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Impact of Diabetes Mellitus on Osseointegrated Dental Implant Failure: A Systematic Review and Meta-Analysis

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KEYWORDS

dental implants, diabetes mellitus, osseointegration, implant failure, systematic review, meta-analysis.

ABSTRACT

Background

Dental implant therapy is recognized as one of the most predictable and effective methods for replacing missing teeth. Although generally successful, the outcome can be compromised by systemic conditions like diabetes mellitus. This review and meta-analysis were undertaken to determine whether diabetes mellitus increases the risk of dental implant failure.

Introduction

Implants have become a routine solution for both partial and complete edentulism. Their long-term survival is influenced by systemic as well as local factors. Among systemic conditions, diabetes mellitus remains widely debated due to its potential to impair bone healing. Given its high prevalence in clinical practice, understanding its influence on implant success is crucial.

Methodology

A comprehensive electronic search was performed in PubMed, Scopus, and Web of Science for studies published between January 2000 and March 2025. Only investigations comparing implant outcomes in diabetic and non-diabetic patients were included. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated using a random-effects model, while heterogeneity was analyzed using the I^2 statistic.

Results

Eleven studies fulfilled the eligibility criteria. The pooled results demonstrated that diabetic patients exhibited a significantly higher risk of implant failure compared with non-diabetic controls. Considerable heterogeneity was observed, and subgroup analyses were performed to explore contributing factors.

Conclusion

Diabetes mellitus is significantly associated with increased implant failure rates compared to non-diabetic individual. These findings underscore the importance of thorough medical evaluation, careful case selection, and individualized treatment planning when considering implant therapy in diabetic patients.

1. Introduction

The objective of contemporary dentistry is to return patients to a state of normal contour, function, comfort, aesthetics, speech, and health, whether it involves restoring a single tooth or replacing multiple teeth. Osseointegrated Dental implants have provided better treatment option for individuals who have lost their teeth, serving as an alternative to traditional prostheses. The positioning of implants is dictated by the anatomy of the remaining ridges[1]. These implants have demonstrated promising long-term outcomes for patients. But these implants may subjected to failure due to several reasons. Systemic disorders, smoking, age and sex, implant placement, bone quantity and quality, and implant surface treatments and characteristics are some of the statistically investigated factors associated with implant failure[2]. Depending on whether they occur before or at abutment connection surgery (early) or after occlusal loading by a prosthetic restoration (late), dental implant failure may occur either before (early) or after (late) the prostheses are placed[3].

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The relationship between systemic diseases and failure of dental implant is a critical area of investigation, particularly as the population ages and the prevalence of such conditions increases[4]. Systemic diseases, including diabetes, cardiovascular diseases, and autoimmune disorders, can significantly impact the healing process and osseointegration of dental implants[5]. One of the most significant chronic health issues in the globe is diabetes mellitus. Diabetes is a complicated condition with several etiologies that causes a host of issues that impact the entire body[6].Diabetes mellitus is a common endocrine disease that results when the amount of available insulin drops below the value required for normal body functions. Insulin is an anabolic hormone produced in the pancreas[7,8].

Hyperglycemia results from inefficient glucose transport into cells and adipose tissues caused by low insulin levels. Ketoacidosis and serious metabolic problems may arise if the fasting glucose blood level hits or above 126 mg/dl. Type 1 (insulin-dependent), type 2, and gestational diabetes are the three categories of diabetes[9].

Furthermore, the length of time a person has had diabetes may influence their clinical and functional condition, regardless of their blood sugar control or age[10]. These consequences usually result from a set of negative effects of the disease, which include delayed wound healing[11], microvascular complications[12], impaired response to infection[13], impaired bone metabolism, and bone strength[14], among others. For individuals who have onset of type 2 diabetes in youth, the risk of microvascular and other complications increases steadily over time[15].

Dental implants are predictable and successful treatment for replacing missing teeth, though implant success dependent upon an effective osseointegration process while healing takes place. The presence of type II diabetes mellitus may disrupt this process leading to impaired bone healing[16].Tight and intensive glycemic control in diabetic patients can delay the onset and the progression of many microvascular-related complications associated with the condition[17], although the effects of this control seem to become weaker once complications have been manifested[18].

