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SYSTEMATIC REVIEW

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Influence of low insertion torque values on survival rate of immediately loaded dental implants: A systematic review and meta-analysis

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Abstract

Aim: The aim was to systematically evaluate the effect of low insertion torque values on the survival rate of immediately loaded dental implants.

Materials and Methods: The protocol was registered with PROSPERO (ID CRD42020189499). An electronic search was performed in PubMed, Embase, Web of Science, and Cochrane Central Register of Controlled Trials until June 2022 in English and Spanish. Studies analysing the failure or survival rate of immediately loaded dental implants according to different insertion torque values were included.

Results: Five-hundred seventy-three articles were assessed for eligibility, of which seven articles, four randomized clinical trials (RCTs), one controlled clinical trial, and two prospective case series studies were included in the qualitative analysis. The RCTs were classified as having low risk of bias and the non-RCTs as having moderate and serious risk of bias. The mean survival rate for implants with low insertion toque (≤35 Ncm) was 96% (p > .001, 95% confidence interval [CI]: 0.91–0.98) and that for implants with medium or high insertion torque (>35 Ncm) was 92% (p > .001, 95% CI: 0.86–0.96) (incidence rate ratio [IRR] = 1.05, 95% CI: 0.79–1.39, p = .175, I^2 = 0.0%). Splinted implants with insertion torque >20 Ncm and single implants with insertion torque >35 Ncm had a higher survival rate than implants with lower insertion torque values (IRR = 1.05, 95% CI: 0.78–1.43, p = .956, I^2 = 0.0%, and RR = 0.92, 95% CI: 0.48–1.75, p = .799, I^2 = 0.0%, respectively). Different insertion torque values achieved equivalent outcomes. The mean follow-up was 24 months.

Conclusions: Low insertion torque values have no significant effect on survival rates of immediate loading implants at a mean follow-up of 24 months.

KEYWORDS
dental implants, immediate loading, insertion torque

Clinical Relevance

Scientific rationale for study: Implant insertion torque is the most common endpoint assessed for adequate primary stability. This systematic review aimed to assess the effect of low insertion torque (≤35 Ncm) on the survival rate of immediately loaded dental implants.

Principal findings: The pooled survival rate of implants with insertion torque ≤35 Ncm was 5% higher than implants with >35 Ncm (Incidence rate ratio = 1.05, 95% confidence interval: 0.79–1.39, $p = .175$), without any significant difference. Both groups attained high survival rates.

Practical implications: Implants with insertion torque ≤20 Ncm can be immediately loaded with splinted prostheses and those with >20 Ncm with single-unit prosthesis.

1 | INTRODUCTION

The long-term success of an implant-supported restoration is dependent on successful osseointegration. It has been described that primary stability and absence of micro-movements are two of the main factors necessary to achieve a high predictable success of osseointegrated oral implants (Albrektsson et al., 1981). Ledermann, in 1977, was the first to describe the use of implants with immediate loading to stabilize mandibular overdentures, in order to minimize discomfort and problems related with the use of provisional full dentures (Ledermann, 1977). This technique was further demonstrated in several subsequent articles (Szmukler-Moncler et al., 2000). Most early publications using this concept showed excellent results, mainly reporting high implant survival rates (Sanz-Sánchez et al., 2015). A recent systematic review has estimated a 96.8% survival in 1880 immediate loading dental implants with a mean follow-up of 21.9 months (Chen et al., 2019).

Reduced overall treatment times within immediate loading protocols, together with the potential to avoid a removable provisional prosthesis, present attractive solutions for clinicians and patients (Gallucci et al., 2018). Immediate loading can be an alternative to conventional loading in specific cases when patient-centred advantages are present (Morton et al., 2018), and is currently accepted as being earlier than 1 week after implant placement (Weber et al., 2009; Gallucci et al., 2014).

Implant insertion torque is the most common endpoint assessed for an adequate primary stability, which is required by most of the studies when attempting to conduct immediate loading (Gallucci et al., 2018). This indicator is judged intra-operatively by the surgeon; however, the specific value may vary among studies (Gallucci et al., 2018). Additionally, the minimum insertion torque needed to achieve successful osseointegration of immediately loaded single implants is still inconclusive (Benic et al., 2014). For any type of prostheses, the minimum torque required is not accurately established (Sanz-Sánchez et al., 2015), though an accepted interval ranges from 25 to 45 Ncm (Morton et al., 2018). In cases of immediate loading with full-arch fixed prostheses, a minimum insertion torque of 30 Ncm has been recommended (Papaspyridakos et al., 2014); however, implants with lower insertion torques splinted with implants with torque ≥30 Ncm did not show low survival rates (Eckert et al., 2019). The level of evidence regarding an insertion torque of 30 Ncm for implant survival in cases of immediate loading is currently considered not strong (Douglas De Oliveira et al., 2016). A correlation between high insertion torque values (>45 Ncm) and primary stability has been reported, because the micromotion of implants is reduced (Trisi et al., 2009); however, implants immediately placed and loaded using a low insertion torque protocol of ≤25 Ncm yield a favourable clinical outcome (Norton, 2011). Furthermore, the impact of torque on the survival rate of implants with immediate loading was deemed not possible to analyse due to data inconsistencies of the included randomized controlled trials (RCTs) (Chen et al., 2019). Also, a consensus on the definition of high, regular, and low torque is lacking (Lemos et al., 2021).

