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Do dental implants installed in different types of bone (I, II, III, IV) have different success rates? A systematic review and meta-analysis

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ABSTRACT

Purpose: The objective of this systematic review and meta-analysis was to evaluate the survival rate of implants installed in bone type IV (Lekholm and Zarb, 1995) compared to that of implants installed in bone types I, II, and III.

Material and methods: This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) and was registered in the PROSPERO International Database of Systematic Reviews (CRD42021229775). The PubMed/MEDLINE, Scopus, and Cochrane databases were searched through July 2021. The PICO question was: "Dental implants installed in type IV bone have a lower success rate when compared to implants installed in type I bone, II and III?". The established inclusion criteria were: 1) controlled and randomized clinical trials (RCT), 2) prospective and retrospective studies with at least 10 participants with dental implants, and 3) patients with dental implants installed in bone tissue types I, II, III, and IV (Lekholm and Zarb, 1985). The minimum followup duration was 1 year.

Results: After searching the identified databases, 117 articles were selected for full reading and 68 were excluded. Thus, 49 studies were included for qualitative and quantitative analyses. The total number of participants included was 12,056, with a mean age of 41.56 years and 29,905 implants installed. Bone types I, II, and III exhibit a lower implant failure rate when compared to bone type IV.

Conclusion: Dental implants installed in bone types I, II, and III showed significantly higher survival rates than those installed in type IV. The bone type I success rate was not significantly different than that of type II; however, the success rate of bone type I and II was higher than that of type III.

1. Introduction

Dental implants are a commonly recommended option for rehabilitating lost teeth (Singh et al., 2020), with a survival rate of 98.8 % over 10 years of function documented in the literature (Buser et al., 2012). The success of this treatment depends on factors related to the patient and the surgical procedure (Beer et al., 2003). In a clinical study carried out by Branemark research group, shows that some requirements are necessary for successful osseointegration, are included: controlled surgical technique, macroscopic and microscopic characteristics of the implants, individualization of the process depending on the quantity and quality of bone and adequate application of chewing load (Albrektsson, et al., 1981; Thomkova et al., 2023) Among patient-related factors, bone quantity and quality play important roles (Singh et al., 2020) and are critical prerequisites for achieving primary stability of dental implants (Eskandarloo et al., 2019).

Many types of classifications for bone quality have been suggested, but the most common is the Lekholm-Zarb classification (Sargolzaie et al., 2019). According to Lekholm and Zarb (1985), bone quality can be classified into four types depending on the relationship between the quantity and quality of cortical and spongy bone. Their classifications include type I, homogeneous compact bone with high density; type II,

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high-density spongy bone surrounded by thick cortical bone; type III, high-density spongy bone surrounded by thin cortical bone; and type IV, low-density spongy bone surrounded by thin cortical bone. In addition to these types, in 1992 Bahat proposed a modification to the Lekholm-Zarb classification with the addition of bone type V, a bone without the upper and lower cortical bone.

The posterior maxilla bone changes significantly after tooth extraction due to resorption of the alveolar and maxillary sinus pneumatization, resulting in reduced width and height of the alveolar bone. Further, type IV bone is present in the posterior maxilla, on account of this poor quality, making site preparation difficult as it shown thin cortical bone and interfere with primary stability (King EM, Schofield J, 2023).

Reports show that implants inserted in areas of poor bone quality are more likely to fail. A systematic review by Goiato et al. (2014) reported a reduction in the survival rate of implants inserted into bone types IV and V, with the type V without cortical bone resulting from grafting. However, these estimates are controversial (Eskandarloo et al., 2019). This is mainly due to the development of technologies to improve the performance of implants in low-density bone, such as the use of self-threaded implants and applied surface treatments (Orestein et al., 2000). Therefore, this systematic review aimed to evaluate the success rate of implants installed in bone type IV compared to that in types I, II, and III, according to the classification of Lekholm and Zarb (1995).

2. Materials and methods

2.1. Registration protocol

This systematic review adhered to the guidelines delineated by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and was duly registered on the global platform dedicated to the registration of systematic reviews, PROSPERO (CRD42021229775).