Prior to treatment, the most widely used approach is to determine glycosylated hemoglobin Alc (HbAlc) levels. Diabetic individuals that keep a level up to 6.5% HbA1c are considered patients with controlled diabetes mellitus[19,20]. Therefore, this systematic review analyzes clinical studies to evaluate the impact diabetes mellitus on osseointegrated dental implant failure.

2. Aim

To evaluate the effect of diabetes mellitus on osseointegrated implant failure.

3. Study design and methods:

Protocol registration and review reporting:

This systematic review and meta- analysis were registered at the international prospective register of systematic review- Prospero CRD42024626266. This review followed the guidelines of Preferred Reporting Items in Systematic Review and Meta-Analysis (PRISMA)

Statement of problem

There is still conflicting information about their recognised impacts on healing. The purpose of this study is to explain how diabetes mellitus affect osseointegrated dental implant failure.

Clinical implication

Clinical professionals can better identify high-risk patients, supervise preoperative care, and customise treatment regimens by knowing how diabetes mellitus affect dental implant failure. In order to enhance long-term results, this research may help choose implant methods, encourages more informed consent conversations, and emphasises the significance of glycaemic management.

PICO:

This systematic review encompasses following PICO strategy: (Population, Intervention, Comparison, Outcome)

Population (P): Partially and completely edentulous requiring implant-supported prostheses.
Intervention (I): Partially and completely edentulous patients with diabetes mellitus requiring implant-supported prostheses.
Comparison (C): Partially and completely edentulous healthy patients requiring implant-supported prostheses.

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Outcome (O): Evaluation and comparison of the effect of diabetes mellitus on osseointegrated implant failure.

Review questions:
The PICO modeled questions were:

Q1: Is there any effect of diabetes mellitus on osseointegrated implant failure?
Q2: How does the severity or control level of diabetes mellitus (e.g., HbA1c levels) affect the failure rate of osseointegrated dental implants?

Q3: Do patients with diabetes mellitus have a higher rate of osseointegrated dental implant failure compared to patients without these risk factors?

Search strategy:

A systematic search was conducted on electronic MEDLINE (PubMed) to identify relevant clinical studies published in English (Table 1). Various combinations of search terms were employed, encompassing "tooth implant placement," “diabetes mellitus”, "implant failure factors," “Diabetes Complications," “Osseointegration,” and “Hyperglycemia,” “Glycated Hemoglobin-A.” To refine the search results and ensure relevancy, Boolean operators such as "AND" and "OR" were utilized in conjunction with a blend of search terms and MeSH terms.While PubMed utilizes MeSH terms to improve search precision and recall, Google Scholar adopts a different syntax, using a plus sign (+) to denote mandatory inclusion of specific terms. In addition to PubMed, the Cochrane library was also explored, focusing on "risk factors for implant failure" and "diabetes mellitus effect on dental implants" in all text fields. Furthermore, to expand the search scope, references from both included and excluded articles were also scrutinized for additional studies. The search was complemented with manual search of implant dentistry journals.

Inclusion criteria:

- Patients age ≥ 18 years irrespective of gender
- Patients had to be partially edentulous or fully edentulous with osseointegrated dental implants
- Patients with diabetes mellitus received dental implant treatment
- Patients with good oral hygiene

Exclusion criteria:

- Severe clenching or bruxism
- Drug or alcohol abuse.
- Patients with poor oral hygiene
- Any other systemic condition affecting dental implant osseointegration

Data extraction:
Two reviewers collaboratively evaluated all titles and abstracts obtained to identify potential inclusions. Subsequently, full-text articles corresponding to the selected abstracts were retrieved. The selected full-text articles underwent scrutiny by two reviewers against pre-defined inclusion and exclusion criteria. Relevant information from eligible articles was independently extracted by both reviewers and subsequently cross-checked for accuracy by the same pair of reviewers. Only clinical studies were selected. The extracted data included details such as authors, year of publication, study design, number of implants placed in healthy individuals, number of implants placed in patients with diabetes mellitus, number of implants failed during follow-up period as well as the age range and gender distribution of participants. Any discrepancies encountered during data collection were resolved through discussion and consultation with a third reviewer. Studies with missing data were excluded from the review process.

success while minimizing complications in this high-risk population.