The aim of this systematic review was to assess the effect of low insertion torque (≤35 Ncm) on the survival rate of immediately loaded dental implants. Secondly, the type of restoration, changes in marginal peri-implant bone levels, changes in peri-implant soft tissues, as well as mechanical, biological, and technical complications were evaluated in terms of the insertion torque value.

2 | MATERIALS AND METHODS

2.1 | Reporting format

The protocol of this review was prepared and registered on the PROSPERO (International Prospective Register of Systematic Reviews) database (CRD42020189499). No modifications were made in the materials and methods section in comparison with the protocol registered in PROSPERO. This review was reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

2.2 | Eligibility criteria

The focus question was: "In immediately loaded dental implants, what are the effects of lower insertion torques compared to medium or higher insertion torques in terms of implant survival rate?" This question considered the following PECO (Stone, 2002) definitions:

- P (Population): patients receiving immediately loaded dental implants.
- E (Exposure): low insertion torques (≤35 Ncm).
- C (Comparison): medium or high insertion torques (>35 Ncm).
- O (Outcome): implant survival rate.

The following secondary outcomes variables were considered: marginal bone levels changes (in mm); peri-implant soft tissues changes (changes in the position of the mucosal margin); mechanical (failure of a prefabricated component caused by mechanical forces), technical (e.g., screw loosening, prostheses fracture, contouring adjustments), and biological complications (consisting of peri-implantitis and peri-implant mucositis).

2.3 | Search strategy

An electronic search was undertaken on The National Library of Medicine (MEDLINE via PubMed), Embase, Web of Science, and Cochrane Central Register of Controlled Trials, including studies published until June 2022. The search was limited to publications on trials involving humans published in English and Spanish. Grey literature was not considered. The following search terms were used:

- CENTRAL and MEDLINE
  - Population: ((((“Dental Implants”[Mesh]) OR “Dental Implantation”[Mesh]) OR dental implant*[Title/Abstract]) OR oral implant*[Title/Abstract]) AND ((“Immediate Dental Implant Loading”[Mesh]) OR ((immediate*[Title/Abstract]) AND ((((((load* [Title/Abstract]) OR crown*[Title/Abstract]) OR bridge*[Title/Abstract]) OR prosthes*[Title/Abstract]) OR restoration*[Title/Abstract]) OR rehabilitat*[Title/Abstract]))).
  - Intervention: (((primary stability[Title/Abstract]) OR implant stability[Title/Abstract]) OR insertion torque*[Title/Abstract]))).
- EMBASE
  - Population: ((‘tooth implant’/exp) OR (‘tooth implantation’/exp) OR (dental AND implant*: ab, kw, ti) OR (oral AND implant*: ab, kw, ti)) AND ((immediate*: ab, kw, ti) AND ((((((load*: ab, kw, ti) OR crown*: ab, kw, ti) OR bridge*: ab, kw, ti) OR prosthes*: ab, kw, ti) OR restoration*: ab, kw, ti) OR rehabilitat*: ab, kw, ti)).
  - Intervention: (((primary stability: ab, kw, ti) OR implant stability: ab, kw, ti) OR insertion torque*: ab, kw, ti).

2.4 | Selection process

The evaluation of titles and abstracts, as well as full-text analysis, was conducted according to the following eligibility criteria:

Articles were selected based on the following inclusion criteria:

- Randomized clinical trials, controlled clinical trials (CCTs), and prospective studies with a minimum sample of 10 patients;
- Patients aged 18 years or older and in good general health;
- Immediately loaded dental implants reporting the insertion torque values (the immediate loading protocol is defined as implant loading earlier than 1 week after placement [Gallucci et al., 2014]);
- Titanium alloy dental implants;
- Minimum follow-up period of 12 months after implant placement.

The exclusion criteria were as follows:

- Animal or in vitro studies;
- Zygomatic implants;
- Insufficient information to determine implant survival rate.

2.5 | Data selection and data extraction

The selection of studies was carried out in two stages by two independent reviewers (ID and FM). In the first stage, reviewers screened titles and abstracts according to pre-set eligibility criteria. In the second stage, the selected studies were assessed for eligibility based on a full-text analysis. The reasons for exclusion were recorded. Data extraction was conducted independently by two reviewers using customized data extraction tables (ID and AS). Any disagreement was resolved by discussion with a third reviewer (YL). In case of multiple publications on the same study population, only the study with the longest follow-up was included. The inter-reviewer reliability of the data extracted was determined via Cohen Kappa scores.

The following data were extracted from the full-text publications: author(s), year of publication, country, study design, blind, founding source, number of centres, setting, number, age and sex of patients included, number of patient drop-outs, number of implants placed, number of implant drop-outs, number of failed implants, sample size calculation, randomization, risk factors, follow-up period, time of implant placement following tooth extraction, loading protocol, jaw, intraoral region, implant system, implant length and diameter, simultaneous bone augmentation procedure, and type of restoration. Also, mean values of implant insertion torque, survival rate (primary outcome), marginal bone levels changes, changes in the position of the mucosal margin, as well as mechanical, technical, and biological complications (secondary outcomes) were recorded.