2.2. Eligibility criteria

The PICO question (patient, intervention, comparison, outcome) was: "Do dental implants installed in type IV bone have a lower success rate when compared to implants installed in type I, II and III bone? The "Population" included patients submitted to the installation of dental implants; "Intervention", implants installed in type IV bone tissue; "Comparison", implants installed in type I, II and III bone, according to the Lekholm-Zarb classification; "Outcome", the success rate of implants installed in bone type IV, was the primary outcome, as a secondary outcome, success rates were evaluated between bone types I, II and III and to evaluate the influence of surface treatment on the success of implants. implants installed in type IV bone.

The established inclusion criteria were: controlled and randomized clinical trials (RCT), as it is considered the most reliable source of evidence on the effectiveness of interventions (Higgins and Green, 2011) and prospective and retrospective studies, as many times the amount of RCT is insufficient and well-conducted cohort studies improve the strength of the comparison and the result (Ramamoorthi, Narvekar and Esfandiari, 2017). Studies that evaluated at least 10 participants, with patients presenting dental implants installed in type IV bone tissue, as well as in type I, II and III bone tissues (Lekholm and Zarb, 1985), and a minimum follow-up time of 1 year.

Exclusion criteria were: studies with patients younger than 18 years, studies that use a classification other than that of Lekholm and Zarb, 1985, studies that did not present bone types I, II, III, and IV in the same study, studies that did not present the number of implants installed and the number of implants that failed for a minimum follow-up period of 1 year, studies that included patients undergoing radiotherapy, chemotherapy, use of bisphosphonates and osteoporosis patients.

2.3. Search strategy

Two investigators (CDDRDR and CAAL) performed the search independently in the following databases: PubMed/MEDLINE, Scopus and Cochrane. Surveying the studies published until July 2021, according to the eligibility criteria.

The search strategy was based on the combination of the following terms: *"(dental implants) AND (bone quality OR bone type)"*. Likewise, a manual search was performed in high-impact journals in implant dentistry, such as *Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery*. In addition, a manual search of the references of the included articles was performed.

2.4. Data analysis

Two reviewers (CDDRDR and CAAL) independently reviewed the search results and identified potentially relevant studies based on title and abstract. Relevant studies were selected for reading in full and included in the systematic review according to the eligibility criteria. One author (CDDRDR) collected data from the included studies and a second author (CAAL) verified the information. If there was any disagreement between the reviewers, a third reviewer (EPP) was consulted. Qualitative data collected were study author and year, type of study, number of patients, mean age of study participants, implant systems, implant surface treatment, diameter and length, follow-up time in years, number of implants installed and flawed.

2.5. Data synthesis

The performed meta-analysis was based on the Mantel – Haenszel (MH) and Inverse Variance (IV) methods. Failure rates were assessed by hazard ratio (RR) RR values were considered significant when the P value was < 0.05. For statistically significant heterogeneity ($P < 0.10$), a random effects model was used to assess the significance of treatment effects. When no statistically significant heterogeneity was found, the analysis was performed using a fixed effects model. Reviewer Manager 5 software (Cochrane Group) was used for meta-analyses.

2.6. Risk of bias

Two authors (VAAB, JPJOL) performed risk of bias analysis on the included RCTs using the Cochrane risk of bias tool; this tool checks for selection bias (random sequence generation and allocation), performance bias (blinding of participants and staff), detection bias (blinding of outcome evaluation), attrition bias (result of incomplete data), reporting (selective reporting) and other biases (other sources of bias). The Newcastle-Ottawa (NOS) scale was used for non-randomized studies. NOS verifies three elements: selection, comparability and outcome for cohort studies. The scale classifies studies with a maximum of 9 stars; $>$ 6 stars indicates a low risk of bias and scores $\leq$ 5 stars indicate a high risk of bias.