Overview of Outcome:

Included studies (Table 4) used Dental implant failure, Diabetes mellitus and dental implants, Glycated hemoglobin level and implant failure, Risk factors for dental implant, Risk factors for osseointegration.

Risk of bias tool for non-randomized trials was used for analysing the risk of bias/ Quality appraisal based on 6 domains (Table 3). Due to confounding, selection of patient, classification of intervention, deviation from intended outcome, missing data, measurement outcome, and selection of reported result.

Morris et al., 2000[7]

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Evaluated factors affecting implant success, possibly including patient habits and bone quality. Some bias domains were marked as unclear.

Tawil et al., 2008[22]

Investigated the long-term outcomes of dental implants with a focus on survival and success rates. The study showed a low risk of bias across all domains.

Alsaadi et al., 2008[21]

A follow-up or related study to their 2007 work, with clearer methodology. Mostly low risk of bias.

Loo et al.,2009[29]

Investigated the suitability of diabetic patients to have dental implants and the efficacy of number of dental implants related to the success rates.

Anner et al.,2010[23]
Analyzed risk indicators for implant failure in routine dental practice. Exhibited a low bias profile across the board.

Aguilar-Salvatierra et al., 2015[20]

Explored diabetes as a factor in implant integration. All bias categories were rated low.

Chrcanovic et al., 2016[25]

A large-scale meta-analysis or cohort study on implant failure, often cited. Displayed a strong methodology with low bias.

Niedermaier et al., 2017[26]

Focused on implant success in compromised patients or settings. Demonstrated rigorous methods with low bias.

Maló et al., 2016[51]

Studied the "All-on-4" concept or full-arch rehabilitation success. Strong methodology with low bias overall.

Atarchi et al., 2020[27]

Likely focused on implant performance in a clinical setting. Some unclear bias areas, especially selection and detection.

Singh et al., 2020[28]

Examined implant outcomes under risk factors like smoking or systemic disease. High risk of bias was noted in most categories.

4. Result

A meta-analysis was conducted to evaluate the impact of diabetes mellitus on dental implant failure rates by pooling data from nine studies (Figure 1): Morris et al. (2000), Alsaadi et al (2008), Tawil et al. (2008), Loo et al (2009), Anner et al (2010), Aguilar-Salvatierra et al (2015), Chracanovic et al (2016), Nidermaier et al (2017), Atarchi et al (2020). A total of 17784 implants were included, comprising 1643 implants placed in diabetic patients and 16141 in non-diabetic individuals.

The pooled results indicated a higher number of implant failures in the diabetic group (n = 256) compared to the non-diabetic group (n = 1020). However, when analyzed statistically, the combined odds ratio (OR) for implant failure in diabetic patients was **1.89** with a 95% confidence interval (CI) of **0.94 to 3.81**. This suggests that while diabetics had **35% higher odds** of implant failure than non-diabetics, the result was **not statistically significant** (**P = 0.07**), as the confidence interval crossed the null value of 1.0.

Individually, the study by Aguilar-Salvatierra et al. reported the highest odds ratio (OR = 5.74), though the wide confidence interval (0.32–103.27) reflects the small sample size and low statistical power.

Importantly, the meta-analysis demonstrated **no significant heterogeneity** among studies (**I^2 = 0.8%, Chi^2 = 80.02, P = 0.07),** indicating that the pooled effect estimate is reliable and the studies are relatively homogeneous. The I2 value indicates that 90% of the variability among studies arises from heterogeneity rather than random chance.

Although a trend toward increased implant failure in diabetic patients was observed, the difference was not statistically significant. These findings suggest that **well-controlled diabetes** may not substantially compromise implant outcomes, aligning with clinical recommendations that glycemic control is a key determinant of implant success in diabetic populations.