Descriptive analyses were performed to determine the quantity of data, in relation to the characteristics, interventions, and results of the included studies.

2.6 | Risk of bias assessment

The quality assessment of the selected articles was performed by two reviewers independently and in duplicate (ID and AS). Disagreements over the risk of bias in particular studies were resolved by discussion between the two reviewers and in consultation with a third reviewer (YL) if required.

Risk of bias assessment of randomized clinical trials was done using the RoB 2.0 tool (Sterne et al., 2019), which is structured into five bias domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result. Studies were classified as having low risk of bias, some concerns, or high risk of bias. The risk of bias of the included CCT and the case series studies was assessed using the ROBINS-1 tool (Sterne et al., 2016). Criteria for quality assessment comprise seven main domains: bias due to confounding, bias in selection of participants into the study, bias in classification of interventions, bias due to departures from intended interventions, bias due to missing data, bias in measurement of outcomes, and bias in selection of reported results. The categories for risk of bias judgements in which articles can be classified are low risk, moderate risk, serious risk, and critical risk of bias (Sterne et al., 2016).

2.7 | Statistical analysis

The software Mendeley (Elsevier BV, Amsterdam, The Netherlands) was used to manage the records and review the outcomes of the systematic search, and a standard spreadsheet software (Excel for Mac, version 16.50. Microsoft, Redmond, WA) was used to carry out data extraction. We used Stata 11 (StataCorp LLC, College Station, TX) to perform statistical analysis. To compute pooled survival rates we used the *meta* package for R (R Core Team, 2020). Regarding binomial data and single proportions, the *metainc* command was used to perform random-effects models of survival rate of implants with >35 or >20 Ncm and implants with ≤35 or ≤20 Ncm, using the Cochran–Mantel–Haenszel method. To compare medium or higher insertion torque implants with lower insertion torque implants, the *metabin* command was used with the inverse calculation method and random-effects model.

Heterogeneity was statistically analysed using the Q-test at a 5% significance level and I^2 index. The I^2 index assesses the heterogeneity in meta-analysis and the extent of that heterogeneity. Forest plots were produced to illustrate the differences between groups. Publication bias was

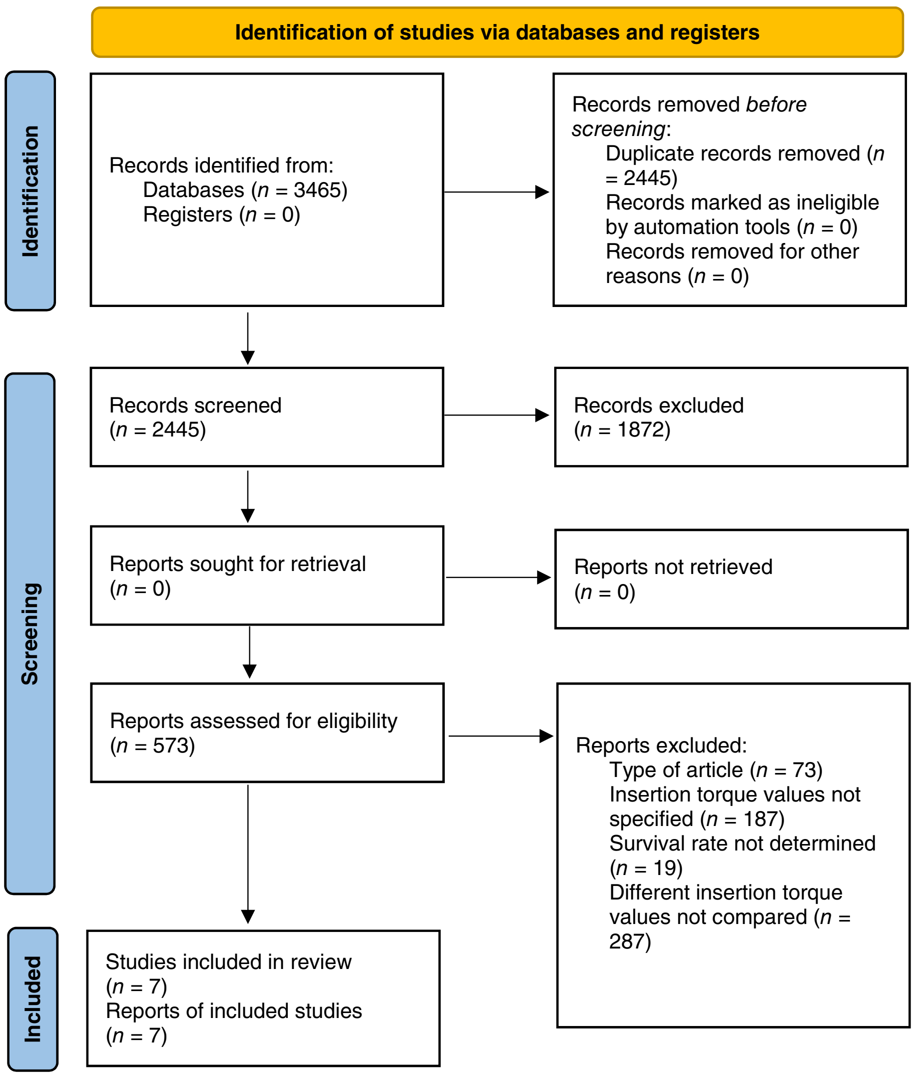

FIGURE 1 PRISMA 2020 flow diagram

not measured because survival rates are always a positive number, and the likelihood of asymmetric funnel plots will be due to publication bias.

