Evaluation of osseointegration between traditional and modified hydrophilic titanium dental implants – Systematic analysis

ABSTRACT
The aim of the study was to conduct a systematic review to access the osseointegration between traditional and modified Hydrophilic Titanium Dental Implants for period of 10 years. PUBMed articles were searched from last ten years up to 15/12/2019 from which 24 studies included in this review. This systematic review compiles the data about osseointegration in hydrophilic titanium implants in human trials. It sheds light on the mechanism of integration of hydrophilic surfaces and numeric data to support the purpose of the review.

Keywords: Dental implants, hydrophilic titanium dental implants, osseointegration, systematic review

INTRODUCTION
Dental implants are root analogs that take the form of a root embedded in the bone tissue. The major factor that determines the success of dental implantation is osseointegration. The texture and the properties of the implant surface determine the amount of bone-implant contact (BIC), in turn determining the osseointegration, implant stability, and longevity of the restoration.

A series of different techniques and materials have led to the constant evolution of implant surfaces, from smooth to micro rough, followed by nano rough to hydrophilic surfaces. Hydrophilic surfaces are the latest development in broad-spectrum implant surface characteristics. Most studies have found that hydrophilic surfaces tend to enhance the early stages of cell adhesion, proliferation, differentiation, and bone mineralization compared to hydrophobic surfaces. SLAactive, Photo-functionalized, and Electro-wetted implant surfaces are the hydrophilic surfaces that are commercially available.

Literature has lacked systematic studies of hydrophilic dental implants. We have taken this opportunity to conduct a systematic review of clinical trials conducted on hydrophilic titanium dental implants.

MATERIALS AND METHODS
An electronic search was carried out on PubMed database with the following search terms-Hydrophilic Dental Implants, Modified Dental Implant Surfaces, Hydrophilic Dental Implant Surfaces, Hydrophilic Titanium Dental Implants.

The PRISMA guidelines by the Cochrane library for the formulation of the systematic review were followed.

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Received: 17 April 2020, Revised: 19 May 2020, Accepted: 04 July 2020, Published: 16 December 2020

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How to cite this article: Arya G, Kumar V. Evaluation of osseointegration between traditional and modified hydrophilic titanium dental implants – Systematic analysis. Natl J Maxillofac Surg 2020;11:176-81.
A total of 2071 articles were obtained on the PubMed database. The authors screened through the abstract and eliminated 981 duplicate articles. 1082 articles were screened from which 984 articles were eliminated. Through this method, 98 full-text articles were assessed for eligibility, of which 74 articles did not belong to the inclusion criteria of this review. A total of 24 articles were included in the study.

**Inclusion criteria**

- Articles published in the past 10 years up to December 15, 2019
- Studies conducting human trials
- Studies using dental implants
- Studies using hydrophilic implant surfaces.

**Exclusion criteria**

- Any study published before 2009
- Studies using nondental implants
- *In vitro* and animal studies.

**PICOT**

The studies were included in the review following the PICOT research criteria as follows:

- Population-clinical trials conducted on adult humans of either sex
- Intervention-placement of endosseous root-form hydrophilic or modified wetted surface implants in the human jaw
- Control-patients without any implants or implants with surfaces other than hydrophilic surfaces
- Outcome-osseointegration of the hydrophilic implants to the bone
- Time-period from the insertion of implants to the osseointegration of the implants to the surrounding bone.

**Studies included in this systematic review as PRISMA format**

**Identification**

- Records obtained through the PubMed database search, \( n = 2071 \)
- Additional records identified through other sources, \( n = 0 \)
- Records after duplicates were removed, \( n = 1082 \).

**Screening**

- Records screened, \( n = 1082 \)
- Records excluded, \( n = 984 \).

**Eligibility**

- Full-text articles assessed for eligibility, \( n = 98 \)
- Full-text articles excluded, \( n = 74 \).

**Included**

- Studies included in qualitative synthesis, \( n = 24 \).

**OBSERVATIONS AND RESULT**

Twenty-four studies included in this review; thus, a total of 4498 implants were placed in 2037 patients of which 37 implants were lost.