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5. Discussion

Dental implants rely heavily on successful osseointegration, a process that can be adversely affected by systemic and behavioural risk factors such as diabetes mellitus. This systematic review, a meta-analysis was conducted to evaluate the impact of diabetes mellitus on osseointegrated dental implant failure.

Diabetes mellitus (DM), particularly when poorly controlled, significantly disrupts the biological processes required for successful osseointegration and maintenance of dental implants. The pathophysiological mechanisms through which diabetes increases implant failure are multifactorial and involve impaired wound healing, altered bone metabolism, vascular complications, and increased susceptibility to infection.

Eleven (11) studies comprising 3448 patients (approximately 16141 implants in control group and,1643 implants in patients with diabetes mellitus) were included, published between January 2000 and March 2025. The majority studies were retrospective and prospective while 1 study was controlled clinical trial.

Morris et al (2000)[7] did a clinical controlled trial in which 663 patients were included. In this study 2,887 implants were placed, reported failure rates of 7.8% in diabetics (20/255) compared to 6.8% in non-diabetics (180/2632). Although the difference may appear modest, the large sample size underscores its significance.

Total of 2887 implants (HA Coated Implants vs non-HA coated) were placed amongst which 255 implants were placed in diabetic group (Type II DM) and 2632 implants placed in non-diabetic group with the mean follow up period of 3 years. They concluded that the use of endosseous dental implants in Type 2 diabetic patients involves a marginal risk to long-term implant survival. The survival of implants in Type 2 diabetic patients is improved if HA-coated implants are used. Bone density did not appear to have a major influence on implant survival in Type 2 diabetic patients.

Tawil et al (2008)[22] placed 499 implants (turned surface and anodized implant surface) in 90 patients mean follow up period of 42.4 months with concluded that well- to fairly well-controlled diabetic patients with a mean HbA1c of 7.2% in the perioperative period had the same overall survival rate as controls in conventional and advanced implant therapy. Implant survival rate was independent from age, gender, diabetes duration, and smoking in a well- to fairly well controlled diabetic population. HbA1c is the most important factor affecting implant complication rate.

Like Tawil et al[22], Aguliar- Salvatierra et al (2016)[20], placed 52 implants (SLA surfaced implant) in diabetic patients with different HbA1c levels in maxillary arch out of which 4 implants failed during follow up period while out of 33, no implants failed in non-diabetic group. They concluded that patients with diabetes can safely undergo treatment with immediately loaded implants providing their diabetes is well managed and they present moderate HbA1c values (not more than 8% and always controlled by an endocrinologist). Tawil et al. (2008)[22] and Aguilar-Salvatierra et al. (2016)[20] reported on patients with confirmed HbA1c levels. In the latter study, poorly controlled diabetics (HbA1c >7%) had a failure rate of 7.7% (4/52), while no failures occurred in the non-diabetic group (0/33).

Another study done by Alsaadi et al (2008)[21], assessed Impact of local and systemic factors on the incidence of failures up to abutment connection with modified surface oral implants in type I and Type II diabetes mellitus. Total of 283 patients with 720 implants (anodized implant surface) placed in diabetic and non-diabetic group. They found that hand, diabetes type I increases the incidence of early implant failures.

Loo et al. (2009)[29], aimed to evaluate the impact of diabetes on the success of dental implants and periodontal healing in 278 patients reported 68.2% failure (174/255) in diabetic group implants versus 13.8% (48/346) in non-diabetics, despite using plasma-sprayed surfaces.

Anner et al (2010)[23] did a long-term retrospective evaluation of 475 patients with 1626 implants followed for up to 10 years, found no evidence of diminished clinical success or significant early healing complications as sociated with implant therapy in patients with controlled type II diabetes mellitus.