3 | RESULTS

3.1 | Study selection

The search resulted in 3465 articles: 702 obtained via PubMed, 2097 via Embase, 315 via Web of Science, and 351 via Cochrane Central Register of Controlled Trials. After removal of duplicates, 2445 records were screened for title and abstract, and 1872 studies were excluded owing to not meeting the inclusion criteria, leaving 573 articles for full-text assessment. After full-text examination, 566 articles were excluded, 73 because they were retrospective, included less than 10 patients, or the follow-up was less than 12 months; 187 because insertion torque values were not specified; 19 because the survival rate was not determined; and 287 because they did not compare different insertion torque values. Therefore, seven articles were included in the systematic review and in the quantitative analysis (Figure 1) (PRISMA FLOW DIAGRAM; Page et al., 2021). Out of these seven studies, four were randomized clinical trials, one was a CCT, and two were prospective studies. The global agreement between the two reviewers was 94.78% and the Kappa score was 0.61 (95% confidence interval [CI]: 0.35–0.87) for the selected studies (full-text articles), indicating substantial agreement (Landis & Koch, 1977) between the reviewers.

3.2 | Methodological quality assessment

According to RoB 2.0 tool (Sterne et al., 2019), all articles (Cesaretti et al., 2016; Schincaglia et al., 2016; Daher et al., 2019; Vogl et al., 2019) were classified as of low risk of bias (Figure 2). The CCT (Ottoni et al., 2005) and the prospective case series study of Degidi et al. (2012) were judged to be of moderate risk of bias and the study of Koutouzis et al. (2011) of serious risk of bias (Figure 3) according to ROBINS-I tool (Sterne et al., 2016).

3.3 | Characteristics of the included articles

The characteristics, insertion torque values, survival rate, and conclusions of the included trials are presented in Table 1.

Most selected articles were funded by the industry (Ottoni et al., 2005; Koutouzis et al., 2011; Schincaglia et al., 2016; Daher et al., 2019) or by a research association (Cesaretti et al., 2016), and all but one (Degidi et al., 2012) were university-based studies. The studies were carried out in Brazil (Ottoni et al., 2005), United States (Koutouzis et al., 2011; Schincaglia et al., 2016), Italy (Degidi et al., 2012; Cesaretti

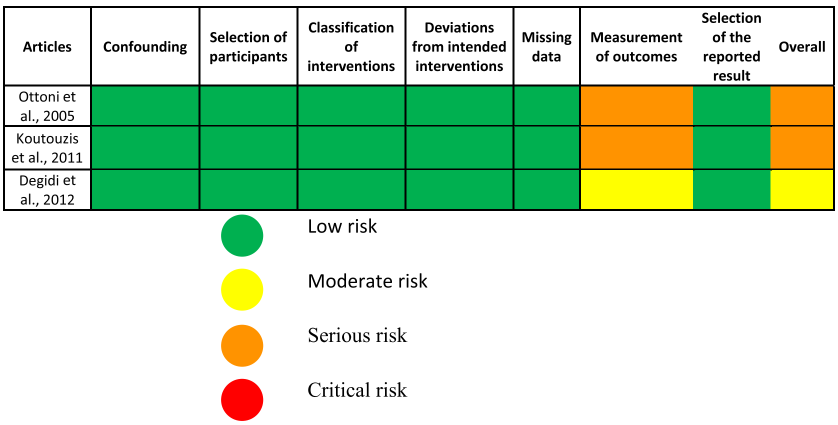

FIGURE 3 ROBINS-1 tool for assessment the risk of bias in non-randomized studies

Articles	Randomisation process	Deviations from the intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Cesaretti et al., 2016	+	+	+	+	+	+
Schincaglia et al., 2016	+	+	+	+	+	+
Vogl et al., 2019	+	+	+	+	+	+
Daher et al., 2019	+	+	+	+	+	+