Therefore, the cumulative survival rate was 99.18%. The studies included in the review are listed in Table 1.

From these, seven studies observed the MBL (marginal bone loss) as listed in Table 2 and 10 studies observed the ISQ (implant stability quotient) values as listed in Table 3.

**DISCUSSION**

Osseointegration is the process by which the titanium implants fuse to the underlying bone. Many factors seem to influence the process of osseointegration, like host factors-quality and type of bone, surgical factors like the drilling procedure, and speed.[29] Mostly the quality of surface which contacts the bone determines the type and speed of osseointegration. The role of surface characteristics gained importance since the early 80s, Albrektsson et al.[30] further pioneered the concept of osseointegration by ascribing to surface properties a possible role for the biological response to an implant.[31] Many surface modifications have been done than the traditional machined surfaces of the titanium implants.

Hydrophilicity is nothing but wettability of a surface. Contact angle (CA) is the angle between the tangent line to a liquid drop’s surface at the three-phase boundary and the horizontal solid’s surface. In principle, the CA can range from 0° to 180°. Surfaces with water CAs lower than 90° are designated as hydrophilic, and those with CAs very close to 0° are superhydrophilic. Surfaces with water CAs above 90° are considered hydrophobic, and those with CAs above 150° are termed superhydrophobic.[32]

Lately, the most commonly used implant surfaces are the solution instead of air (SLA) surfaces, Sandblast and acid-etched surfaces, which are inherently hydrophobic. These SLA surfaces are hydrophilized by surface neutralization after acid etching is done in a contaminant-free, protective nitrogen environment, and the implants are finally stored in a neutral saline SLA active. Recent reviews highlight numerous *in vitro*, *in vivo* and clinical studies focusing on this hydrophilic surface.[24,31,32]
Photo-functionalization accelerated the rate and enhanced of implant stability

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**Table 1: List of the studies included into the review**

| Authors and year | Type of study | Hydrophilic implant brand | Number of patients | Number of implants | Number of implants lost | Parameters observed | Outcomes |
|------------------|---------------|---------------------------|--------------------|-------------------|------------------------|--------------------|----------|
| Donos et al., 2011[9] | Prospective | SLActive | 9 | 18 | NA | Gene expression | SLActive is pro-ostogenetic and pro-angiogenic |
| Lang et al., 2011[9] | Prospective | SLActive | 28 | 49 | NA | Histomorphometry | SLActive has better osseointegration than others |
| Ivanovski et al., 2011[1] | Prospective | SLActive | 9 | 9 | 0 | Gene ontology | I-kB kinase/NF-kB cascade, early inflammatory changes, osteogenesis-related mechanisms are regulated by TGF-b/BMP |
| Bosshardt et al., 2011[4] | Prospective | SLActive | 28 | 49 | NA | Histomorphometry | New bone formation mediated by old bone |
| Roccuzzo and Wilson 2009[8] | Prospective | SLActive | 35 | 35 | Survival rate on early loading | Surface modified hydrophilic implants are suitable for loading at 3 weeks in maxillary molar areas |
| Iezzi et al., 2013[9] | Retrospective | FRIADENT PLUS | 14 | 14 | NA | Histomorphometry | The efficacy of dental implants is related to biological and biomechanical stability and to the integration between the bone and the implant |
| Hinkle et al., 2014[10] | Prospective | INICELL | 21 | 23 | 0 | Clinical and radiological outcome | Hydrophilic implants loading is a safe and predictable treatment |
| van Eekeren et al., 2015[11] | Prospective | INICELL | 32 | 76 | 0 | ISQ values | Bone level implants had level of ISQ quotient throughout |
| Dolanmaz et al., 2015[12] | Prospective | SLActive | 47 | 47 | 0 | BMP 2, 7 | Cytokines in PICF during early healing of implants reflects the degree of peri-implant inflammation, rather than differences in the implant surfaces |
| Gac and Grunder 2015[13] | Retrospective | INICELL | 1063 | 2918 | 30 | Survival rate | Failure was less with hydrophilic implants |
| Hicklin et al., 2016[14] | Prospective | SLActive | 15 | 20 | 0 | ISQ values | Functional occlusal loading possible with hydrophilic implants in posterior mandible |
| Hirota et al., 2016[15] | Prospective | Nobel active | 7 | 49 | 0 | OSI/ISQ | Photo-functionalization accelerated the rate and enhanced of implant stability |
| Degasperi et al., 2014[16] | Retrospective | Neoss active | 49 | 102 | 1 | Survival rate/MBL | Novel hydrophilic implants result in favourable short term outcomes |
| Şener-Yamaner et al., 2017[17] | Prospective | SLActive | 55 | 175 | 3 | MBL | SLActive have successful clinical results |
| Novellino et al., 2017[18] | Prospective | Drive cm acqua, neodent | 21 | 64 | 0 | ISQ | Implants with hydrophilic surfaces integrate faster |
| Makowiecki et al., 2017[19] | Prospective | INICELL/RN SLActive | 15 | 15 | 0 | ISQ/MBL | Insertion of short dental implants with a hydrophilic conditioned surface significantly shows INICELL was better than straumann in osseointegration |
| Cabrera-Dominguez et al., 2017[20] | Prospective | SLActive | 29 | 29 | 0 | MBL | Patients with glycemic control exhibit similar outcomes |
| Rosen et al., 2018[21] | Retrospective | PROActive, neoss | 76 | 86 | 3 | ISQ | Treatment with short implants with high survival rate |
| Siqueira et al., 2018[22] | Prospective | Titanmax cm acqua, neodent | 11 | 55 | 0 | ISQ | Survival rate similar in both tested implant surfaces |
| Ghazal et al., 2019[23] | Prospective | SLActive | 47 | 47 | 0 | Survival rate and MBL | Noninferiority of the narrow versus standard diameter Ti-Zr implants |
| Puisys et al., 2019[24] | Prospective | Biohorizons | 180 | 360 | 0 | Removal torque | Photoactivation increases removal torque values |
| Tallarico et al., 2019[25] | Prospective | Hiossen ET III (NH)/(SA) | 14 | 28 | 0 | ISQ | NH viable alternative to SA, as they seem to avoid ISQ drop in remodeling phase |