3. Results

A total of 9429 studies were found in the previously selected databases, 4721 in PubMed, 4167 in Scopus, 519 in Cochrane and 22 articles in the manual search. With the removal of duplicate references, 7727 articles were analyzed by title and abstract, of which 117 were chosen for full reading. Sixty-eight references were excluded, the causes are; Patients undergoing radiotherapy and/or chemotherapy; Patients using bisphosphonates (Alsaadi et al., 2008; Alsaadi et al., 2008; Chrcanovic et al., 2016; Tovalino et al., 2019; Friberg & Jemt, 2008; Friberg et al., 2005); Absence of any bone type or absence of separation of bone types (Anitua et al., 2016; Bahat et al., 1992; Becker et al., 1998; Demiralp

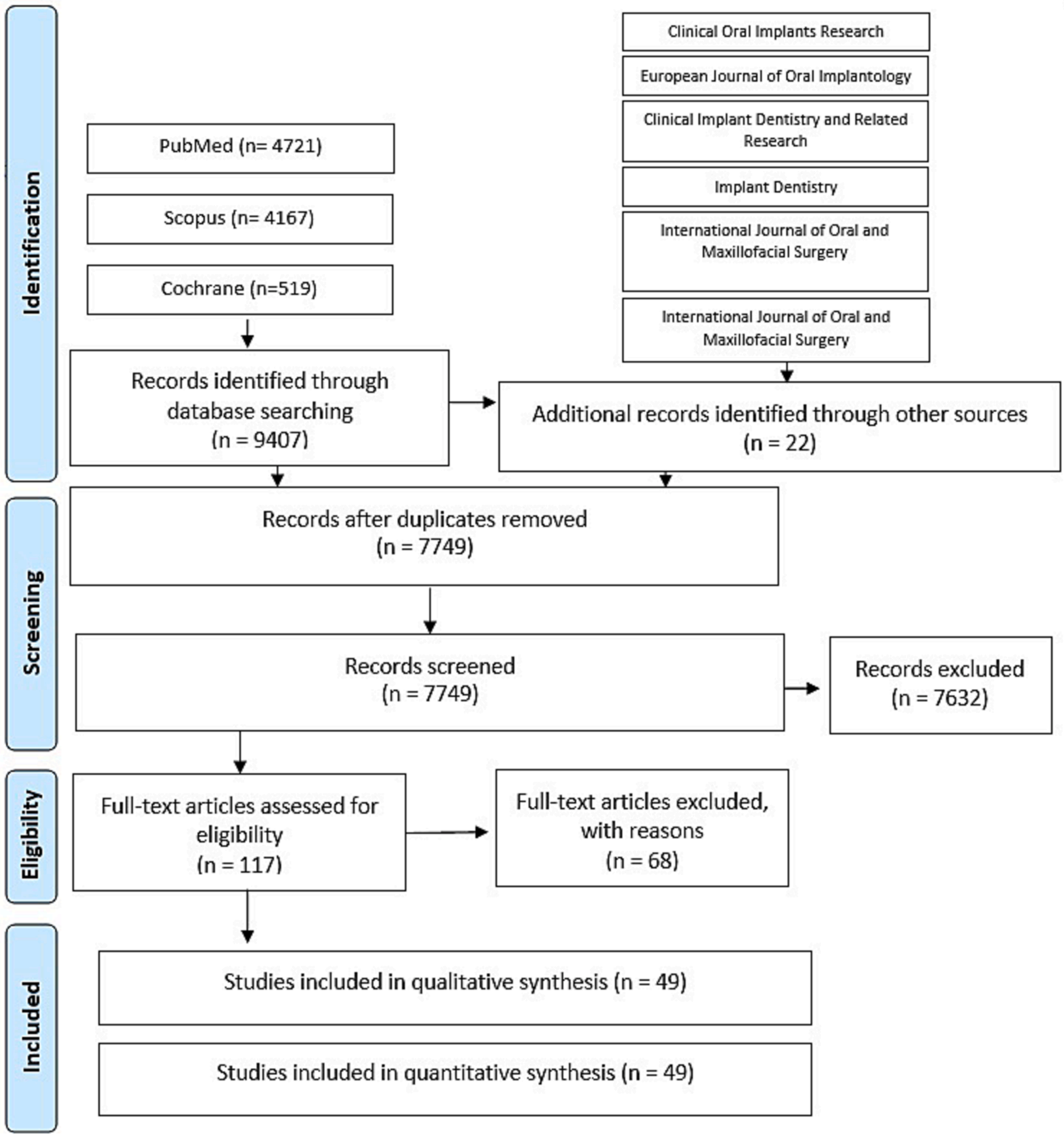

Fig. 1. Search strategy.

