

Evaluation of the maxillary and mandibular implant failure rate in patients with type 1 and type 2 diabetes: a systematic review and meta-analysis

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Aim: The present study evaluated maxillary and mandibular implant failure rates in patients with type 1 diabetes and type 2 diabetes. **Methods:** All articles published in international databases such as PubMed, Scopus, Science Direct, ISI Web of knowledge, and Embase between 2016 to July 2022 are included. 95% confidence interval on odds ratio and mean differences were done with a fixed effect model. Meta-analysis data collected from selected studies were performed using Stata/MP.V17 software. **Results:** In the initial review, duplicate studies were eliminated, abstracts of 1311 studies were reviewed, two authors reviewed the full text of 243 studies, and finally, 37 studies were selected. The odds ratio of implant failure rate between diabetic and non-diabetic patients was 5.31 (OR, 95% CI 5.06, 5.56; p=0.00). The mean difference in marginal bone loss between diabetic and non-diabetic patients was 1.63 (MD, 95% CI 0.89, 2.37; p=0.00).

Conclusion: Based on the findings of the present study, the survival rate of implants in patients with diabetes was lower than in non-diabetic patients. Also, marginal bone loss was higher in patients with diabetes than in non-diabetic patients.

Keywords: Dental implants. Diabetes mellitus. Diabetes complications.



Introduction

Diabetes mellitus is a metabolic disease confirmed by high glucose levels in the blood (Hyperglycemia); In this disease, the body cannot use the produced insulin, and the pancreas cannot produce enough insulin, which indicates a defect in insulin secretion¹. Type 2 diabetes is the most common type of diabetes mellitus, and about 90 to 95% of patients with diabetes are type 2 diabetes. According to global statistics, by 2030, 643 million adults will be diagnosed with type 2 diabetes². These figures are very high and double the importance of investigating this disease. Long-term hyperglycemia caused by diabetes mellitus can affect the function of many tissues and organs, and we will see significant clinical complications after that^{3,4}.

Studies show that two factors, age, and blood sugar level, can affect people's clinical and functional status. Evidence shows that the duration of diabetes also affects the clinical and functional status⁵. Among the negative effects of diabetes on the patient, we can mention the following; microvascular complications^{6,7}, impaired metabolism and bone strength⁸, delayed wound healing⁹, and impaired response to infection^{10,11}. Based on the results of studies, there is a direct relationship between glycemia and microvascular and macrovascular¹². In patients with diabetes, controlling blood sugar levels can prevent or delay the progression of the disease and related complications¹³.

The hemoglobin A1c (HbA1c) test measures the amount of blood sugar (glucose) bound to a person's hemoglobin. Hemoglobin is the part of red blood cells that carries oxygen from the lungs to the rest of the body. It is a very important blood test indicating how a person's diabetes is controlled^{14,15}. Based on the results of the studies, if the HbA1c level is maintained up to 6.5%, the person is considered in the controlled diabetes group¹⁶. Based on the results of a previous study, diabetes, with its negative effect on bone metabolism, can endanger the long-term survival of dental implants⁵.

Nevertheless, investigating the survival of dental implants in diabetic patients compared to non-diabetic patients is of great importance. Stronger evidence can be reached by updating information in this field and using newer studies; therefore, the present study was conducted to evaluate maxillary and mandibular implant failure rates in patients with type 1 diabetes and type 2 diabetes.

Materials and Methods

Search strategy

Based on PRISMA guidelines¹⁷, the present study conducts a systematic review and meta-analysis of all articles published between January 2016 and 2022 in international databases, including PubMed, Scopus, Science Direct, Embase, and ISI Web of Knowledge. The reason for examining the studies in this period was to examine newer studies with newer evidence; It should be noted that if the number of studies and the sample size were small, the search would be conducted from 2010 to 2022. The Google Scholar search engine employed the PICO strategy to answer the research questions (Table 1).

Table1. PICO strategy.