Contd...
It is observed that most manufacturers claim their implants to be super-hydrophilic and recommend the implant to be wetted by a special solution to increase its wettability and osseointegration. The purpose of the wetting could be to avoid the formation of the titanium oxide layer, which forms as soon as the implant is exposed to the atmosphere.

Hicklin et al.\textsuperscript{[15]} describes the method to convert the hydrophilic implants (INICELL; Thommen medical AG) to super-hydrophilic by chairside conditioning procedure following the manufacturer’s instructions that included wetting with 0.05M NaOH solution pH 12.24 using a dedicated applicator immediately prior to implant placement.
A recent study has revealed that time since surface preparation or aging can significantly reduce the osteoconductivity of implants. This phenomenon, known as “biologic aging of titanium,” results from time-dependent loss of hydrophilicity and progressive accumulation of hydrocarbon impurities on titanium surfaces. Ultraviolet light treatment of titanium immediately before use, or photo-functionalization, has been found to counteract the biologic aging of titanium by regenerating hydrophilicity and removing hydrocarbon impurities. Indeed, the BIC of photo-functionalized implants is increased from 53% to nearly 100% in animal models. Photo-functionalization of dental implants is rapid and simple to perform chairside immediately before placement. Various clinical studies have indicated that photo-functionalization may accelerate and enhance the osseointegration of dental implants.

Researchers have quantified the wettability of an implant surface by either the sessile drop method, where liquid drops are set on a surface and the CA is directly measured from the drop shape surface and second, tensiometry, where CAs are measured indirectly according to the Wilhelmy balance technique, where in the samples have to be fixed to an electro balance and the forces detected during continuous immersion and withdrawal of the samples into and from the wetting liquid allow the calculation of advancing and receding CAs, respectively. In general, dynamic CAs can be measured if there is a relative movement between the material and the wetting liquid. Without such a movement, static CAs can be analyzed.