+ Low risk
! Some concerns
- High risk

FIGURE 2 Risk of bias summary for selected randomized clinical trials

TABLE 1 Characteristics of the included articles

	Trial design of immediate loading implants										Immediate loading protocol				Outcomes			
			Participants'		No. of implants													
						By groups												
Articles included	Study design	Funding	Number	Mean age (range) (years)	Total	≤35 Ncm	>35 Ncm	Risk factors	Drop-outs	Follow-up period	Implant type	Intra-oral region	Occlusion	Type of restoration	Time-point of failure	Survival rate (self-calculated)	Reason of failure and number	Conclusions
Ottoni et al. (2005)	CCT; split-mouth; non-blinded	Industry (Friadent)	23	35.4 (18–60)	23	20 (10 ≤ 20 Ncm)	3	None	None	24 months	Machined collar, tapered implants with v shaped threads (Frialit-2, Friadent); length: 10–15 mm; diameter: 3.8 and 4.5 mm	Anterior maxilla and mandible	Infraocclusion	Single crowns	3–9 months	≤35 Ncm = 50%; >35 Ncm = 100%	Failures = 10 implants. Insertion torque 20 Ncm (9) and >20 Ncm and ≤35 Ncm (1)	Lower insertion torque values affected survival rate
Cesaretti et al. (2016)	RCT; parallel; blinded	Research Association (ITI Research Grant, ARDEC [Ariminum Odontologica SRL, Rimini, Italy] and by the Clinical Research Foundation for the Promotion of Oral Health [Brienz, Switzerland])	15	64.5 (51–76)	36	36 (25 ≤ 20 Ncm)	—	Smokers ≥ 10 cigarettes/day = 2 patients	None	36 months	Polished neck of 2.8 mm implants (Tissue Level SLA Standard, Straumann); length: 8–12 mm; diameter: 4.1 mm	Posterior maxilla	Centric occlusion and centric relation contacts and physiological lateral movements	Screw-retained bridges (on ≥2 implants)	3 weeks	94.4%	No osseointegration = 2 implants (1 patient). Insertion torque >20 Ncm and ≤35 Ncm	Insertion torque values did not affect osseointegration
Daher et al. (2019)	RCT; split-mouth; blinded	Industry (Nobel Biocare AG, grant number 2010-954)	24	49.2 (34–67)	84	32 (17 ≤ 20 Ncm)	48	Smokers ≥ 10 cigarettes/day = 13 patients	2 patients	36 months	Variable-thread tapered implants (NobelActive, Nobel Biocare); length: 10–15 mm; diameter: 3.5, 4.3, and 5 mm	Posterior maxilla	Very light occlusal contacts in MI, no lateral working and non-working contacts	Screw-retained 3- to 4-unit bridges (no pontics or cantilevers)	6 months	≤35 Ncm = 100%; >35 Ncm = 91.6%	No osseointegration = 4 implants (1 patient). Insertion torque >35 Ncm	Test implants splinted with other implants presenting higher insertion torque can achieve and maintain osseointegration and have similar success rates and crestal bone remodelling to control implants
Degidi et al. (2012)	Prospective case series; parallel; non-blinded	N/A	13	(42–81)	82	67 (51 ≤ 20 Ncm)	15	Smokers < 20 cigarettes/day	None	12 months	Self-tapping thread (XiVE implants, Dentsply Friadent); length: 11–18	Posterior and anterior maxilla and mandible	Light centric occlusion	Screw-retained full-arch prostheses	6 months	≤35 Ncm = 98%; >35 Ncm = 100%	No osseointegration = 1 implant. Insertion torque 20 Ncm	The success rate and the crestal bone remodelling were very similar between

(Continues)

TABLE 1 (Continued)

Articles included	Trial design of immediate loading implants: Study design	Funding	Participants': Number	Mean age (range) (years)	No. of implants: Total	By groups: ≤35 Ncm	>35 Ncm	Risk factors	Drop-outs	Follow-up period	Immediate loading protocol: Implant type	Intra-oral region	Occlusion	Type of restoration	Outcomes: Time-point of failure	Survival rate (self-calculated)	Reason of failure and number	Conclusions
											mm; diameter: 3.4, 3.8, 4.5, and 5.5 mm							test and control groups without statistically significant differences
Koutouzis et al. (2011)	Prospective case series; non-blinded	Industry (Astra Tech)	18	53.4 (21–77)	20	16	4	N/A	None	12 months	Straight implant with MicroThread neck (OsseoSpeed, Astra Tech); length: 9–15 mm; diameter: 3.5 and 4.05 mm	Anterior (until second premolar) maxilla and mandible	Light centric occlusion with no interferences in lateral excursions	Screw-retained single crowns	3 months	≤35 Ncm = 100%; >35 Ncm = 75%	No osseointegration = 1 implant. Insertion torque >35 Ncm	It might not be a simple relationship between placement torque value and implant failure for immediately loaded implants for single tooth replacements
Schincaglia et al. (2016)	RCT; parallel; blinded	Industry (Astra Tech/Dentsply)	17	66.6 (53–79)	34	12 (5 ≤ 20 Ncm)	22	Smokers < 10 cigarettes/day = 2	None	12 months	Straight implant with MicroThread neck (TX OsseoSpeed, Astra Tech/Dentsply); length: 8–15 mm; diameter: 4.0 mm	Anterior mandible (canine/lateral site)	Full occlusal loading (no limitation to chewing)	Locator overdentures	4 weeks	≤35 Ncm = 100%; >35 Ncm = 90.9%	No osseointegration = 2 implants (1 patient). Insertion torque >30 Ncm	No difference was observed for insertion torque between groups, no correlation between inserti and radiographic bone level change
Vogl et al. (2019)	RCT; parallel; non-blinded	N/A	19	54 (33–70)	53	5	48	Smokers < 10 cigarettes/day	1 patient	36 months	Self-tapping thread (XiVE implants, Dentsply Friadent); length: 9.5–15 mm; diameter: 3.5, 3.8, 4.5, and 5.5 mm	Posterior and anterior mandible	Full occlusal loading (test), infraocclusion in MI (control)	Screw-retained or cemented single or splinted crowns	24 months	≤35 Ncm = 100%; >35 Ncm = 97.9%	Implant loss = 1 implant. Insertion torque >35 Ncm	Implants with insertion torques <35 Ncm had no notable effects on clinical outcomes. Splinting of the provisional restoration may well have prevented micromotion of these implants

