What Affects Postoperative Sinusitis and Implant Failure after Dental Implant: A Meta-analysis

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Abstract
Objective. The dental implant is an innovative instrument that enables the edentulous patient to chew. Many factors have a bearing on the success of dental implantation. There are also many complications after dental implantation. In this meta-analysis, we investigated which factors increase the risk of postoperative sinusitis and implant failure after dental implant for the first time.

Data Sources. Included data were searched through the PubMed, EMBASE, and Cochrane library databases. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, and 2 authors (J.S.K., S.H.K.) independently extracted data by multiple observers.

Review Methods. We used a random-effects model considering the variation between and within the included studies.

Results. Twenty-seven studies were included in our final meta-analysis. The proportion of postoperative sinusitis, perforation of the sinus membrane, and implant failure was 0.05 (95% confidence interval [CI], 0.04-0.07), 0.17 (95% CI, 0.13-0.22), and 0.05 (95% CI, 0.04-0.07), respectively, using the single proportion test. The only factors that affected postoperative sinusitis were preoperative sinusitis and intraoperative perforation of the Schneiderian membrane (P < .01 and P < .01, respectively). The only factors that affected dental implant failure were smoking and residual bone height of the maxilla (P < .05 and P < .01, respectively).

Conclusions. Two factors affect postoperative sinusitis after implant surgery: preoperative sinusitis and Schneiderian membrane rupture. It should also be noted that the factors affecting implant failure are residual bone height and smoking. These findings will have a significant impact on the counseling and treatment policy of patients who receive dental implants.

Keywords
dental implant, survival, sinusitis, Schneiderian membrane perforation, implant failure, smoking

Received November 16, 2018; revised December 19, 2018; accepted January 18, 2019.

With the rapid development of implant technology in recent years, a large number of dental implant procedures are now being performed annually worldwide. Mandibular implants provide a stable support for the mandible in the surrounding structures, but the following factors increase the difficulty of the procedure: (1) insertion of the maxillary implant in a direction opposite to gravity and (2) lack of support to serve as a stable pedestal for the implant when the maxilla is thin. To resolve these factors and to supplement the maxilla with a short pedestal, a sinus lift procedure is needed to elevate the maxillary sinus mucosa before the maxillary sinus implant. When pneumatization of the maxilla is excessive or the maxilla of the upper alveolar bone is thin, bone grafts that transplant bone to thicken the maxilla are performed in maxillary sinus implantation.
implants. These are examples of procedures used to increase the success rate of dental implants.

Sinus lift or dental implantation may cause complications such as Schneiderian membrane perforation or infections such as sinusitis. These complications can often be resolved by medication or by endoscopic sinus surgery. Despite these efforts, however, the implant often fails. In this study, we have systematically investigated the factors that give rise to complications in dental implant surgery.

**Materials and Methods**

**Search Strategy**

This study was exempt from institutional review board approval as it is a review of previously published deidentified data. We systematically searched PubMed, EMBASE, and Cochrane library databases. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.1

The search terms were dental implant/s and sinusitis. Two authors (J.S.K., S.H.K.) independently searched the literature by multiple observers (E.J.L., M.H.L., C.D.Y., S.G.K., J.S.R., J.H.Y., S.M.C.) and searched all documents published before July 2018.

The search string used in Medline was as follows: (“dental implants”[MeSH Terms] OR (“dental”[All Fields] AND “implants”[All Fields]) OR “dental implants”[All Fields] OR (“dental”[All Fields] AND “implant”[All Fields]) OR “dental implant”[All Fields]) AND (“sinusitis”[MeSH Terms] OR “sinusitis”[All Fields]).

**Selection of Studies**

The inclusion criteria were articles that satisfied the following conditions:

1. Articles related to dental implants and sinusitis
2. Articles published in the English language
3. Articles with appropriate dichotomous data related to preoperative and postoperative sinusitis, implant failure, and perforation of the sinus membrane

The exclusion criteria were as follows:

1. Facial implants other than dental implants (eg, zygoma implants)
2. Case reports or case series
3. The target contents were correct, but there were no data
4. Articles containing questionnaire data
5. Review articles
6. Articles in a language other than English
7. Articles related to animal experiments

**Data Extraction**

Article titles and abstracts were independently searched by 2 authors (S.H.K., J.S.K.). The following information was extracted: author names, publication year, study design, the number of patients, the number of procedures, the number of cases of sinusitis, the number of implants, and the number of dental implant failures.