et al., 2015; Duminil et al., 2008; Glauser et al., 2003; Glauser et al., 2013; Goçmen et al., 2016; Hingsammer et al., 2017; Jaffin et al., 1991; Jeong et al., 2015; Kumar et al., 2017; Rocci et al., 2003; Romanos et al., 2016; Sonal et al., 2017; Tawil et al., 2001; Trbakovic et al., 2020; Wang et al., 2016; Zinser et al., 2013; Burdulu et al., 2021; Kim et al., 2021; Staedt et al., 2020; Becker et al., 2015; Turner & Nentwig., 2014; Maiorana et al., 2015; Salimov et al., 2014; Mangano et al., 2014; Lai et al., 2013; Montero et al., 2012; Guarnieri et al., 2021; Boboeva et al., 2021; Bielemann et al., 2018; Waechter et al., 2017; Polizzi et al., 2000; Khang et al., 2001; Feldman et al., 2004); Presence of patients under 18 years of age (Balshi et al., 2015; Ottoni et al., 2005; Becker et al., 2013; Bianco et al., 2000; Widmark et al., 2003); Absence of number failed implants (Collaert et al., 2008; Ganeles et al., 2008; Simmons et al., 2016; Zumstein et al., 2019; Raikar et al., 2017; Blume et al., 2020; Triches et al., 2019; Doan et al., 2014; Shivu et al., 2021; Castellanos-Cosano et al., 2019; Blus et al., 2010); Use of another classification for bone type (Degidi et al., 2005; Grandi et al., 2012; Al-Nawas et al., 2013); Follow-up less than 1 year (Fu et al., 2017; Nappo et al., 2019; Sargolzaie et al., 2019; Shin et al., 2014; Toia et al., 2017; Mohajerani et al., 2017). Thus, 49 studies were part of the qualitative and quantitative analysis. Details of the search strategy are illustrated in Fig. 1.

3.1. *Characteristics of the selected studies*

Detailed data from the forty-nine selected studies are listed in Table 1. The total number of patients included was 12056, with a mean age of 41.56 years, 29,905 implants were analyzed, of which 2570 were installed in type I bone, 12,434 in bone type II, 12,240 in bone type III

Table 1
Details of included studies.