Chrcanovic et al (2016)[25], assessed the influence of local and systemic factors on the occurrence of dental implant failures up to the second-stage surgery (abutment connection). This retrospective study is based on 2,670

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patients who received 10,096 implants. out of these 10,096 implants; 7,068 implants placed in diabetic as well as non-diabetic group and noted higher failure rates in both Type I diabetics (6.0%, 7/117) and Type II diabetics (6.5%, 33/510) compared to non-diabetics (6.3%, 404/6441).

Niedermaier et al (2017)[26] examined the implant survival rates of 2081 implants in 308 patients applying an immediate loading protocol with 4, 5, or 6 implants per restoration in a retrospective 7-year clinical study. Out of these 2081 implants, 1298 implants (53 implants and 1245 implants placed in diabetic and non-diabetic group respectively). Using acid-etched/anodized surfaces, they found 5.7% failure in diabetics (3/53) vs. 1.5% in non-diabetics (19/1245).

Atarchi et al (2020)[27] placed 2323 implants in 1343 patients to evaluate the early failure rate and associated risk factors for dental implants placed with and without maxillary sinus augmentation. Atarchi et al. (2020)[57] included patients with HbA1c ≤ 8 and still observed nearly a fivefold higher failure rate in diabetics 19.2% (10/52) compared to non-diabetics 4.1% (93/2271). They concluded that, diabetes mellitus showed a positive association with the increased implant failure rate.

It is also important to consider the potential for many other factors, such as technological advances in implant designs to enhance survival rates for implants in patients with diabetes.

Some of the included studies had a retrospective design, and the nature of a retrospective study inherently results in flaws. These problems were manifested by the gaps in information and incomplete. For more definite conclusion, we believe that future controlled studies with a larger number of patients in the diabetic group are required to determine the real effect of the condition on the dental implant outcome.

Based on the study result it can be stated that surface treated implants can be more beneficial for better osseointegration in medically compromised cases like diabetes mellitus also levels of glycated hemoglobin play vital role in predicting the prognosis of placed implant. Patients with well-controlled diabetes can successfully receive dental implants when they adhere to regular follow-up visits and maintain good oral hygiene. However, when comparing Type I and Type II diabetes mellitus, implant failure rates tend to be higher in Type I diabetic patients, primarily due to poorer glycemic control.

6. Conclusion

Based on the analysis of studies, the current systematic review and meta-analysis it is evident that diabetes mellitus and smoking significantly increases the risk of dental implant failure. Across nearly all studies, diabetic patients and smokers demonstrated a consistently higher failure rate compared to non-diabetic and non-smokers.
As compared to type ii dm, type i dm show early-stage failure dental implants due to poor control of blood sugar levels.
Interestingly, surface modification of dental implants shows comparatively lower implant failure rate in diabetic patient as compared to normal implants.

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Conflict of Interest:
The authors declare that there are no conflicts of interest related to this study.

