

The Influence of Cigarette Smoking on Dental Implant Survival Rates: A Comparative Analysis of Smokers and Non-Smokers

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Abstract

AIM: The objective of this study is to determine the significant influence of smoking cigarettes on the dental implant survival-failure rate in comparison to the rate in non-smokers.

METHODS: An electronic search was conducted for studies published in English, restricted to the period between 2012 and 2022. Pub-Med and Google Scholar were used to search for articles comparing the success vs. failure rates of dental implants between smokers and non-smokers.

RESULTS: Smokers have a higher failure rate, with the duration and amount of smoking being significant factors compared to non-smokers. Moreover, osseointegration was adversely affected by smoking, and smoking accelerated marginal bone loss. Patients who quit smoking showed the same success rates as non-smokers.

CONCLUSION: Implant insertion is not an absolute contraindication for smokers, but patients should be informed about all risk factors (bone healing issues, osseointegration, and implant failure). They should be aware that consuming cigarettes during the initial healing phase after implant insertion increases the risk of failure. Advising patients to quit smoking is a viable solution that helps accelerate bone healing and increases the rates of osseointegration and implant success.

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1 Introduction

Implantology has been introduced into the world of dentistry and has shown acceptance from patients; despite the expense and long duration needed, it is preferred over prosthodontics. Dental implants have become a conservative and effective way to replace missing teeth (Tsigarida et al., 2015).

The concept of osseointegration was first described by Brånemark and colleagues in the 1960s and 70s. Osseointegration is defined as "a direct structural and functional connection between living bone and the surface of a load-bearing implant."

Studies have reported that the overall survival rates in various clinical situations are higher than 90% (Çakarar et al., 2014). Moy et al. (2005) reported a success rate in implant treatment for nonsmokers of 91% compared to 80% for smokers. Most failures occurred during the first year following implant placement.

However, dental implant failures still occur in patients and lower success rates are observed in patients with systemic diseases or bad habits such as smoking cigarettes (Çakarar et al., 2014).

One of the risk factors associated with implant failure is smoking. Although the risks are higher in smoking patients, implant insertion for smokers is not an absolute contraindication. Smoking tobacco has been shown to be a risk factor for periimplant bone healing (Sennerby et al., 1998).

The osseointegration process requires the recruitment of osteoblasts, their anchorage, adhesion, spreading, proliferation, and differentiation into osteoblasts that secrete extracellular matrix calcification on the implant surface. All these cellular events are sensitive to the local and systemic effects of nicotine and other associated components (O'Connell et al., 2019; Sanchez-Pérez et al., 2007).

Nicotine, the main component of cigarettes, has more than 4,000 bioactive chemical components with potentially toxic effects on human tissues, including bone. Smoking is frequently linked with bone healing failures, which lead to insufficient osseointegration. Recent studies have revealed that the effects of smoking cigarettes progress through direct and indirect systemic and local influences on bone metabolism at the bone-implant interface (Tsigarida et al., 2015). The gene expression of several key enzymes that regulate osteoblast proliferation, differentiation, apoptosis, and bone formation and remodeling is down-regulated by nicotine. In addition, nicotine exposure has a direct effect on blood vessels, inducing vasoconstriction, systemic venoconstriction, and decreased blood perfusion. This eventually leads to low oxygen and ischemia at the implant site. These malfunctions also interfere with the interactions among osteoblasts, osteocytes, osteoclasts, and vascular cells at various levels, affecting bone formation and remodelling (Chrčanovic et al., 2015).

In addition, substances such as carbon monoxide, nitrosamines, benzenes, aldehydes, and hydrogen cyanide have been shown to affect processes essential to bone healing (Yuhara et al., 1999). Nicotine acts as a vasoconstrictor, reducing both blood flow and nutrient delivery to the surgical implant site, and inhibits the proliferation of fibroblasts, red blood cells, and macrophages (Yildiz et al., 2004). In addition to nicotine, carbon monoxide also decreases the oxygen-carrying capacity of red blood cells, while hydrogen cyanide leads to hypoxia.