Abbreviations: CCT, controlled clinical trial; MI, maximum intercuspation; RCT, randomized controlled trial.

et al., 2016), Lebanon (Daher et al., 2019), and Austria (Vogl et al., 2019). Sample size calculation was present in only two RCTs (Schincaglia et al., 2016; Daher et al., 2019) using differences in marginal bone level changes. In all studies, the operator was a single surgeon, who inserted the implants in healed sites, without simultaneous bone augmentation procedure. The definition of implant loss or failure varied between articles, including implant mobility, progressive peri-implant bone loss requiring implant removal, and pain, among others.

This systematic review pooled data from 326 implants, from 129 participants (58 males and 71 females), 108 with an insertion torque ≤20 Ncm (10 single implants and 98 splinted implants), 80 with an insertion torque between >20 and ≤35 Ncm (31 single implants and 49 splinted implants), and 138 with an insertion torque >35 Ncm (55 single implants and 83 splinted implants). Insertion torque values ≤35 Ncm were considered as low insertion torque and those >35 Ncm as medium or high insertion torque. According to the data of the selected articles, a cut-off point of 20 Ncm was determined. Subgroup analysis compared splinted implants with insertion torque >20 Ncm versus implants with insertion torque ≤20 Ncm, and single implants with insertion torque between 20 and 35 Ncm versus single implants with insertion torque >35 Ncm. The maximum follow-up period was 36 months (Cesaretti et al., 2016; Daher et al., 2019; Vogl et al., 2019) and the minimum was 12 months (Koutouzis et al., 2011; Degidi et al., 2012; Schincaglia et al., 2016). One patient in the study of Vogl et al. (Vogl et al., 2019) was not available for the last follow-up, and two patients dropped out before the delivery of the definitive prostheses in the study of Daher et al. (2019). These patients were not included in the analysis.

3.4 | Survival rate

The pooled survival rate of implants with insertion torque ≤35 Ncm was 5% higher than that of implants with insertion torque >35 Ncm (Incidence rate ratio [IRR] = 1.05, 95% CI: 0.79–1.39, $p = .175$), however without a significant difference and with absolute homogeneity ($I^2 = 0.0\%$) (Figure 4). The survival rate was similar in the control and test groups, achieving equivalent outcomes in both groups. The mean survival rates were 96% (SR = 0.96, 95% CI: 0.91–0.98, $p > .001$) for implants with insertion torque ≤35 Ncm and 92% (SR = 0.92, 95% CI: 0.86–0.96, $p > .001$) for implants with insertion torque >35 Ncm. The level of heterogeneity was considered insignificant in the test and control group ($I^2 = 0.0\%$).

The subgroup analysis, comparing splinted implants with insertion torque >20 Ncm versus implants with insertion torque ≤20 Ncm, resulted in no statistically significant superiority between groups. The survival rate for implants with an insertion torque >20 Ncm was 5% higher than that for implants with an insertion torque less than 20 Ncm (IRRI = 1.05, 95% CI: 0.78–1.43, $p = .956$, $I^2 = 0.0\%$) (Figure 5). Single implants with an insertion torque between 20 and 35 Ncm had 8% less risk of failure than single implants with an insertion torque >35 Ncm (IRR = 0.92, 95% CI: 0.48–1.75, $p = .799$, $I^2 = 0.0\%$) (Figure 6). No statistical superiority was found with different insertion torques in immediately loaded single implants.

The heterogeneity in the meta-analysis was $I^2 = 0$, which means that all variability in effect size estimates was due to sampling error within studies.

3.5 | Marginal bone levels changes

Only Degidi et al. (2012) reported changes on the peri-implant crestal bone levels measured with periapical x-rays according to the insertion torque values. The mean bone loss was 0.6 mm (±1.0 mm) in implants with insertion torque ≤20 Ncm and 0.5 mm (±0.8 mm) for implants with insertion torque ≥25 and ≤50 Ncm after 1 year. This difference was not statistically significant.