PICO strategy	Description
P	Population: partially and fully edentulous patients with type 1 diabetes and type 2 diabetes.
I	Intervention: maxillary and mandibular implant
C	Comparison: non-diabetic patients
O	Outcome: marginal bone loss (MBL) and implant failure

The following keywords were used to search:

(((((“Jaw, Edentulous, Partially”[Mesh]) OR (“Mouth, Edentulous”[Mesh] OR “Jaw, Edentulous”[Mesh])) AND “Dental Implants”[Mesh]) OR “Dental Implants/statistics and numerical data”[Mesh]) OR “Dental Implants/adverse effects”[Mesh]) AND (“Diabetes Mellitus”[Mesh] OR “Diabetes Complications”[Mesh] OR “Diabetes Mellitus, Type 2”[Mesh] OR “Diabetes Mellitus, Type 1”[Mesh]).

Eligibility criteria

Inclusion criteria

1. Randomized controlled trials, controlled clinical trials, and cohort studies.
2. Availability of full text.
3. Only english-language articles were selected.
4. Diabetic patients with controlled glycemcic
5. Human samples.

Exclusion criteria

1. Cross-sectional studies, in-vitro and in-vivo studies, review studies, case reports, and letters to the editor.
2. No comparison with the control group.

Selection process and Data collection process

Two reviewers blindly and independently extracted data from the included papers’ full texts and abstracts for data extraction. Kappa statistics were used to check the amount of agreement between the reviewers before the screening. The values of kappa were higher than 0.80. Studies data were reported by the first author’s name, years, study design, several patients, and outcome.

Risk of bias assessment

The quality of studies was assessed using the National Institutes of Health tools (NHLBI)¹⁸. This tool has 9 items; each item is given a score of 1 or 0; the range of grades is from 0 to 9, and grades 0 to 3 indicate the low quality of the study, 4 to 6 indicate average quality, and 7 to 9 indicate high quality.

Data analysis

Effect measures and synthesis methods

Stata/MP.V17 software was used to analyze the data. Odds ratio and mean differences (95% confidence interval) were done with the fixed effect model, Mantel-Haenszel, and inverse-variance method. The level of heterogeneity was assessed using the I² index test (I² 50% = low levels, 50-I² 75% = moderate, and I²>75% = high levels).

Results

After the initial search for them in databases, 1311 articles were identified. Duplicate articles were deleted (n=149) after importing all articles into the EndNote.X9 software. In the second stage, one thousand one hundred sixty-two articles were entered and examined. At this stage, 919 unrelated articles were excluded from the study while reviewing the titles and abstract articles. The full texts of 243 articles were reviewed in the third step, and incomplete articles without data and inconsistency with the objectives of the study were excluded (206 articles). Thirty-seven articles that met the inclusion criteria were included (Figure 1).