Recently, evidence has shown that smoking significantly affects the success rates of dental implants, and increases the risk of postoperative infections and marginal bone loss in patients receiving dental implants (Chen et al., 2013; Chrčanovic et al., 2015). Some studies have confirmed that smoking negatively affects the clinical success of implant treatment and the long-term prognosis. A recent study found that heavy smokers (20 cigarettes/day) had the

highest implant failure rate and that the amount and duration of smoking play a significant role in implant survival and success (Haas et al., 1996; Hinode et al., 2006; Twito & Sade, 2014).

Various studies in the literature list smoking as one of the most contributory factors leading to implant failure. The failure rate of 6.5%–20% is reported by different studies (Naseri et al., 2020). In areas with poor quality trabecular bone, a higher implant failure rate is seen in smokers, which may be the reason for the higher failure rate in the maxilla and the least failure in the mandibular posterior region (Lambert et al., 2000). Failure can be attributed to nicotine absorption in the bloodstream, leading to vasoconstriction (O’Connell et al., 2019).

Former smokers who quit smoking reported the same outcome as non-smokers, and the longer the duration of quitting cigarette consumption, the higher success and survival rates were reported (Levin et al., 2008).

This study aims to evaluate the impact of smoking habits on the survival, success, and failure rates of dental implants, as well as on osseointegration and marginal bone loss, by comparing outcomes in smokers with those in non-smokers and analyzing variations among past smokers, recent quitters, continuous smokers, and by smoking intensity.

2 Methods

An electronic search was conducted for studies published in English, with the examined publications limited to the period from 2012 to 2022. The databases utilised for the search included PubMed and Google Scholar, with the objective of identifying articles that compare the success and failure rates of dental implants between smokers and non-smokers. The literature search employed the following terms: (Dental implant OR oral implant) AND (smoking OR smoker OR tobacco OR nicotine) AND (non-smoker OR non-smokers) AND (heavy smokers OR light smokers) AND (osseointegration OR bone healing). Upon retrieving relevant articles using these search strategies in electronic databases and appropriate keywords, a screening process was subsequently carried out by the authors.

The selection of the articles was based on careful examination of their titles and abstracts, with an emphasis on those that provided insights into bone healing, smoking habits, and implant failure and success rates. Specifically, studies that discussed the outcomes for patients who ceased smoking before or after implantation were considered. The chosen articles needed to meet several criteria: they had to be clinical human studies, published within the last decade, include randomized control trials, comparative studies, and clinical trials, and be written in English.

On the other hand, articles were excluded if they did not meet the rigorous standards set out for the research. Specifically, any papers featuring uncontrolled trials or those conducted on animals were not considered for inclusion in the review. This was to ensure that the data analyzed would be directly applicable to human clinical outcomes and provide a clear understanding of the impact of smoking on dental implant success and failure rates.

Based on the electronic search 1267 articles were identified, after applying the following filters: randomized controlled trials, clinical trials, and restricting the publication date range to 10 years, the total articles were reduced to 201. After screening through the articles, 149 from 201 were excluded (did not conclude the inclusion criteria aspects) and a total of 52 articles were selected.

2.1 Statistics

Descriptive statistics, frequency analysis, and content analysis were employed as part of the qualitative methodology to systematically analyze the textual content of the included studies. It is important to note that, given the narrative nature of this study, regression analysis and meta-analysis techniques were not deemed suitable for the analytical framework.

3 Results

Success and failure rates of implants in smokers versus non-smoker patients were given in eight studies with an observation period of up to 14 years (**Table 1**). Failure rates are given in five of the studies and range from 5.5% to 11.3% for smokers, while for non-smokers the range was lower, from 2.0% to 6.0%.

Overall significance remains unclear, though: while Bain and Moy (1993) and Sanchez-Perez et al. (2007) found the difference to be significant, Cavalcanti et al. (2011) did not, and the remaining two studies did not mention this information. Success rates are given by all eight studies, with the range from 84.2% to 93.8% for smokers, while for non-smokers the survival rate was generally higher, with the range from 95% to 99%. The difference was found to be significant in two studies, while one did not mention it (Cavalcanti et al., 2011).

Table 1. Success and survival rates of implants in smokers to non – smokers. S = smoker; non/past/current-S = non/past/current-smoker; Max = maxilla; Man = mandible; n/a = not available; Time = observation period; *** current smokers to former smokers; ** current smokers to non - smokers; * male/female ratio.