3.6 | Mechanical, technical, and biological complications

None of the articles reported mechanical complications or peri-implantitis or peri-implant mucositis. Some technical complications occurred in temporary restorations, such as imprecise fit ($n = 3$ [Vogl

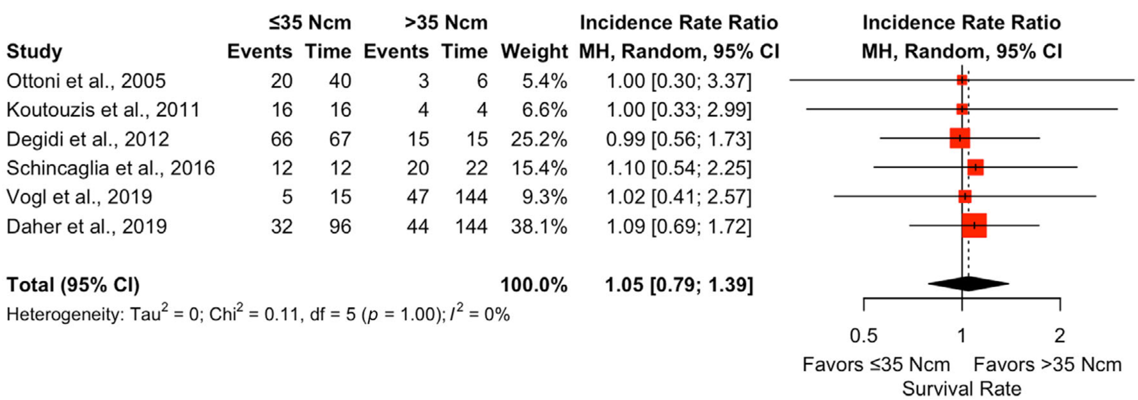

FIGURE 4 Risk ratio forest plot comparing implants with ≤35 Ncm with >35 Ncm. CI, confidence interval

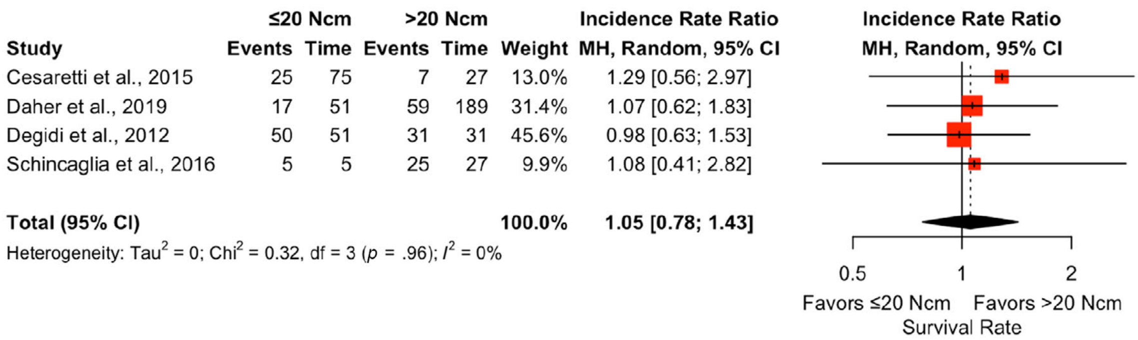

FIGURE 5 Forest plot comparing splinted implants with ≤20 Ncm versus implants with >20 Ncm. CI, confidence interval

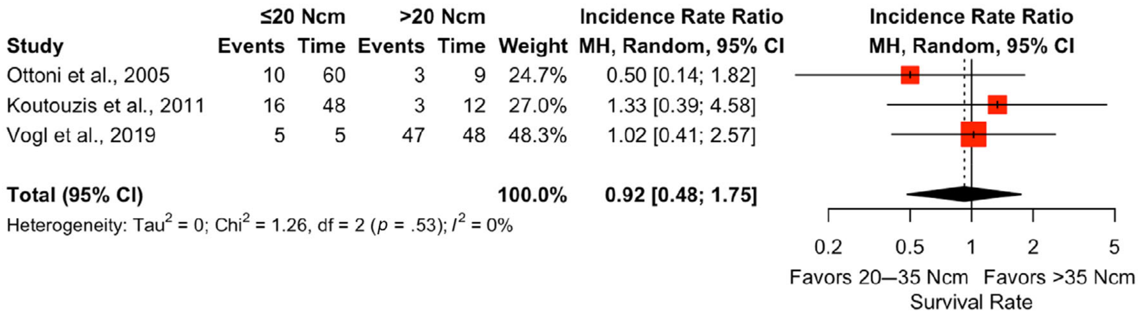

FIGURE 6 Forest plot comparing single implants with 20–35 Ncm versus implants with >35 Ncm. CI, confidence interval

et al., 2019]), chipping of the acrylic (Degidi et al., 2012; $n = 4$ [Daher et al., 2019]), or fracture ($n = 2$ [Vogl et al., 2019]). Seven technical complications occurred with the dentures in the study of Schincaglia et al. (2016) and two ceramic fractures in the definitive prostheses (Daher et al., 2019; Vogl et al., 2019). However, none of the articles reported these complications as a function of the insertion torque values.

4 | DISCUSSION

This systematic review supports that immediately loaded dental implants with lower insertion torques have similar implant survival rates as those with medium or higher insertion torques. The quantitative analysis provided by both randomized and non-randomized intervention trials revealed substantial survival rates (96% for insertion torque ≤35 Ncm and 92% for insertion torque >35 Ncm).