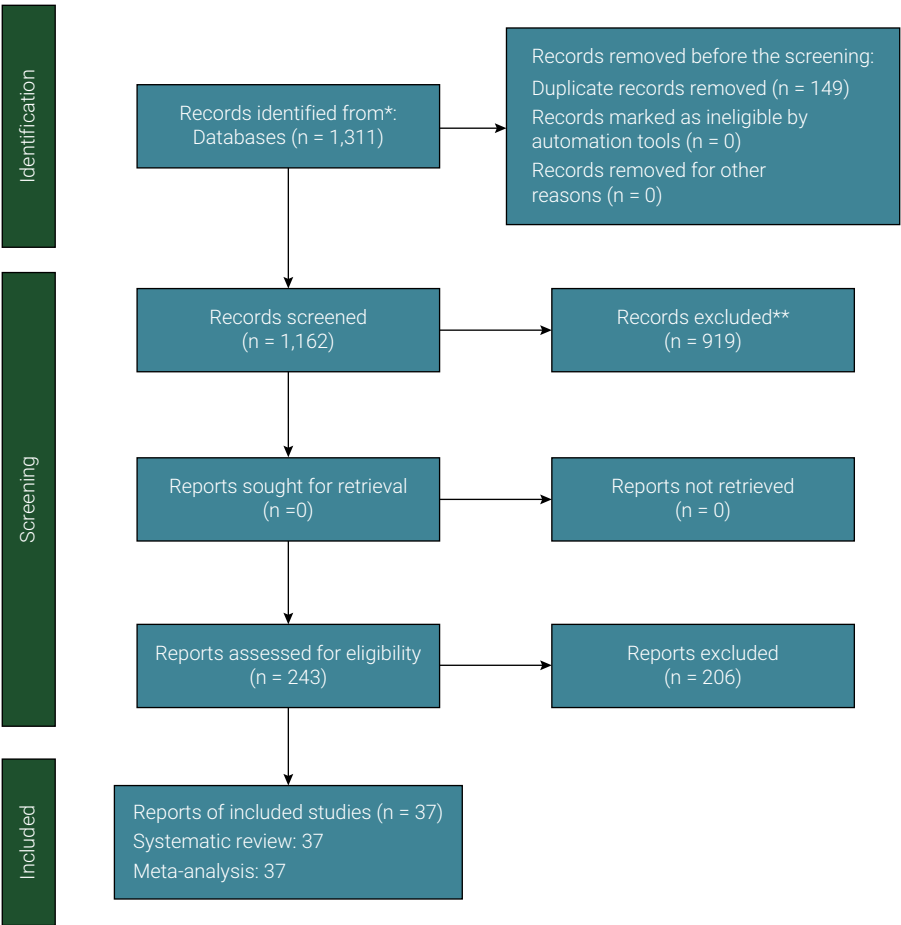


Figure 1. PRISMA 2020 checklist.

Characteristics

This study selected and included five prospective studies, 28 retrospective studies, one controlled clinical trial study, and four randomized controlled trial studies. A total of 4606 patients with type 1 or type 2 diabetes were examined; Table 2 shows the number of patients by gender. Also, demographic information is reported in table 2 (average age of patients, number of smoking patients, and location of implant placement).

Table 2. Demographic information was extracted from the full text of the selected studies.

No.	Study. Years	Study design	Number of patients		Mean of age	Implant location		Number of smokers	Quality of studies
			Male	Female		Maxilla	Mandible		
1	Coskunes and Tak ¹⁹ , 2021	Prospective	17	11	52	✓	✓	6	9/9
2	Boboeva et al. ²⁰ , 2021	Retrospective	584	711	46.7	✓	✓	78	9/9
3	Troiano et al. ²¹ , 2021	Retrospective	63	46	58	✓	✓	31	8/9
4	Schoenbaum et al. ²² , 2021	Retrospective	181	197	60	✓	✓	56	8/9
5	Sicilia et al. ²³ , 2021	Retrospective	268		50	-	✓	75	9/9
6	Tattan et al. ²⁴ , 2021	Retrospective	95	106	60	✓	✓	37	9/9
7	Stacchi et al. ²⁵ , 2021	Retrospective	61	95	60	✓	-	29	9/9
8	Werbelow et al. ²⁶ , 2020	Retrospective	13	10	64	✓	✓	2	9/9
9	Wang et al. ²⁷ , 2020	Randomized controlled trial	15	34	46	✓	✓	1	8/9
10	Rondon Rmero et al. ²⁸ , 2020	Retrospective	26	22	68	-	✓	22	7/9
11	Park et al. ²⁹ , 2020	Retrospective	87	91	53	✓	-	NR	8/9
12	Lobato et al. ³⁰ , 2020	Randomized controlled trial	22	22	50	✓	✓	NR	7/9
13	Higuchi et al. ³¹ , 2020	Prospective	50	60	61	-	✓	23	9/9
14	Feher et al. ³² , 2020	Retrospective	505	627	50	✓	✓	217	8/9
15	Chang ³³ , 2020	Retrospective	222	154	49	✓	✓	67	9/9
16	Atarchi et al. ³⁴ , 2020	Retrospective	516	827	61	✓	-	58	8/9
17	Alqahtani et al. ³⁵ , 2020	Retrospective	101	0	NR	✓	✓	51	7/9
18	de Souza et al. ³⁶ , 2019	Retrospective	4	6	60	✓	-	1	9/9
19	Alsahhaf et al. ³⁷ , 2019	Retrospective	76	43	43	✓	✓	0	9/9
20	Klotz et al. ³⁸ , 2019	Retrospective	28	56	60	✓	✓	NR	9/9
21	Lee et al. ³⁹ , 2019	Retrospective	70	86	59	✓	✓	NR	8/9
22	Romandini et al. ⁴⁰ , 2019	Retrospective	24	28	68	✓	✓	14	8/9