The study of osseointegration in the retrieved implants in the human trials revealed that the hydrophilic implants had a better bone to implant contact and better osseointegration than hydrophobic implants. Histology and histomorphometry show that the hydrophilicity of hydrophilic implants during the early osseointegration period help the implant surface in neovascularization and thus the bone contact around the titanium implants is more when compared to other implants. Gene ontology was done in some of the studies suggest that a hydrophilic surface indeed improves early bone deposition around the implants through the expression of bone mimetic proteins such as osteoprotegrin.

Many additive morphology changes also have been done to the titanium implant surfaces to be able to osseointegrate better to the bone. Hydrogels, crosslinked, have been engineered to coat on the implant surface, can act as a scaffold to deliver the biomimetic drugs like bone morphogenic proteins, antibiotics like amoxicillin. The results are improved osseointegration with bone due to increased wettability caused by the hydrogels.

This systematic review compiles the data about osseointegration in hydrophilic titanium implants in human trials. It sheds light on the mechanism of integration of hydrophilic surfaces as they have a positive impact on osseointegration. Given the limited data, the authors would like to conclude that hydrophilic implants offer better osseointegration as compared to other implants. The authors feel there is a need for more randomized clinical trials to support the findings from this review.

CONCLUSION

Total 4948 implants placed in 2037 patients in the studies included, in which almost all the implants osseointegrated and 37 were lost due to implant failure. The cumulative survival rate for the implants were 99.18%. It was observed that the hydrophilic implants showed higher ISQ values during the early osseointegration period, and then the ISQ values further increased in the duration of 3–6 months showing solid osseointegration of at least 2.25 times more. The marginal bone loss also was considerably less for the hydrophilic implants as compared to the hydrophobic implants.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Branemark PI. The Osseointegration Book– From Calvarium to Calcaneus. USA: Quintessence Books; 2005. p. 24.
2. Eriksson C, Nygren H, Ohlson K. Implantation of hydrophilic and hydrophobic titanium discs in rat tibia: Cellular reactions on the surfaces during the first 3 weeks in bone. Biomaterials 2004;25:4759-66.
3. Bornstein MM, Valderrama P, Jones AA, Wilson TG, Seibl R, Cochran DL. Bone apposition around two different sandblasted and acid-etched titanium implant surfaces: A histomorphometric study in canine mandibles. Clin Oral Implants Res 2008;19:233-41.
4. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann Int Med 2009;151:264-9.
5. Donos N, Hamlet S, Lang NP, Salvi GE, Huynh-Ba G, Bosshardt DD, et al. Gene expression profile of osseointegration of a hydrophilic compared with a hydrophobic microrough implant surface. Clin Oral Implants Res 2011;22:365-72.
6. Lang NP, Salvi GE, Huynh-Ba G, Ivanovski S, Donos N, Bosshardt DD. Early osseointegration to hydrophilic and hydrophobic implant surfaces in humans. Clin Oral Implants Res 2011;22:349-56.
7. Ivanovski S, Hamlet S, Salvi GE, Huynh-Ba G, Bosshardt DD, Lang NP, et al. Transcriptional profiling of osseointegration in humans Clin Oral
18. Degasperi W, Andersson P, Verrocchi D, Sennerby L. One-year clinical follow-up on consecutively placed 7-mm-long dental implants with an electrowetted surface. Int J Implant Dent 2017;2:61-8.

19. Cabrera-Domínguez J, Castellanos-Cosano L, Torres-Lagares D, Machuca-Portillo G. A prospective case-control clinical study of titanium-zirconium alloy implants with a hydrophilic surface in patients with type 2 diabetes mellitus. Int J Oral Maxillofac Implants 2017;32:1135-44.

20. Rosen PS, Sahlin H, Seemann R, Rosen AS. A 1-7 year retrospective follow-up on consecutively placed 7-mm-long dental implants with an electrowetted surface. Int J Implant Dent 2018;4:24.

21. Siqueira RAC, Aparecida de Mattias Sartori I, Freitas Santos PG, Thiesen MJ, Gonçalves MC, Gasparini Kiatake Fontão FN. Resonance frequency analysis of dental implants with 2 types of surface treatment submitted to immediate loading: A prospective clinical study. Implant Dent 2018;27:282-7.