**Statistical Analysis**

Cochrane Review Manager (RevMan version 5.3; The Cochrane Collaboration, Oxford, England) and R version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria) software were used for the meta-analysis. The heterogeneity of each study was calculated according to the extracted data. Dichotomous data were expressed as odds ratios (ORs).

The overall interpretation was broadly divided into a fraction with postoperative sinusitis and a fraction with dental implant failure. The OR of the primary outcome was obtained from the dichotomous data of the individual articles. Summarized ORs were calculated using a random-effects model with a 95% confidence interval (CI), taking into account the variance within each study and between studies.2

Hedge’s $g$ effect size and standard error were used for each primary outcome calculation.3 The standard error was calculated using the inverse variance method considering the number of samples. The heterogeneity of the study was assessed using the $I^2$ test.4 Forest plots were constructed using the random-effects model, and funnel plots were used for publication bias. The first proposed funnel plot was calibrated using Duval and Tweedie’s trim-and-fill method, which is a method of validity testing by correcting the overall effect size assuming unpublished studies being published.5,6

**Results**

**Search Results and Overall Meta-Analysis**

The flowchart for the study selection process according to PRISMA guidelines is shown in Figure 1. Among 342 studies searched, 13 duplicate studies, 21 studies with irrelevant content, 231 studies that were case reports or case series, 21 studies not in English, and 12 review articles were excluded; thus, the full text of 44 studies was thoroughly investigated. After excluding a further 17 studies not relevant to our topic, 27 studies were finally selected for our quantitative and qualitative meta-analysis. Table 1 includes the authors, publication year, methodology, total number of patients, number of implant procedures, and risk of bias for these final 27 articles. We used a random-effects model considering the differences between studies and the dispersion within studies (Table 1).7,33

**Postoperative sinusitis.** Among 25 studies and 2301 patients, postoperative sinusitis occurred in 118 patients. The proportion of sinusitis using the single proportion test was 0.05 (95% CI, 0.04-0.07) (Figure 2A).

**Perforation of the sinus membrane.** Among 24 studies and 3162 sinus lift procedures, perforation of the sinus membrane occurred in 644 sinuses. The proportion of sinusitis using the single proportion test was 0.17 (95% CI, 0.13-0.22) (Figure 2B).
Implant failure. Among 23 studies and 5215 dental implant procedures, implant failure occurred in 296 cases. The proportion of implant failure using the single proportion test was 0.05 (95% CI, 0.04-0.07) (Figure 2C).

Conditions Affecting Postoperative Sinusitis

Preoperative sinusitis. Nine studies concerning preoperative sinusitis were included with a total sample of 707 patients. Analysis of postoperative sinusitis following postoperative sinusitis revealed an OR of 21.21 (95% CI, 8.25-54.52; \( P < .01 \)) with low heterogeneity \( (I^2 = 13\%) \) (Figure 3A).

Intraoperative perforation of the Schneiderian membrane. Twelve studies concerning intraoperative perforation of the Schneiderian membrane were included with a total sample of 1541 patients. Analysis of postoperative sinusitis following intraoperative perforation of the Schneiderian membrane revealed an OR of 2.86 (95% CI, 1.72-4.77; \( P < .01 \)) with no heterogeneity \( (I^2 = 0\%) \) (Figure 3B).

Smoking. Three studies concerning smoking were included with a total sample of 385 patients. Analysis of postoperative sinusitis with smoking revealed an OR of 2.01 (95% CI, 0.51-7.94; \( P = .18 \)) with no heterogeneity \( (I^2 = 0\%) \) (Figure 3C).

Diabetes mellitus. Two studies concerning diabetes mellitus (DM) were included with a total sample of 248 patients. Analysis of postoperative sinusitis with DM revealed an OR of 4.89 (95% CI, 2.11-113.06; \( P = .32 \)) with moderate heterogeneity \( (I^2 = 56\%) \) (Figure 3D).