Continue

Continuation

23	Altay et al. ⁴¹ , 2018	Retrospective	6	7	55	✓	✓	0	8/9
24	Nogueira et al. ⁴² , 2018	Prospective	11	34	63	-	✓	23	9/9
25	Saridakis et al. ⁴³ , 2018	Retrospective	49	49	61	✓	✓	0	8/9
26	Kim et al. ⁴⁴ , 2018	Retrospective	496	385	51	✓	✓	NR	9/9
27	Niedermaier et al. ⁴⁵ , 2017	Retrospective	188	192	61	✓	✓	141	7/9
28	Norton et al. ⁴⁶ , 2017	Prospective	10	12	63	✓	✓	1	7/9
129	Boardman et al. ⁴⁷ , 2016	Retrospective	21	77	51	✓	-	7	7/9
30	Chrcanovic, et al. ⁴⁸ , 2016	Retrospective	2670		54	✓	✓	521	8/9
31	Daneshvar et al. ⁴⁹ , 2016	Retrospective	40	71	56	✓	✓	8	9/9
32	Gherlone et al. ⁵⁰ , 2016	Prospective	22	46	55	✓	✓	42	9/9
33	Ghiraldini et al. ⁵¹ , 2016	Controlled clinical trial	28	23	56.4	✓	✓	0	8/9
34	Kappel et al. ⁵² , 2016	Randomized controlled trial	34	12	69	✓	✓	8	7/9
35	Malchiodi et al. ⁵³ , 2016	Randomized controlled trial	24	16	52	✓	✓	10	7/9
36	Zumstein and Sennerby ⁵⁴ , 2016	Retrospective	22	28	58	✓	✓	4	7/9
37	Malo et al. ⁵⁵ , 2016	Retrospective	299	422	51	✓	✓	477	9/9

Implant failure rate

The odds ratio of implant failure rate between diabetic and non-diabetic patients was 5.31 (OR, 95% CI 5.06, 5.56; p=00) ($I^2=99.50\%$; $P=0.00$; high heterogeneity). In terms of implant failure rate, a statistically significant difference was observed between the two groups. Based on these findings, the implant failure rate was higher in diabetic patients than in the non-diabetic group (Figure 2).