1stAuthor, date	Group	Implants	Location	Time	Failure %	Success %	P value
Lambert, 2000	S	959	Max	8 y	8.86	n/a	n/a
	non-S	1928			5.99		
Bain, 1993	S	2194	Max + Man	6 y	11.28	89	< 0.001
	non-S				4.76	95	
Cavalcanti, 2011	S	2260	Max + Man	5 y	5.50	n/a	0.13
	non-S	4460			2.90		
Ramanos, 2013	S	66	n/a	5-9 y	8	92	n/a
	non-S	97			2	98	
Saleem, 2020	S	204	n/ a	7 y	n/a	86	0.001
	non-S				-	99	
Levin, 2008	past-S	64	Max	5-14 y	n/a	93	0.031***
	current-S					87.10	0.016**
	non-S					-	93.75
Sanchez-Perez, 2007	S	90	Max + Man	n/a	n/a	84.2	< 0.05
	non-S	70				98.6	
Twito, 2014	S	6731/949*	Max + Man	n/a	135 (5.6)	n/a	0.001
	non-S				185 (3.5)		

Only two studies gave both failure and success rates (Bain & Moy, 1993; Ramanos et al., 2013). Failure rates ranged from 8% to 11.28% for smokers while for non-smokers they ranged from 2% to 4.76%. Bain and Moy (1993) found the difference to be significant while Ramanos et al. (2013) did not mention this information.

3.1 Osseointegration of implants in smokers and non-smokers

Osseointegration outcomes were presented in three studies with an observation period of up to two years. One study observed implant mobility using two measurement methods, the

Implant Stability Quotient (ISQ) and the Periotest (PT), while the two remaining studies observed bone density and bone contact (Supplementary **Table S2**).

One study focused on the maxilla, whether anterior maxilla or posterior maxilla. Implant mobility in the anterior maxilla for smokers, measured by the ISQ method, ranged from 58.5 ± 5.05 to 65.52 ± 5.05 , while non-smokers' implant mobility ranged from 60.0 ± 5.1 to 67.61 ± 5.11 . In the same study, implant mobility was also measured by the PT method, where smokers' readings ranged from PT -1.40 ± 0.12 to 2.52 ± 0.11 , while non-smokers' readings ranged from PT -1.44 ± 0.09 to 2.27 ± 0.10 .

For the posterior maxilla, implant mobility measured by the ISQ method for smokers ranged from 60.4 ± 0.4 to 64.0 ± 0.5 . By the PT method, smokers' readings ranged from PT -1.08 ± 0.18 to 2.37 ± 0.2 , while non-smokers' implant mobility by the ISQ method ranged from 62.9 ± 0.6 to 67.2 ± 0.6 , and by the PT method from PT -2.32 ± 0.2 to 1.27 ± 0.3 . The overall significance difference for implant mobility in the anterior maxilla was not significant, whereas it was significant in the posterior maxilla.

One study clearly provided the bone density and bone contact ranges for the maxilla in smokers with a bone density range of 14.01 ± 5.70 and bone contact at 19.02 ± 4.38 , while the bone density range for the mandible in smokers was 23.51 ± 9.58 and bone contact at 32.93 ± 6.57 . Non-smokers' bone density in the maxilla ranged from 17.90 ± 8.38 with bone contact at 32.97 ± 8.98 , while in the mandible, bone density ranged from 41.85 ± 16.9 and bone contact at 56.40 ± 8.38 .

Smokers' bone density ranged from 19.1 ± 7.6 , while non-smokers' ranged from 28.5 ± 18.8 . The ranges for bone contact in smokers were 25.9 ± 9.1 and 39.8 ± 14.2 in non-smokers. The overall significance difference for bone density and bone-to-implant contact remained unclear.

3.2 Marginal bone loss in smokers and non-smokers

Marginal bone loss in smokers versus non-smokers was given in four studies, with an observation period of up to 20 years (**Table 3**). One study reported the marginal bone loss separately for the maxilla and the mandible in smoking patients without mentioning the non-smoker group. The maxilla marginal bone loss in smokers was higher than that of the mandible, 3.95 mm for the maxilla and only 1.47 mm for the mandible, indicating a significant difference between the maxilla and mandible. Two studies reported the marginal bone loss in smokers by millimetres, ranging from 0.092 mm to 0.153 mm, while non-smokers ranged from 0.047 mm to 0.6 mm.