Sex. Three studies concerning sex were included with a total sample of 274 patients. Analysis of postoperative sinusitis with regard to sex revealed an OR of 0.41 (95% CI, 0.11-1.49; \( P = .18 \)) with no heterogeneity \( (I^2 = 0\%) \) (Figure 3E).

One-stage implant surgery. Three studies concerning simultaneity of dental implant surgery were included with a total sample of 316 patients. Analysis of postoperative sinusitis following 1-stage dental implant surgery revealed an OR of 1.14 (95% CI, 0.12-10.87; \( P = .91 \)) with substantial heterogeneity \( (I^2 = 63\%) \) (Figure 3F).

Recurrence of sinusitis according to surgery vs medical treatment only. Three studies concerning the recurrence of sinusitis according to the treatment method were included with a total sample of 98 patients. Analysis of the recurrence of sinusitis with regard to treatment method revealed an OR of 0.58 (95% CI, 0.05-6.55; \( P = .66 \)) with moderate heterogeneity \( (I^2 = 55\%) \) (Figure 3G).

Conditions Affecting Dental Implant Failure

Intraoperative perforation of the Schneiderian membrane. Four studies concerning intraoperative perforation of the Schneiderian membrane were included with a total sample of 699 patients. Analysis of dental implant failure following intraoperative perforation of the Schneiderian membrane revealed an OR of 1.76 (95% CI, 0.73-4.28; \( P = .21 \)) with moderate heterogeneity \( (I^2 = 44\%) \) (Figure 4A).

Smoking. Three studies concerning smoking were included with a total sample of 675 patients. Analysis of dental implant failure with regard to smoking revealed an OR of 2.44 (95% CI, 1.04-5.69; \( P = .04 \)) with no heterogeneity \( (I^2 = 0\%) \) (Figure 4B).

Sex. Five studies concerning sex were included with a total sample of 569 patients. Analysis of dental implant failure with regard to sex revealed an OR of 1.83 (95% CI, 0.84-3.98; \( P = .13 \)) with low heterogeneity \( (I^2 = 20\%) \) (Figure 4C).

One-stage implant surgery. Five studies concerning simultaneity of dental implant surgery were included with a total sample of 664 patients. Analysis of dental implant failure following 1-stage dental implant surgery revealed an OR of 1.91 (95% CI, 0.68-5.36; \( P = .22 \)) with moderate heterogeneity \( (I^2 = 46\%) \) (Figure 4D).

Surgical procedure used. Two studies concerning surgical procedure used were included with a total sample of 316 patients. Analysis of dental implant failure with regard to surgical method revealed an OR of 1.14 (95% CI, 0.12-10.87; \( P = .91 \)) with moderate heterogeneity \( (I^2 = 63\%) \) (Figure 4E).

Age. Two studies concerning age were included with a total sample of 81 patients. Analysis of dental implant failure with regard to age revealed an OR of 0.34 (95% CI, 0.08-1.51; \( P = .16 \)) with no heterogeneity \( (I^2 = 0\%) \) (Figure 4F).
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Abbreviations: NA, data not available; RCT, randomized controlled study.
*aCochrane Risk of Bias Tool.
*bNewcastle Ottawa Scale.
Residual bone height. Three studies concerning residual bone height were included with a total sample of 152 patients. Analysis of dental implant failure with regard to residual bone height revealed an OR of 5.18 (95% CI, 1.61-16.61; \( P = .006 \)) with no heterogeneity (\( I^2 = 0\% \)) (Figure 4G).

Conditions Affecting Perforation of the Schneiderian Membrane

Age. Two studies concerning age were included with a total sample of 40 patients. Analysis of perforation of the Schneiderian membrane with regard to age revealed an OR of 2.73 (95% CI, 0.61-12.18; \( P = .19 \)) with no heterogeneity (\( I^2 = 0\% \)) (Figure 4H).

Publication Bias

In funnel plots of the effect of primary outcomes, the studies were clustered near the top and center of the plot, which suggests little publication bias (see Supplemental Figure S1A-O, available in the online version of the article). Egger’s regression test was performed for 1 of 15 primary outcomes and showed no significant bias. When using Duval and Tweedie’s trim-and-fill method to adjust for potentially unpublished studies, there was no significant change of pooled ORs (see Supplemental Figure 2A-O, available in the online version of the article).