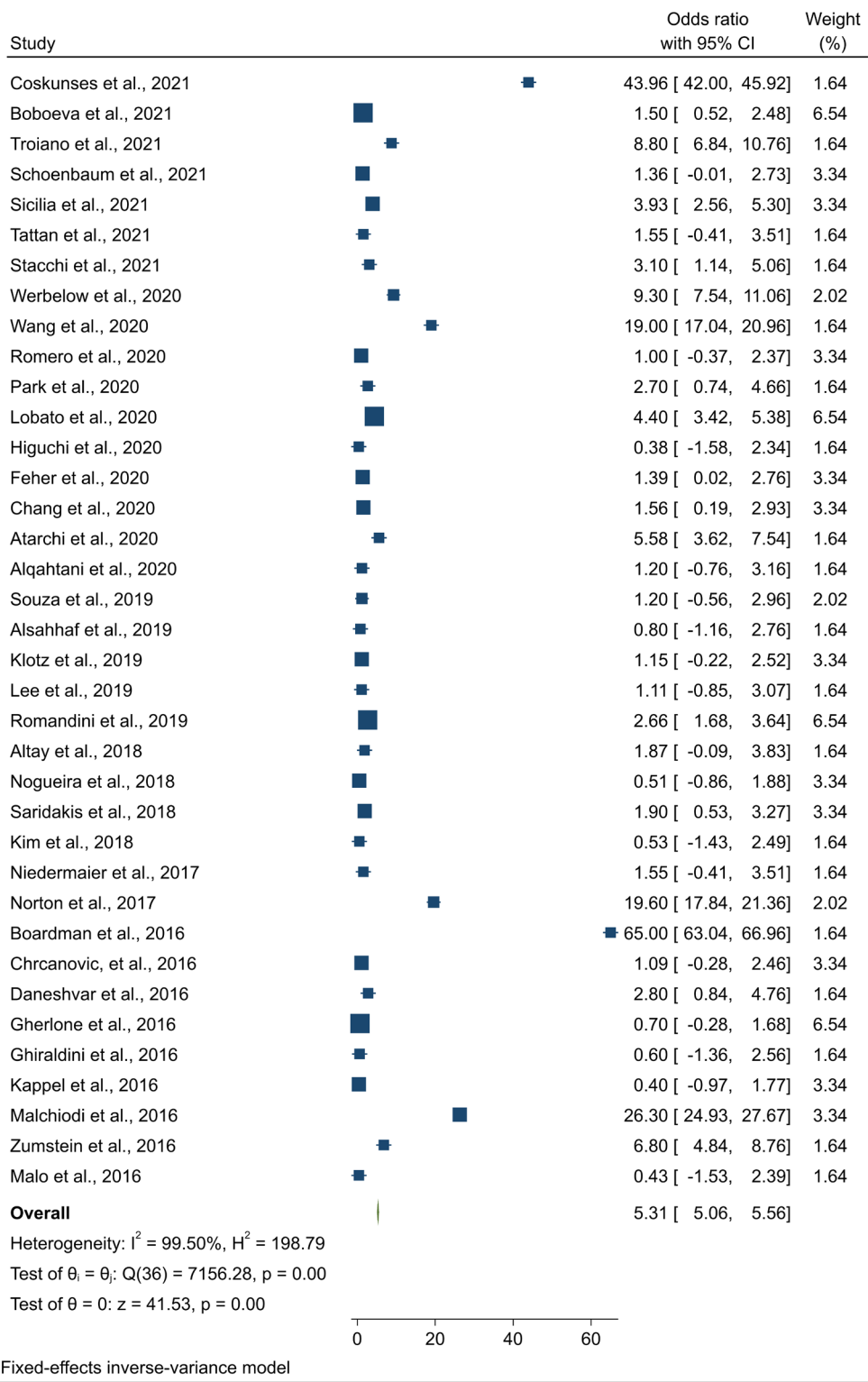


Figure 2. The forest plot showed the implant failure rate between diabetic and non-diabetic patients.

Subgroup meta-analysis showed an odds ratio of maxillary implant failure rate between diabetic and non-diabetic patients was 11.07 (OR, 95% CI 10.35, 11.80) ($I^2=99.85\%$; $P=0.00$; high heterogeneity). The maxillary implant failure rate between diabetic and non-diabetic patients was 11.07 (OR, 95% CI 10.35, 11.80) ($I^2=99.85\%$; $P=0.00$; high heterogeneity). The mandible implant failure rate between diabetic and non-diabetic patients was 1.26 (OR, 95% CI 0.64, 1.87) ($I^2=99.71\%$; $P=0.00$; high heterogeneity) (Figure 3). Test of subgroup differences showed a statistically significant difference between groups ($p=0.00$).