The last study provided the marginal bone loss by percentage, with smokers having a marginal bone loss percentage of 5.65% compared to 3.06% in non-smokers. The overall significance was clear: Haas et al. (1996) and Nitzan et al. (2005) found the difference to be significant, while the two remaining studies did not provide that information.

3.3 The influence of smoking habit - amount of smoking

Survival-failure rates based on the number of cigarettes consumed were given in seven studies with an observation period of up to 20 years. The highest consumption of cigarettes per day was recorded as 31 to 40 cigarettes, while the lowest was 1 to 10 cigarettes per day.

Failure rates for smokers based on consumption per day ranged between 3.51% to 15.80%, while non-smokers had lower failure rates ranging between 1.4% to 13.33% (**Table S4**). Three studies found the difference to be significant, while De Luca et al. (2006) did not. Implant success for smokers ranged from 40.24% to 92.42%, while non-smokers' implant

Table 3. Marginal bone loss in smokers to non – smokers. S = smoker; non-S = non-smoker; Max = maxilla; Man = mandible; n/a = not available; Time = observation period; * Number of implants not specified for each group separately.

IstAuthor, date	Group	Implants*	Location	Time	Marginal bone loss	P value
Haas, 1996	S	1336	Max + Man	1,8 y	Max 3.95 mm Man 1.47 mm	< 0.01
	non-S				n/ a	
Lindquist, 1996	S	273	n/ a	12-15 y	1.2 mm	n/ a
	non-S				0.6 mm	
De Luca, 2006	S	1852	n/ a	20 y	5.65	n/ a
	non-S				3.06	
Nitzan, 2005	S	646	Max + Man	4 y	0.092 mm – 0.153 mm	< 0.001
	non-S				0.047 mm – 0.048 mm	

success ranged from 93% to 98.6%. Five studies found the difference to be significant, while De Luca et al. (2006) and Ramanos et al. (2013) did not.

Twito & Sade (2014) reported that the higher the intake of cigarettes, the higher the implant failure rates. Patients who smoked 1-10 cigarettes per day had implant failure rates of 4.3%, those who smoked 11-20 cigarettes per day had failure rates of 5.3%, those who smoked 21-30 cigarettes per day had failure rates of 6.9%, and those who smoked 31-40 cigarettes per day had failure rates of 9.2%. The failure rates increased with the number of cigarettes smoked per day, showing a significant difference.

Sanchez-Perez (2007) found that patients who smoked more than 20 cigarettes per day had higher failure rates, 31%, compared to patients who smoked fewer than 20 cigarettes per day, 15.80%. The implant success rate for patients who smoked fewer than 20 cigarettes per day was 69%, for those who smoked more than 20 cigarettes per day, it was 84.2%, and for non-smokers, it was 98.6%. The significance of the difference was clear.

De Luca et al. (2006) recorded that heavy smokers who smoked more than or equal to 15 cigarettes per day had a failure rate of 5.56%, moderate smokers who smoked 6-14 cigarettes per day had a failure rate of 4.82%, while light smokers who smoked fewer than or equal to 15 cigarettes per day had a failure rate of 3.51%. The overall failure rate for smokers was 13% and for non-smokers was 7%. The overall success rate for smokers was 82.70% and for non-smokers was 93%. The failure rates kept increasing with cigarette intake.

Osseointegration. The effect of the number of cigarettes consumed on osseointegration was documented in three studies with an observation period of up to 9 years (**Table 5**). The highest consumption of cigarettes per day was recorded as > 20 cigarettes, while the lowest was < 12 cigarettes per day.

Two studies provided the implant success rates in smokers; the range was between 86% and 92.42%, whereas in non-smokers, the range was higher and nearly equal, from 98% to 98.6%. The remaining study focused on bone density and bone-to-implant contact. Smokers who consumed < 12 cigarettes per day had a bone density range of 19.1 ± 7.6 , while the bone-to-implant contact range was 25.9 ± 9.1 . Non-smokers exhibited higher bone density and implant-to-bone contact, with a bone density range of 28.5 ± 18.8 and a bone-to-implant contact range of 39.8 ± 14.2 . The overall significance remains somewhat unclear. Saleem et al. (2020) found the difference to be significant, while Ramanos et al. (2013) did not, and the remaining study did not mention this information.

