	Bone–implant contact.	Zirconia – 65% Titanium – 54%
Kohal et al.	Y-TZP implants and titanium. (which were placed within 5 months after extraction and kept for next 3 months).	Histological assesment of the bone-implant contact (BIC) and peri-implant tissues.	The mean height of the peri-implant tissue was 4.5mm and 5 mm in Zi and Ti. Whereas the soft tissues had similar dimensions. The bone-implant contact (BIC) after 9th months of healing and 5th month of placement was 72.9% (SD: 14%) in titanium implants and to 67.4% (SD: 17%) in zirconia implants.

Aesthetic camouflage and optical properties of zirconia

The most significant edge of zirconia over titanium is concerning its ability to mimic tooth and better aesthetic aspect. The optical property of zirconia is due to its size of crystal, composition, distribution of grains, and methods of machining. The supreme aesthetics of zirconia is due to its ability to camouflage dark substrates with its enhanced opacity and controlled translucency. This is due to its greater crystal size to the length of light wave.[19,20,21]

The implants are sintered in nano sized iron oxide or lanthanum based solution. This makes the zirconia core ready to be covered with translucent ceramics. Now the Zirconia implants that are pure white are adequately coated with ceramics which are translucent to provide a natural looking appearance or similar to that of the adjacent natural teeth. [22,23,19]

Plaque/bacterial accumulation

Brakel et al.[10] in his studies found that there is more bacterial aggregation around the titanium implants and is considerably much less in case of zirconia. Wellender et al.[11] could find only a lesser number of leukocytes present around zirconia implants. As-fired and rectified Y-TZP showed more attachment to S. mutans and S. sanguis showed more attachment to Titanium. The study by Rimondini et al. [13] also showed remarkably lower bacterial aggregation around zirconia than titanium.

Peri-implant tissue compatibility

The average probing depth of zirconia is much lesser to that of titanium says Brakel et al through his research.[10] Tete et al.[16] observed similar orientation of collagen in both zirconia and titanium implants. Spectrophotometer analysis was also shows much lesser mucosal change in colour in zirconia implants than titanium implants. [11,17]

AUTHORS	MATERIALS USED	SPECIMEN AND PARAMETER	RESULTS
Welander et al.	Zirconia and titanium implant and the surrounding hard and soft peri-implant tissues.	Peri implant soft tissue health	Similar soft tissue dimensions were found around Titanium and Zirconia abutments. And less leukocytes are found.
Rimondini et al	• Titanium (pure) • As-fired and rectified tetragonal	Aggregation of bacteria on implants is measured by 'spectrophotometric' assessment	• As-fired Y-TZP showed more attachment to S. mutans .

	zirconia poly crystals stabilized with Y-TZP.	of the slime produced by the Porphyromonas gingivalis, S.mutans, S.sanguis, Actinomyces Naeslundii, A.viscosus	• S. sanguis showed more attachment to Titanium. • Y-TZP adheres very fewer bacteria than Titanium.
Van Brakel et al.	Mandibular implants (zirconia and titanium)	Evaluation of peri-implant hard and soft tissue around titanium and zirconia implants histologically. Inflammation grading ranging from 1 to 4 and vasculature of the peri-implant tissues were determined.	Keratinised stratified squamous epithelium and junctional epithelium is found around the implant surface, with lower signs of inflammation in both zirconia and titanium implants.
Van Brakel et al.	Endosseous mandibular (zirconia and titanium)	The pocket bacterial sampling and evaluvation of the pocket probing depth, gingival recession were evaluvated at 2nd week and 3rd month post-surgery.	• A clinically healthy gingiva is appreciated around the implant surface of both zirconia and titanium. • The mean probing depth of zirconia is slightly lesser than titanium • After 3rd months (2.2 SD 0.8 mm vs. 1.7 SD 0.7 mm, P = 0.03).

STRENGTH:

Minamizato et al[13] compared the compressive strength of the blade type and tunnel type(laser drilled) zirconia. The results showed the compressive strength of tunnelled implants is 237kg/mm2 which is lower than the one with blades or no tunnels showing compressive strength 371.5kg/mm2. Showing the zirconia blades have adequate strength to bear the occlusal forces.

Silva et al [14] examined the strength and sturdiness of the full crown preparation of the one-piece zirconia implant based on their reliability. The study confirmed that that the fracture toughness of unprepared zirconia implants was 1023.3 N, and for full crown preparation it was 1111.7 N. [15]The One piece Zirconia implant is placed in an artificial mouth in which 5 years clinical service is stimulated and the fracture of the implant occurred at 725 to 850 N in unprepared and at 539 to 607N in prepared implants. They conclude that the average fracture toughness of zirconia implants is in range of clinicaly acceptable masticatory load.

Marginal Bone Loss:

Elnayef et al.[9] did a systematic assessment of the marginal bone loss around the Zirconia implants and compared it with currently used Titanium implants. Initially 21 articles were incorporated, Of which 1948 Zirconia implants had a higher survival rate of 91.5%.in which 1250 Zirconia had similar results to titanium implants. Whereas in anterior region and in thin clinical condition with thin marginal mucosa, Zirconia implants are preferred to Titanium implants.

II. Discussion:

Zirconia, due to its mechanical strength [29,30] and tooth simulating color,[11,31] can be used in aesthetic demanding anterior region. Most of the properties have been compared and are found out to be simiar or even better in certain aspects with that of titanium implants. Strength, the fracture toughness are foremost parameters to evaluate the potential of dental ceramic.

Fracture toughness of zirconiais,[1,32] and the distribution of stress to the surrounding bone of YTZP is more similar to titanium. The osseointegration and bone- implant compatibility (BIC) of zirconia is similar to or even better than titanium. Further surface roughness of zirconia helps in enhanced bone-implant contact (BIC).[33,34] The peri-implant bone density and volume is more in zirconia, making the implant more stable in clinical functioning.

Early soft tissue adhesion in zirconia implant material is very much necessary and acts as a effective barrier from the oral environment and microbes and shows a favourable peri-implant response. [33] thus resulting in decreased infection and marginal bone resorption. The mean probing depth and bleeding on probing of zirconia is much lesser to that of titanium [11] and less gingival recession.[16] Zirconia induces least colour change under thin mucosal regions thus favouring aesthetics.[35]

III. Conclusion:

Therefore sufficient study on various properties makes it clear that zirconia has better aesthetics than titanium implants. Zirconia also has very good mechanical properties like adequate strength and fracture

toughness to resist the oral masticatory forces. The aspects of bone implant compatibility and osseointegration is adequately covered through this article and thus zirconia can be crowned as a good potential for implant to osseointegrate within the bone. Also the variou studies(in vivo) shows good peri-implant compatibility with the surrounding tissues. The accumulation of bacteria is lower in zirconia implants. Strength and aesthetics added an edge to zirconia being a better implant, thus paving a hopeful way for "metal-free" implants with an added advantage. [25]

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