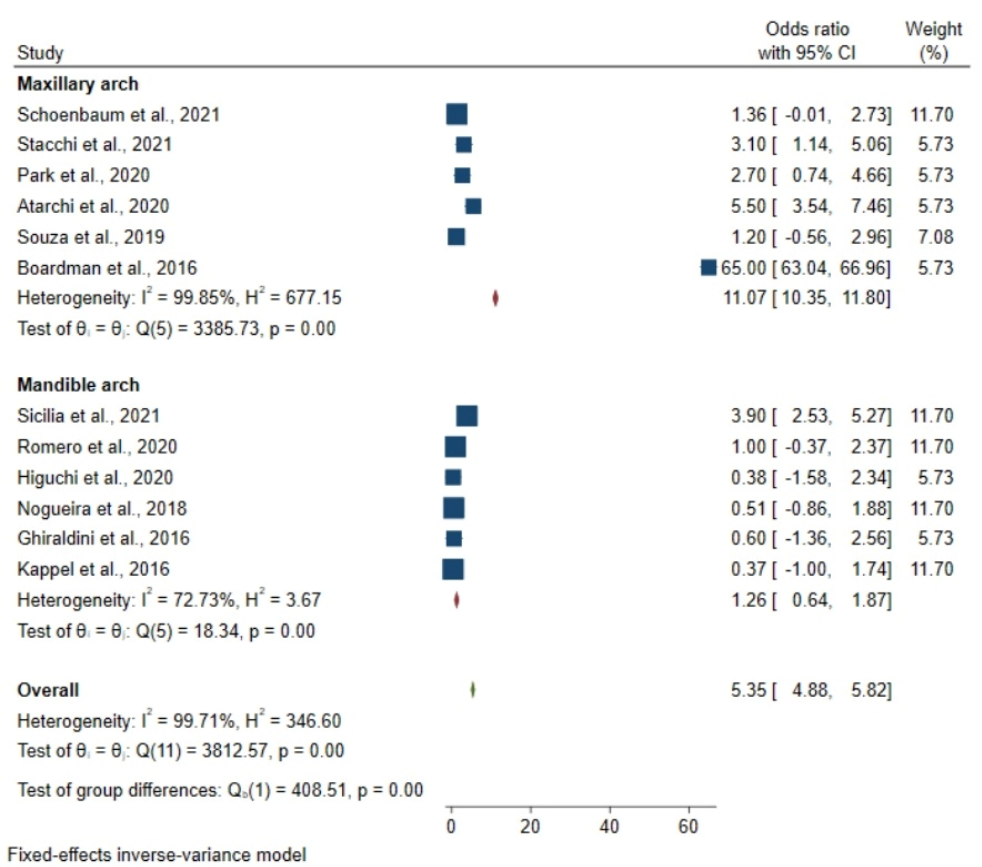


Figure 3. The forest plot showed a subgroup meta-analysis of implant failure rate based on implant location.

The odds ratio of implant failure rate between type 1 and type 2 diabetes was 1.56 (OR, 95% CI 0.69, 2.44; $p=0.00$) ($I^2=88.66\%$; $P=0.00$; high heterogeneity) (Figure 4).

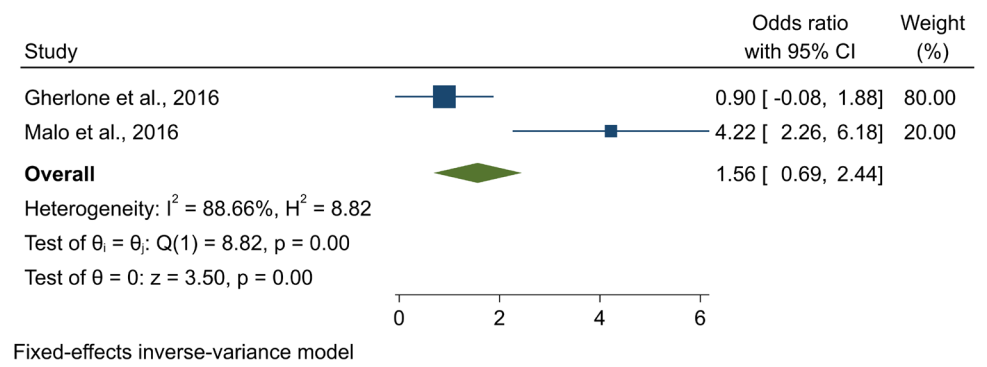


Figure 4. The forest plot showed implant failure rate between type 1 and type 2 diabetes.

Marginal bone loss

The mean difference in marginal bone loss between diabetic and nondiabetic patients was 1.63 (MD, 95% CI 0.89, 2.37; $p=0.00$) ($I^2=78.69\%$; $P=0.00$; high heterogeneity) (Figure 5).

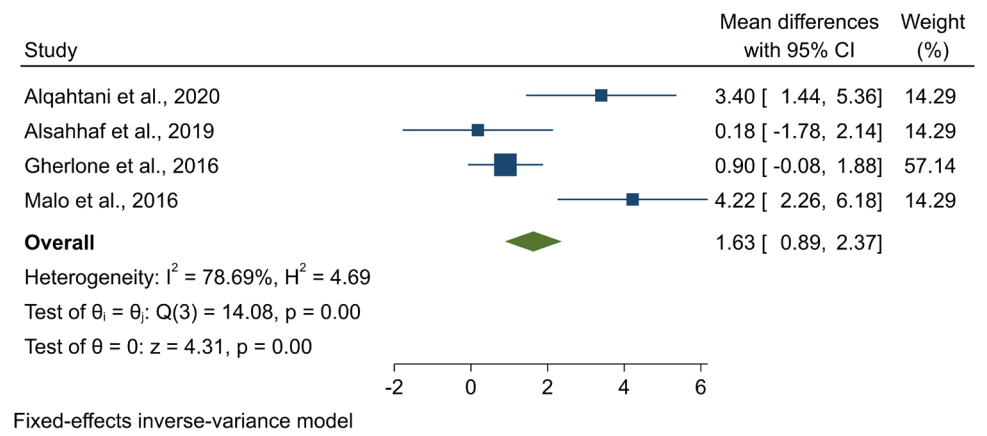


Figure 5. The forest plot showed mean differences in marginal bone loss.