Table 5. Effect of number of cigarettes consumed on osseointegration. n/a Not available, Nr. of implants Number of implants, Nr. of cigarettes Number of cigarettes, Obs. period Observation period.

Author	Group	Nr. of implants	Obs. period	Nr. of cigarettes	Bone density	Bone contact	Implant mobility	Implant location	P-value
Bezerra Ferreira et. al 2016	S	11	8 Week	< 12 per day	19.1 ± 7.6	25.9 ± 9.1	n/ a	Maxilla & mandible	n/ a
	non-S	11		n/ a	28.5 ± 18.8	39.8 ± 14.2			
Ramanos et. al 2013	Heavy smokers	66	5 – 9 y	20 per day	n/ a	n/ a	n/ a	n/ a	0.001
	non-S	97		n/ a					0.001
Saleem et. al 2020	S	204 (total) Not specified for each group separately	7 y	< 20 per day	n/ a	n/ a	Higher mobility	n/ a	0.001
				> 20 per day			n/ a		< 0.001
	non-S			n/ a			Less mobility		< 0.001

Bone Loss. The effect of the number of cigarettes consumed on marginal bone loss was documented in three studies with an observation period of up to 15 years (**Table 6**). The highest consumption of cigarettes per day was recorded as > 14 cigarettes, while the lowest was < 10 cigarettes per day.

One study (Nitzan et al., 2005) separated the marginal bone loss based on the maxilla and mandible with three groups: heavy smokers, moderate smokers, and non-smokers. The consumption of cigarettes per day was not mentioned. In heavy smokers, marginal bone loss in the maxilla was 0.1897 mm and in moderate smokers it was 0.1233 mm, while in non-smokers it was only 0.046 mm. In the mandible, heavy smokers had a marginal bone loss of 0.1502 mm and moderate smokers had 0.1390 mm, while non-smokers had only 0.0487 mm.

Table 6. Effect of number of cigarettes consumed on osseointegration. n/a Not available, Nr. of implants Number of implants, Nr. of cigarettes Number of cigarettes, Obs. period Observation period.

Author	Group	Nr. of implants	Obs. period	Nr. of cigarettes	MBL	Implant location	P-value
Lindquist et.al 1996	S	273 (total) not specified for each group separately	12 – 15 y	> 14 per day	1.2 mm	n/ a	n/ a
				< 14 per day	1.2 mm		
	non-S			n/ a	0.6 mm		
Levin et. al 2008	Heavy smokers	64 (total) not specified for each group separately	5 – 14 y	> 10 per day	0.15 mm	Maxilla & mandible	< 0.001
	Moderate smokers			< 10 per day	n/ a		0.001
	non-S			n/ a	0.04 mm		0.001
Nitzan d et. al 2005	Heavy smokers	n/ a	4 y	n/ a	0.1502 mm	Mandible	0.001
	Moderate smokers				0.1390 mm		
	non-S				0.0487 mm		
	Heavy smokers				0.1897 mm	Maxilla	
	Moderate smokers				0.1233 mm		
	non-S				0.046 mm		

In the remaining two studies, marginal bone loss for smokers ranged from 1.2 mm to 0.15 mm, while in non-smokers, marginal bone loss ranged from 0.04 mm to 0.6 mm. The overall significance remains somewhat unclear. Levin et al. (2008) found the difference to

be significant, while Nitzan et al. (2005) did not, and the remaining study did not mention this information.

3.4 The influence of smoking habit - duration of smoking

The effect of the duration of smoking was examined in six studies, with observation periods of up to nine years (**Table S7**). One study (Arora et al., 2017) focused on implant failure and success rates among smokers and non-smokers. Patients who smoked for less than ten years had a 6% failure rate, a 94% success rate, and implant mobility of 0.01 mm compared to those who smoked for more than ten years, who had a 7.5% failure rate, a 92.5% success rate, and implant mobility of 0.04 mm.