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Figure 1: Prisma flow chart

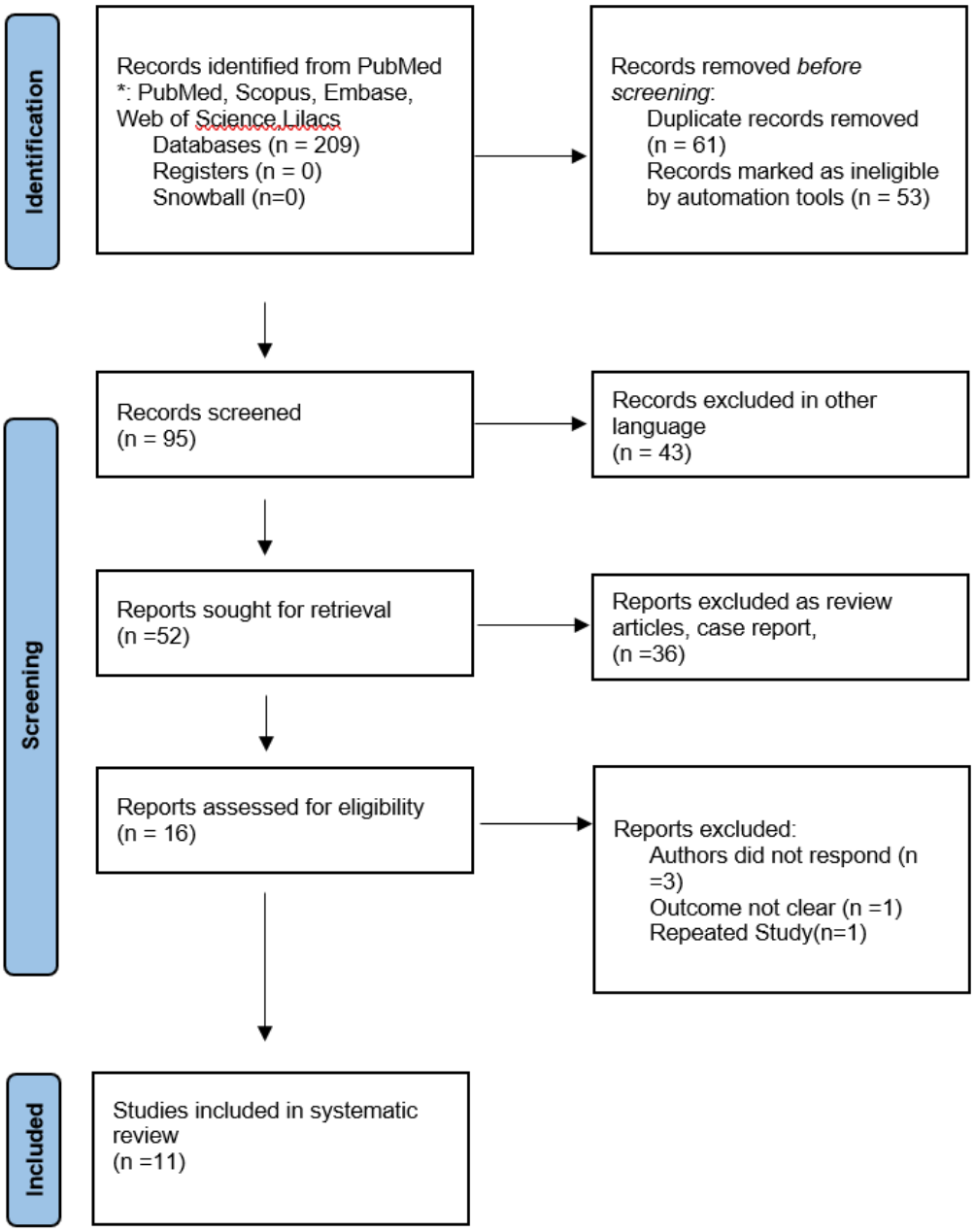

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Figure 2: Forest plot

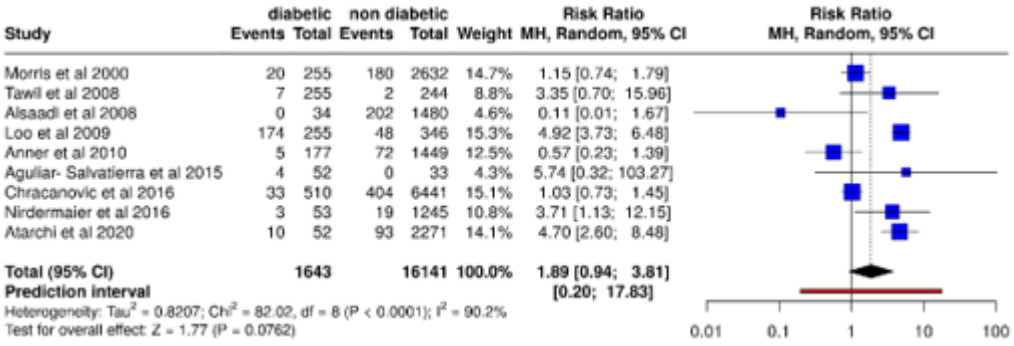

Figure 3: Funnel plot

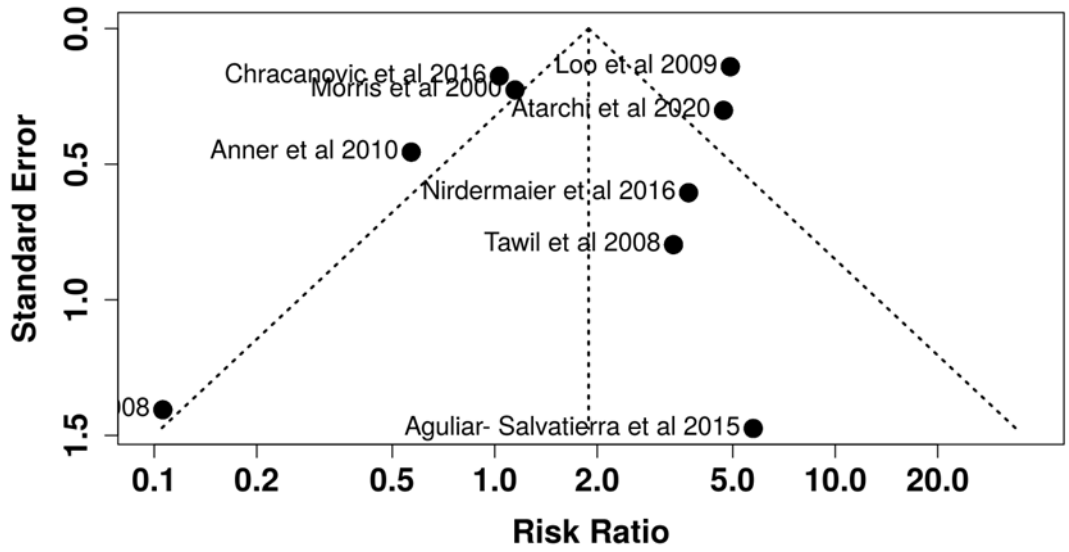

Table 1: Search strategy

Data base	Search strategy
PubMed	MeSH and EMTREE) and keywords were used whenever possible. In the search terms used, "[mh]" represented the MeSH terms and "[tiab]" represented the title and/or abstract. Other terms not indexed as MeSH and filters also were applied. As such, the key terms used were.