Summary of Results

The only factors that affected postoperative sinusitis were preoperative sinusitis and intraoperative perforation of the Schneiderian membrane. On the other hand, smoking, DM, 1-stage dental implant surgery, and sex did not affect postoperative sinusitis. There was no statistically significant difference in the recurrence of sinusitis between surgery and medical therapy alone.

The only factors that affected dental implant failure were smoking and residual bone height of the maxilla. One-stage dental implant surgery, treatment method, age, sex, and intraoperative perforation of the Schneiderian membrane showed no effect on dental implant failure.

Discussion

Dental implant surgery, which allows a person without teeth to chew, is a very important procedure in dentistry. Linkow first performed a dental implant in 1952.7 However, teeth in the maxilla are close to the maxillary sinus and are prone to complications such as sinusitis. Tatum34 attempted to resolve this problem by introducing the sinus lift technique. After that, Summers35 devised a safer and simpler method by introducing the crestal approach. Despite these efforts, complications from sinusitis and implant failure should be avoided if possible. In this study, we have used qualitative and quantitative meta-analysis to study these complications.

The overall rate of postoperative sinusitis in our study was 5% (Figure 2A). The presence of sinusitis before surgery significantly affected the presence or absence of postoperative sinusitis. Preoperative sinusitis was found to increase the probability of postoperative sinusitis by 21.21-fold (Figure 3A). Therefore, it is important to take a history of nasal problems before surgery and to make sure that paranasal computed tomography (CT) is performed to determine the status of the sinus. Tatum34 attempted to resolve this problem by introducing the sinus lift technique. After that, Summers35 devised a safer and simpler method by introducing the crestal approach. Despite these efforts, complications from sinusitis and implant failure should be avoided if possible. In this study, we have used qualitative and quantitative meta-analysis to study these complications.
Rupture of the sinus membrane is an occasional complication that surgeons try to avoid; however, it is the most common complication of the sinus lift procedure. Our study showed that the overall rate of sinus membrane perforation was 17% (Figure 2B). Small perforations of the Schneiderian membrane do not seem to cause major trouble.
problems because they heal more easily. However, the larger the perforation, the more likely a bone graft will extrude from a perforated site. In addition, the rate of mucociliary clearance, which removes bone grafts or foreign bodies, is slower than the healing rate, which increases the probability of sinusitis. In addition, if postoperative edema
or hematoma occurs in the maxillary sinus, sinusitis may develop because these conditions can block the natural ostium of the maxillary sinus. In this meta-analysis, we also confirmed that, when a perforation was present, the probability of developing sinusitis was significantly increased by about 2.86-fold (Figure 3B). However, it is very interesting to note that the presence or absence of a perforation is not directly related to implant failure (Figure 4A). Presumably, when a perforation is present, antibiotics used prophylactically for sinusitis control or timely surgery may prevent implant failure. It is also important to note that the antibiotic-only group, in whom antibiotics were used prophylactically for sinusitis control, had similar postoperative recurrence rates to the surgery group (Figure 3G). Chen et al. reported that sinusitis without chronic change was sufficiently treatable by medical therapy, which is consistent with our meta-analysis.

The surgical procedure used for dental implantation is largely divided into a lateral approach or a crestal approach as mentioned earlier. Both methods use a dental prosthesis supported by endosseous implants to restore normal chewing function. One study reported that the lateral approach is more likely to cause a Schneiderian membrane rupture than the crestal approach and thus increases the probability of sinusitis because graft material is more likely to enter the sinus. However, in that study, the surgical approach itself did not affect the implant survival rate, and similar results were obtained in this meta-analysis. Although sinusitis can occur after dental implant surgery, it can be controlled by medication or surgery, and sinusitis itself has not proven to be an obstacle to implant survival.

The overall rate of dental implant failure was 5% (Figure 2C). So, what are the factors that affect implant survival? A dental implant procedure may be performed simultaneously with the fixture and abutment process, or it may be performed after the healing process, and this decision depends on the amount of bone remaining in the maxilla, the stability of the implant, and the surgeon's preference.