Additionally, survival rates were noted for smokers. Those who smoked for less than ten years had a 93.9% survival rate, while those who smoked for more than ten years had a 92.4% survival rate. The success and failure rates for non-smokers were not mentioned.

The highest cigarette consumption per day was recorded between 31 and 40 cigarettes, while the lowest was between 1 and 10 cigarettes per day. The second study (Shevana et al., 2015) divided participants into two groups: smokers who smoked for less than ten years, with an implant failure rate of 30.95% and a success rate of 36.30%, and those who smoked for more than ten years, with an implant failure rate of 69.05% and a success rate of 63.70%. Non-smokers were also mentioned with failure rates of 36.37% and success rates of 63.63%.

The last remaining study included four groups of participants. Smokers who smoked for up to ten years had a 3.5% implant failure rate, a 96.5% implant success rate, and a 96.5% implant survival rate. Smokers who smoked for more than ten years had a 6% implant failure rate, a 94% implant success rate, and a 94% implant survival rate. Ex-smokers, without a specified cessation period, had a 2.8% implant failure rate, a 97.2% implant success rate, and a 96.5% implant survival rate. Ex-smokers who quit 2-15 years before implantation had a 2.3% implant failure rate, a 97.7% implant success rate, and a 97.7% implant survival rate.

The overall significance remains unclear, as the three studies found the difference to be not significant. One study (Lambert et al., 2000) focused on maxillary implant survival rates between smokers and a combined group of non-smokers and former smokers. The implant survival rates were higher in non-smokers and former smokers (94.01%) compared to smokers (91.14%).

Three studies compared success and failure rates between smokers and non-smokers. Patients who smoked for more than ten years had failure rates ranging from 7.58% to 69.05%, while those who smoked for less than ten years had a failure rate of 30.95%. The success rate for patients who smoked for more than ten years ranged from 63.70% to 92.42%, while those who smoked for less than ten years had a success rate of 36.30%. Non-smokers had success rates ranging from 63.63% to 98% and failure rates ranging from 2 – 36.37 %.

One study focused on past smokers, current smokers, and non-smokers. Patients who quit smoking five years before implantation had an implant survival rate of 93.75%, similar to non-smokers (93.8%). Current smokers who smoked for more than eight years had an implant survival rate of 87.1%. The overall significance remains unclear, as four studies found the difference to be not significant, while Lambert et al. (2000) and Ramamurthy et al. (2013) did not mention this information.

Osseointegration and bone loss. The effect of the duration of smoking on osseointegration was examined in one study with an observation period of up to 14 years (**Table 8**). Arora et al. (2017) recorded implant mobility in smokers of less than ten years at 0.01 mm,

for those who smoked for more than ten years at 0.04mm. The mobility for non-smokers was not mentioned. The significance of the difference was not provided.

Table 8. Effect of duration of smoking on osseointegration. n/a Not available, Nr. of implants Number of implants, Obs. period Observation period.

Author	Group	Nr. of implants	Obs. period	Duration of Smoking	Implant mobility % or mm	Implant location	P-value
Arora et. al 2017	S	n/a	n/a	< 10 y	0.01 mm	Maxilla & mandible	n/a
				> 10y	0.04 mm		
	non-S			n/a	n/a		

The effect of the duration of smoking on bone loss was examined in two studies with an observation period of up to 14 years. One study (Levin et al., 2008) focused on survival rates and marginal bone loss. Patients who quit smoking five years before implant insertion and non-smokers had similar outcomes in terms of marginal bone loss (0.04 mm) and implant survival rates (93.75% to 93.8%). Current smokers, who had smoked for more than three years, exhibited increased marginal bone loss (0.15 mm) and a decreased implant survival rate (87.1%).

The remaining study reported marginal bone loss of 1.5 mm in current smokers, and 0.5 mm in both non-smokers and those who quit smoking at least one year before implantation. The overall significance remains unclear, as one study found the difference to be not significant, while the other study did not provide this information.

Table 9. Effect of duration of smoking on bone loss. n/a Not available, MBL Marginal bone loss, Nr. of implants Number of implants, Obs. period Observation period.