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Google scholar	For google scholar the Boolean used were "+" and "-"
Cochrane library	For Cochrane library "dental implant failure" in all text was used.

Table 2: Excluded articles

Reason for Exclusion	**References**
Authors did not respond	Bell et al Eskow et al Hinode et al
Outcome not clear	Olson et a
Repeated study	Cosano et al

Table 3: Risk of bias

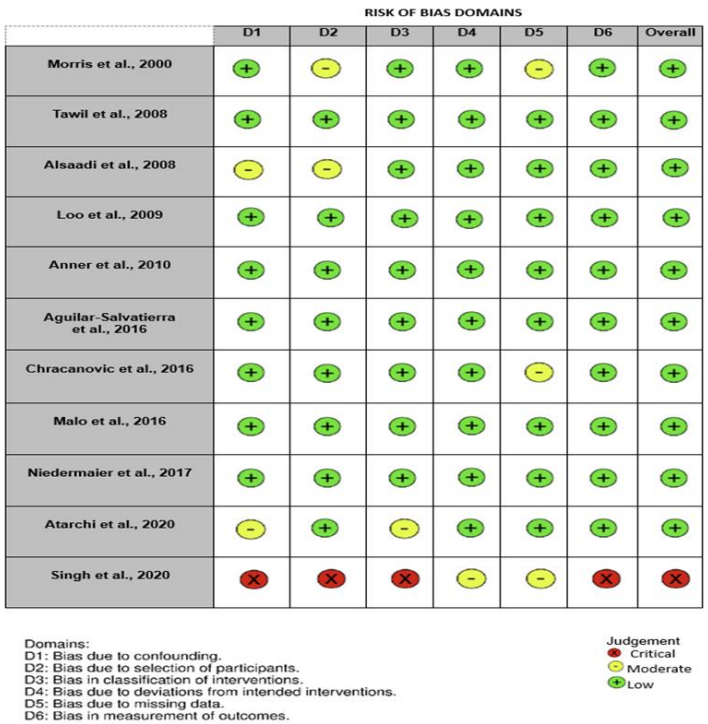

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Table 4: Study characteristic table