Meta-analysis of data from the studies did not reveal differences between the effects of lower insertion torques compared to medium or higher insertion torques in terms of implant survival rate. Both immediate loading with low and medium or high insertion toque attained high survival rates; however, splinted implants with insertion torque >20 Ncm and single implants with insertion torque >35 Ncm had less risk of failure, but statistically the differences were not significant.

Insertion torque refers to the force used to insert an implant into bone and is considered an objective surrogate measure for primary stability (Cooper, 2012). Primary stability is necessary for immediately loaded dental implants. However, there are many confounding factors that affect immediate loading. Adequate bone quality and quantity, implants with a rough surface and adequate dimension, and a good clinical technique to maintain contact between implant and bone are necessary to achieve primary stability (Morton & Jaffin, 2004). Unfortunately, this systematic review could not analyse secondary outcomes, such as marginal bone levels changes, peri-implant soft tissues change, or mechanical, technical, and biological complications, since most of the studies did not report these data. Furthermore, the included studies showed a short follow-up period because only four studies reported follow-up periods over 24 months (Ottoni et al., 2005; Cesaretti et al., 2016; Daher et al., 2019; Vogl et al., 2019). Therefore, the results must be interpreted with care. Previous reviews identified few complications (Douglas De Oliveira et al., 2016; Eckert et al., 2019), unrelated to the loading protocol (Papaspyridakos et al., 2014; Chen et al., 2019). Once osseointegration has been achieved, there are many other factors besides the loading protocol that may be related to biological and technical complications (Romanos, 2004; Papaspyridakos et al., 2014). The smaller number of relevant studies analysed in this systematic review highlights the need for more well-designed comparative studies of immediate loading with different insertion torque values, in order to provide more evidence and to address the question of the minimum insertion toque required to immediately loaded single-implant crowns.

Our results are consistent with a previously published systematic review (Del Fabbro et al., 2019), yet this is the first to present estimates for survival rates according to the insertion torque. The most common indicator when attempting to conduct immediate loading is the implant insertion torque (Gallucci et al., 2018). The literature search and the analysis of the articles about insertion torque and immediate loading revealed that only a few studies compared immediate loading implants with different insertion torque values, due to the lack of standardization in reporting methods and outcomes (Chen et al., 2019).

This systematic review included seven intervention trials, four RCTs, one CCT, and two prospective case series studies, comparing immediate loading with low and medium or high insertion torque.

The findings of the present review are not in agreement with those of the review of Papaspyridakos et al. (2014), which observed that an insertion torque of at least 30 Ncm was a prerequisite reported by most authors for applying immediate loading. Another systematic review could not conclude whether an insertion torque of 30 Ncm was enough for implant survival in cases of immediate loading (Douglas De Oliveira et al., 2016), because the studies reviewed did not include sufficient information to determine the behaviour of 30 Ncm in implant survival rates. Although it has not yet been possible to set the minimum insertion torque required to achieve successful osseointegration, our findings show that the survival rate of implants with low insertion torque (≤35 Ncm) was similar to those of implants with medium or high insertion toque (>35 Ncm). Accordingly, implants with low insertion torque can be immediately loaded.

We found only three articles that studied immediately loaded single implants and compared different insertion torque values. The minimum insertion torque required to be included in these studies was 20 Ncm (Ottoni et al., 2005; Koutouzis et al., 2011; Vogl et al., 2019). According to a systematic review about single-implant crowns (Benic et al., 2014), it is not clear what the required insertion torque should be to immediately load a single implant. The usual insertion torque used for immediate loading of single implants varies between 20 and 45 Ncm (Benic et al., 2014). The findings of the present systematic review show that immediate loading of single implants with low insertion torque (20–35 Ncm) has 0.88 more risk of failure than single implants with medium or high insertion torque (>35 Ncm), without statistically significant differences.

In cases of immediate loading with splinted implants, the insertion torque can be lower than with single implants, as was reported (Eckert et al., 2019). Because joining several implants together reduces micromotion, facilitating immediate loading, immobilization using splinting (cross-arch restorations or partial splinting) increases the stability of the implants after surgery (Javed & Romanos, 2010).

5 | CONCLUSION

Low insertion torque has no significant effect on survival rates of immediate loading implants at a mean follow-up of 24 months. This finding has important clinical implication, as implants with insertion torque less than 20 Ncm can be immediately loaded with full-arch or partial prostheses and implants with an insertion torque of more than 20 Ncm can be immediately loaded with single prosthesis. However, further well-designed studies comparing immediate loading implants with different insertion torque values are required to confirm these findings.

AUTHOR CONTRIBUTIONS

Iria Darriba contributed to the design of the study, data acquisition and analysis, writing of the article, and final approval of the manuscript. Anna Seidel contributed to the acquisition and analysis of data, writing of the article, and final approval of the manuscript. Federico Moreno contributed to the acquisition of data, critical review of the article, and final approval of the manuscript. João Botelho, Vanessa Machado, and José João Mendes contributed to the analysis of data, critical review of the article, and final approval of the manuscript. Yago Leira and Juan Blanco contributed to the design of the study, critical review of the article, and final approval of the manuscript. Ethics statement was not required because this study is based exclusively on published literature.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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