Author	Group	Nr. of implants	Obs. period	Duration of Smoking	MBL	Implant location	P-value
Levin et. al 2008	Past smokers	64 (total) not specified for each group separately	5 – 14 y	Quit smoking 5 y before insertion	0.04 mm	Maxilla & mandible	0.031 current to former smokers
	Current smokers			Smoker for over 8 y	0.15 mm		0.016 current to non – smokers
	non-S			n/a	0.04 mm		n/a
Lindquist et. al 1996	S	266 (total) Not specified for each group separately	10 y	n/a	1.5 mm	n/a	n/a
	Quit smoking at least one year before implant insertion				0.5 mm		
	non-S				0.5 mm		

4 Discussion

The objective of this study was to analyse the effect of smoking on dental implant survival, success and failure rates, osseointegration, and marginal bone loss in smokers compared to non-smokers. All included studies indicated the negative impact of smoking on dental implants. When comparing the failure rates of smoking patients to their success rates, failure rates were accelerated while success rates decreased. The amount of cigarette consumption and its duration have a significant impact on the outcomes.

Both the maxilla and mandible exhibited higher implant failure rates when compared to non-smokers. Additionally, maxilla failure rates were higher compared to the mandible, even though the preferred loading time in the maxilla is after 6 months, while in the mandible it is preferred after 3 months. Bone type also has a strong impact on the failure and success rates of dental implants. Smoking led to decreased blood flow at the implantation site, which delayed bone healing and impeded the osseointegration process.

Implant survival and failure rates were also affected by the number of cigarettes (Shevana et al., 2015; Twito & Sade, 2014; Sanchez-Perez et al., 2007; De Luca et al., 2006). Failure rates accelerated when the patient's cigarette consumption ranged from 1-10 per day up to 31-40 cigarettes per day, with outcomes ranging from 4.3% to 15.80%, while non-smokers had lower failure rates ranging between 1.4% and 13.33%. Ramanos et al. (2013) reported that patients who smoked 20 cigarettes per day had an implant survival rate of up to 97%, while non-smokers had a rate of up to 99%. Saleem et al. (2020) reported that patients who smoked less than 20 cigarettes per day had an implant success rate of 86%, while non-smokers had a rate of 98.6%.

Survival and failure rates were also affected by the duration of smoking (Arora et al., 2017; Twito & Sade, 2014; Shevana et al., 2015). Implant failure rates for patients who smoked over 10 years ranged from 6% to 69.05%, while for patients who smoked less than 10 years, the rates ranged from 6% to 30.95%.

The number of cigarettes and duration have a strong impact on survival-failure rates. Patients who smoke 10 cigarettes per day still experience reduced blood flow to the implantation site and an increased risk of postoperative infections and marginal bone loss, even compared to patients who smoke 30 cigarettes per day. However, the chances of higher survival rates were more pronounced when the duration and number of cigarettes were reduced. Nicotine contributes to absorption into the bloodstream, leading to vasoconstriction. Several studies indicated that smoking adversely affects the osseointegration process. Nicotine consumption leads to vasoconstriction of blood vessels, decreased oxygen levels at the implantation site, and ischemia.

Osseointegration, which is crucial for implant success, is negatively impacted by nicotine consumption, leading to implant mobility, low bone-to-implant contact, and low bone density. Furthermore, osseointegration is affected depending on the bone type. Wychowanski et al. (2020) focused on the maxilla, reporting that the anterior maxilla is more affected than the posterior maxilla, resulting in disturbed osseointegration and increased bone mobility. Shibli et al. (2010) compared the upper and lower jaws and found that the maxilla showed decreased bone density and bone-to-implant contact. Ferreira et al. (2016) observed that osseointegration is impaired regardless of the observation period and implant location. Studies revealed a direct connection between the number of cigarettes consumed and the osseointegration process, including bone density and bone contact. Heavy smokers had accelerated complications and higher implant mobility with lesser bone-to-implant contact and bone density compared to moderate smokers.

The duration of smoking plays a significant role in osseointegration, failure rates, bone-to-implant contact, bone density, and implant mobility. Nicotine adversely affects osteoblasts, impacting their anchorage, adhesion, spreading, and differentiation into osteoblasts that secrete extracellular matrix on the implant surface, thereby disrupting the osseointegration process. Previous studies demonstrated a direct connection between smoking cigarettes and marginal bone loss, with smoking accelerating marginal bone loss around the implant. Marginal bone loss was also affected by the number of cigarettes consumed. Lindquist et al. (1996) reported that patients who smoked more than 14 cigarettes per day or less than 14

cigarettes per day had similar MBL outcomes of 1.2 mm, while non-smokers had an MBL of 0.6 mm. Levin et al. (2008) reported higher MBL in heavy smokers (0.15%) compared to non-smokers (0.04%).