Sr. No.	Author Name And Year Of Publication	Type Of Study	Type Of Implant Surface	Mean Follow Up Period	Type of Diabetes Mellitus And Hba1c Level Given	Number Of Patients And Mean Age Group	Number Of Implants Placed And Implant Site	Failed/Placed Implants In Diabetic Group
1.	Morris HF, Ochi S, Winkler S (2000)[7]	CCT	HA Coated Implants Vs non-HA coated implants	3 years	Type II DM **Hba1c Level:** No	663 **Mean age**: 50 yrs	**Total**: 2887 Maxilla and mandible	20/255
2.	Tawil G, Younan R, Azar P, Sleilati G (2008)[22]	Pros-pective	Turned surface and Anodized implant surface	42.4 months	Type II DM **Hba1c Level:** Yes	90 **Mean age**:64.7 yrs	**Total**: 499 Maxilla only	7/255
3.	Alsaadi G, Quirynen M, Michiles K, Teughels W, Koma´rek A, van Steen-berghe D (2008)[21]	Retro-spective	Anodized implant surface	-	Type I And Type II DM **Hba1c Level:** No	283 **Mean age**:56.2 yrs	**Total**: 720 Maxilla and mandible	Type I: 1/1 DM Type II: 1/25 DM

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4.	Loo WT, Jin LJ, Cheung MN, Wang M (2009)[29]	Pros-pective	Plasma Sprayed Implant surface	-	Type II DM **Hba1c Level:** No	278 **Mean age**:45.5 yrs	**Total**: 601 Maxilla and mandible	174/255
5.	Anner R, Grossmann Y, Anner Y, Levin L (2010)[23]	Retro-spective	-	24.71± 25.84 months	Type II DM **Hba1c Level:** No	475 **Mean age**:51.9 ±11.9 years	**Total**: 1626 Site: -	5/177
6.	Aguilar-Salvatierra A, Calvo-Guirado JL, González-Jaranay M, Moreu G, Delgado-Ruiz RA, Gómez-Moreno G (2016)[20]	Pros-pective	SLA Implant surface	-	Type II DM **Hba1c Level:** Yes	85 **Mean age**: 57± 3.8 years	**Total**:85 Maxilla only	4/52
7.	Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A (2016)[25]	Retro-spective	Turned/ machined or enlarged surfaces; sand-blasted, SLA; Anodized; HA coated surfaces	-	Type I And Type II DM **Hba1c Level:** No	-	**Total**: 7068 Maxilla and mandible	Type I DM: 7/117 Type II DM: 33/510

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8.	Maló P, de Araújo Nobre M, Gonçalves Y, Lopes A (2016)[24]	Retro-spective	Machined And anodically oxidized surface	8 years	Type I And Type II DM **Hba1c Level:** No	721 **Mean age:** 61.66± 12.77 years	**Total:** 3998 **Mean age:** 51 years	7/342
9.	Niedermaier R, Stelzle F, Riemann M, Bolz W, Schuh P, Wachtel H (2017)[26]	Retro-spective	Acid-etched surface And Anodized Implant surface	23.5± 19.2 months	**Type of DM and HbA1C** Not Mention-ed	231 **Mean age**: 61.9 years	**Total**: 1298 Maxilla and mandible	3/53
10.	Atarchi AR, Miley DD, Omran MT, Abdulkareem AA (2020)[27]	Retro-spective	Titanium Oxide blasted and acid ethed; anodized, discrete crystalline deposited; SLA surface	-	**Type of DM:** Not Mention-ed **Hba1c Level:** Less than Or equal To 8	1343 **Mean age:** 61.66± 12.77 years	**Total**: 2323 Maxilla only	10/52
11.	Singh R, Parihar AS, Vaibhav V, Kumar K, Singh R, Jerry JJ (2020)[28]	Retro-spective	-	-	**Type of DM and HbA1C** Not Mention-ed	826	1420	22/108