Discussion

In the present study, implant failure and marginal bone loss in patients with diabetes were investigated, and the results were compared with non-diabetic patients. Compared to previous studies in this field, the present study has advantages, such as the fact that more clinical studies were used in the present study, the sample size was much higher, and a stronger meta-analysis was presented⁵⁶⁻⁵⁸. Also, in the current study, the survival rate of implants in both jaws has been investigated, and marginal bone loss has also been investigated. The present meta-analysis shows that implant survival in diabetic patients was lower than in non-diabetic patients, and higher marginal bone loss was observed in diabetic patients. Since diabetes has negative effects

on bone metabolism and bone strength, so it can be one reason for decreasing implant survival in diabetic patients. Also, hyperglycemia can affect the bone mineral density and increase the risk of fracture^{59,60}. A study found that total body bone density was significantly lower in patients with type 1 diabetes than in non-diabetic patients⁶¹. Another factor that can affect the survival of implants is the delay in wound healing, which is very common in diabetic patients. Also, disturbance in the metabolism of bone cells in diabetic patients can weaken proper bone repair⁶². Microvascular complications in diabetic patients can affect the failure of implants^{63,64}. Hyperglycemia (high blood glucose) can cause vomiting, excessive hunger and thirst, fast heart rate, vision problems, and other symptoms. Untreated hyperglycemia can lead to serious health problems, disrupting the immune response (suppressing cytokine production) and making patients with diabetes more susceptible to infection⁶⁵. It can affect the implant's failure; the immune system is needed to deal with the infection of the tissues around the implants⁶⁶. All the things mentioned above, either directly or indirectly, can affect the survival rate of dental implants.

The present meta-analysis showed that MBL around implants was significantly higher in patients with diabetes than in patients without diabetes. Based on the findings of a study, bone loss around implants can be caused by hyperglycemia⁶⁷. Also, a study showed that the increase in glycemic level is directly related to the prevalence of peri-implantitis⁶⁸. Since the effects of various factors in diabetic patients lead to an increase in MBL; Therefore, it is necessary to control the tissues around the implant in patients with diabetes. A study showed that treating periodontal disease to control blood sugar does not improve blood sugar control in diabetic patients⁶⁹; However, periodontitis was considered and not peri-implantitis. One of the interesting points is the importance of investigating the effect of different implant levels on MBL in patients with diabetes, which can affect the survival rate. Meta-analysis showed that the survival rate of dental implants in the upper jaw between diabetic and non-diabetic patients is statistically significant. It was also observed that implant failure in patients with type 1 diabetes was much more common than in type 2. The cause of these findings can depend on the difference in the pathophysiology of type 1 and type 2 diabetes, treatment regimen, and metabolic control. Symptoms may be more severe in patients with type 1 diabetes. As it is evident, type 1 diabetes begins at a younger age, and its micro and macrovascular complications are observed earlier⁷⁰. Also, bone loss occurs earlier in patients with type 1 diabetes⁷¹. All the mentioned cases can cause patients with type 1 diabetes damage to the implant, and the bone site is more than in patients with type 2 diabetes. One of the limitations of the study was that few studies reported the mean MBL with standard deviation, which could affect the study results.

Conclusion

Based on the findings of the present study, the survival rate of implants in patients with diabetes was lower than in patients without diabetes. Also, marginal bone loss was higher in patients with diabetes than in the control group. Compared to the type of diabetes in affected people, it was observed that patients with type 1 diabetes are more at risk of dental implant failure.

Conflict of Interest

The authors declared that there is no conflict of interest.

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Authors contribution

Asal Moravej: Methodology, Data analysis, Writing - Original Draft and Writing - Review and Editing.

Elnaz Mousavi: Methodology, Review and Editing.

Amir Azizi: Methodology, Writing - Original Draft and Writing - Review and Editing.

Ali Amiri: Conceptualization, Methodology, Formal Analysis, Investigation, Writing - Original Draft, Writing - Review and Editing and Visualization.

Ayda Sameie: Validation and Writing - Review and Editing.

Data availability

Datasets related to this article will be available upon request to the corresponding author.

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