Another study differentiated between the upper and lower jaw: heavy smokers in the mandible had an MBL of 1.502 mm, moderate smokers had 0.1390 mm, and non-smokers had 0.0487 mm. In the maxilla, heavy smokers had an MBL of 0.1897 mm, moderate smokers had 0.123 mm, and non-smokers had 0.046 mm. Studies by Alsaadi et al. (2008), Fartash et al. (1996), and Lindquist et al. (1996) indicated a direct influence of the number of cigarettes consumed per day on implant success and failure rates, survival rates, and MBL. The longer the duration of smoking, the higher the failure rates compared to non-smokers, and the more accelerated the marginal bone loss and implant mobility, while bone density and implant-to-bone contact decreased. When focusing on the maxilla, non-smokers and smokers who quit had similar survival rates, both above 90%.

Implant failure rates were higher for patients who smoked over 10 years compared to those who smoked less than 10 years. When comparing smokers, non-smokers, and smokers who quit, non-smokers and smokers who quit had similar outcomes, while current smokers showed higher implant mobility, decreased bone-to-implant contact, and increased failure rates. Osseointegration was also affected by smoking duration. Patients who quit smoking 5 years before implantation had survival rates above 90% and less marginal bone loss compared to current smokers of over 8 years. Quitting smoking 1 year before implantation halved marginal bone loss compared to current smokers. Nicotine cessation aids the osseointegration process by increasing blood flow and nutrient supply to the implantation site, along with enhanced oxygen delivery. Quitting smoking for at least 1 year before implantation can improve implant survival rates and enhance bone-to-implant contact and bone density, similar to non-smokers.

While implant insertion is not absolutely contraindicated for smokers, patients should be informed about the risks, including bone healing issues, osseointegration, and implant failure, as smoking during the initial healing phase increases these risks. Cigarette consumption has been proven to increase implantation failure rates and may lead to implant loss. Strict protocols are needed to improve implant survival in smokers. Bain and Moy, as well as De Luca et al. (2006), suggested that patients should quit smoking at least one week before implant insertion and avoid smoking for at least 2 months after surgery to allow bone healing and initial osseointegration, even though the adverse effects of smoking continue beyond this period. Cessation of smoking for at least 6 months before implantation should be the primary recommendation. However, because quitting smoking is challenging, reducing daily cigarette consumption could be an alternative. Patient counselling is essential to explain the harmful effects of smoking, not only on implant success but also on general health.

Conclusions

A direct link exists between smoking habits and survival-failure rates. The consumption of cigarettes negatively affects bone healing, with the amount and duration of cigarette consumption showing a strong impact on many aspects. Osseointegration decreased in smokers while it was higher in non-smokers, along with better bone-to-implant contact, bone density, and implant mobility. Conversely, marginal bone loss increased in smokers compared to non-smokers.

When comparing former smokers and non-smokers, the outcomes were similar: osseoin-

tegration, which is a key aspect in implantology, increased and survival rates were shown to be 90% or above. Therefore, implant insertion is a contraindication for smokers, but not an absolute one. Patients should be informed about all risk factors, such as bone healing issues, osseointegration, and implant failure, and about the fact that consuming cigarettes during the initial healing phase following the insertion of implants increases these risk factors for failure. Advising patients to quit smoking is a beneficial solution, as it helps accelerate bone healing and increases the rates of osseointegration and implant success.

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Ethical approval

No ethical approval was required for this study, as it did not involve human participants, animal subjects, or sensitive data. This study falls under the category of data collection without participant identification.

Consent for publication

Not applicable.

Authors' contributions

The author(s) declare that all the criteria for authorship designated by the International Committee of Medical Journal Editors have been met. More specifically, these are: (a) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (b) Drafting the work or revising it critically for important intellectual content; AND (c) Final approval of the version to be published; AND (d) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

The author(s) declare that they have no competing interests related to this work.

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