Some researchers have suggested that a staged operation increases the likelihood of infection, whereas others have concluded that it does not. In this meta-analysis, it was found that dental implantation in 1 stage or 2 stages did not affect postoperative sinusitis or dental implant failure (Figures 3F and 4D). Rather, the most important factor in implant placement was residual bone height. In the present study, it was found that the implant failure rate was 5.18 times higher when the residual bone height was less than 5 mm compared to cases where residual bone height was more than 5 mm (Figure 4G). Therefore, it can be said that it is important to increase primary stability through a bone graft when the residual bone height is less than 5 mm, and this can be established by taking a preoperative CT scan.

Levin et al. showed that smoking did not increase the risk of infectious complications such as sinusitis but increased the risk of implant failure by 2.44-fold (Figures 3C and 4B). Other authors have shown that smokers have a 3.5-fold increased risk of implant loss in the implanted area compared to nonsmokers. Smoking induces deficiencies of oxygen in tissues and in the microcirculation, and it slows wound healing through the presence of carbon monoxide, hydrogen cyanide, and other toxic products in the smoke.

Some studies have shown that smoking increases the prevalence of Staphylococcus aureus compared to nonsmokers, but it is also reported to lower the prevalence of S. aureus. Smoking has also been reported to increase cytokines such as interleukin-17a and has been reported to interfere with chemotaxis and adherence of leukocyte phagocytosis, and there is controversy as to whether smoking increases or decreases postoperative sinusitis when performing dental implantation. Our study supports these results, finding that smoking did not affect postoperative sinusitis. Nevertheless, it is noteworthy that smoking itself increases the implant failure rate.

There are many reasons for this result. Smoking may not induce sinusitis significantly, but it may be assumed that multiple inflammatory reactions such as peri-implantitis and marginal bone loss combine to cause implant failure. The results of our study are consistent with the results of previous studies that smoking slows wound healing and is related to implant failure.

There are several limitations in our study. First, there was no consideration of the quality of bone, which is thought to be an important factor in dental implantation. Because of the nature of meta-analysis, the final result of some topics cannot be produced without the individual data. Second, there were many observational studies in our meta-analysis, and the results from these are less persuasive than those from randomized controlled trials. Further well-controlled studies would substantiate and enrich our study.

Despite these limitations, we should note carefully the symptoms of sinusitis such as purulent rhinorrhea, nasal obstruction, headache, and foul odor. If the patient is suspected of having sinusitis, preoperative CT should be performed, and consultation with an otolaryngologist can help to prevent postoperative sinusitis. Surgeons should try to avoid rupture of the Schneiderian membrane so as to minimize the risk of sinusitis after surgery. Knowing whether the patient is a smoker and measuring residual bone height through preoperative CT can have a big impact on the counseling and treatment policy for patients with regard to postoperative sinusitis and survival of the dental implant.

Conclusion

Two factors increase the risk of postoperative sinusitis after implant surgery: preoperative sinusitis and Schneiderian membrane rupture. It should also be noted that the factors that increase the risk of dental implant failure are residual bone height and smoking. These findings will have a significant impact on the counseling and treatment policy of patients who receive dental implants.
Author Contributions

Jong Seung Kim, substantial contributions to the conception, design of the work; the acquisition, analysis, interpretation of data for the work; drafting the work, revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy, integrity of any part of the work are appropriately investigated and resolved; Sang Moon Choi, substantial contributions to the conception, design of the work; the acquisition, analysis, interpretation of data for the work; drafting the work, revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy, integrity of any part of the work are appropriately investigated and resolved; Ji Hyun Yoon, substantial contributions to the conception, design of the work; the acquisition, analysis, interpretation of data for the work; 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agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy, integrity of any part of the work are appropriately investigated and resolved; Yeon Seok You, substantial contributions to the conception, design of the work; the acquisition, analysis, interpretation of data for the work; drafting the work, revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy, integrity of any part of the work are appropriately investigated and resolved.

Disclosures

Competing interests: None.

Sponsorships: None.

Funding source: This study was supported by Fund of Biomedical Research Institute, Chonbuk National University Hospital and by research funds for newly appointed professors of Chonbuk National University in 2018.

Supplemental Material

Additional supporting information is available in the online version of the article.

References