Author	study type	Patients	mean age	implant system	Surface	Diameter and Length	follow-up	Placed/Failed implants			
								Type I	Type II	Type III	Type IV
De Bruyn & Collaert, 1994	Retrospective	117	53.0	Brånemark System	Machined	D = 3.75–4 mm L = 7; 10; 13; 15 mm	3 years	1/38	6/84	3/51	71/0
Becker et al., 1995	Retrospective	24	58.6	NR	NR	10 x 3.75 mm 13 x 3.75 mm 15 x 3.75 mm 10x4mm 6x5mm 8x5mm	1 year	3/0	6/0	9/0	6/0
Bergendal & Engquist, 1998	Prospective	49	66	Brånemark System	Machined	D = 3.75 mm L = 7;10;13;15;18;20 mm	7 years	4/0	38/0	55/2	11/18
Becker et al., 1999	Prospective	212	55.0	Branemark System	Machined	D = 3.75;4.0;5.0 mm L = 8.5;10;11.5;13;15;18 mm	6 years	77/4	151/4	11/49	5/0
Lekholm et al., 1999	Prospective	125	18–70	Brånemark System	Machined	D = 3.75–4 mm L = 7;10;13;15;18; 20 mm	10 years	6/0	70/6	320/22	65/6
Balshi et al., 1999	Retrospective	189	60.0	Brånemark System	Machined	D = 3.75;4.0;5.0 mm L = 7;8.5;10;11.5;13;15;18;20 mm	4.68 years	2/0	2/26	131/16	217/24
Friberg et al., 1999	Prospective	105	64.0	Brånemark System MK-II	Machined	D = 3.75;4.0;5.0 mm L = 6;7;8.5;10;11.5;12;13;15;18;20 mm	3 ye ars	7/0	236/11	105/1	72/2
Truhlar et al., 2000	Prospective	NR	20–80	Spectra-System (CoreVent Corporation, Las Vegas, NV)	Acid-etched HA-coated and uncoated	D = 3.5;4.5 mm L = 8;10;10.5;13;16 mm	3 years	242/16	1294/93	1007/93	231/22
Orenstein et al., 2000	Retrospective	800	NR	Spectra system (micro -vent, Screw Vent, Bio Vent, Core-Vent)	Acid-etched HA-coated and uncoated	NR	3 years	238/14	1260/77	1026/83	238/19
Glauser et al., 2001	prospective	41	52	Brånemark System IV	Machined	D = 4.0;5.0 mm L = 7;8.5;10;11.5;13;15;18 mm	1 year	8/1	4/43	6/38	11/38
Morris et al., 2001	prospective		31–90	ankylos implants	NR	D = 3.5;4.5;5.5 mm L = 8;9.5;11;14;17 mm	18 months	163/1	601/21	543/22	95/5
Cochran et al., 2002	Prospective	110	54.5	ITI SLA solid screw	Sandblasted and acid-etched	D = 4.1 mm L = 8;10;12;14 mm	1 year	30/0	163/1	133/2	57/0
Engquist et al., 2002	Prospective	82	64.9	Brånemark System	Machined	L = 10;13;15;18;21 mm	1 year	4/16	2/128	11/152	24/0
Cal andriello et al., 2003	Prospective	26	52.3	Brånemark System (standard fixture, Mk II, Mk III, and Mk IV)	Machined	3.75;4.0 x 13 mm 5 x 10 mm	1 year	5/0	17/0	24/0	4/0
Raghoebar et al., 2003	Prospective	40	18–70	Brånemark System	Machined	3.75 x 10;13;15;18 mm	3 years	13/0	93/4	3/57	7/4
Tawil & Younan, 2003	Prospective	111	53.6	Brånemark System	Machined	D = 3.3; 3.75; 4.5 mm L = 6;7;8;8.5;10 mm	12–92 months	3/0	79/2	8/160	2/27
Friberg et al., 2005	Prospective	187	53.0	Brånemark System MK-III, MK-IV	oxidized	D = 3.75 mm L = 7;8.5;10;11.5;13;15;18 mm	1 year	12/0	150/1	230/1	10/0
Herrmann et al., 2005	Retrospective	487	51.3	Brånemark System; Nobel Biocare, Goteborg, Sweden	Machined	3.75 x 7 mm 3.75 x 10 mm	5 yea lol	2/18	7/155	265/15	12/49
Noguerol et al., 2006	Retrospective	316	NR	Brånemark System	Machined	D = 3.3; 3.75; 4.0; 5 mm L = 7, 8, 8.5, 10, 11.5, 12, 13, 15 and 18 mm	10 years	4/58	449/13	493/31	79/7
Romeo et al., 2006	Prospective	120	55.8	ITIs (Institute Straumann)	plasma-sprayed titanium	D = 3.3;4.1 mm L = 10;12 mm	3–6 years	1/42	122/3	115/6	51/5
Becktor et al., 2007	Prospective	77	64.5	Brånemark System	Machined	Standard and MKII – 8.5;10;11.5;13;15;18 mm	36 months	1/38	12/227	8/122	1/17
Siddiqui et al., 2008	Prospective	65	41	Tapered Screw-Vent MTX, Zimmer Dental	Sandblasted and HA-coated	D = 3.7;4.7;6.0 mm L = 10;13;16 mm	1 years	10/0	32/0	19/0	8/1
Fischer et al., 2009	Prospective	32	54.0	Replace Select TiUnite	oxidized	D = 4.3;5.0 mm L = 10;13;16 mm	1 year	1/0	29/0	20/0	3/1

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Table 1 (*continued*)

Author	study type	Patients	mean age	implant system	Surface	Diameter and Length	follow-up	Placed/Failed implants Type I	Type II	Type III	Type IV
Ostman et al., 2010	prospective	35	>18	PREVAIL®, BIOMET 3i	Acid-etched and CaP-coated	D = 4.0;5.0 mm L = 8.5;10;11.5;13;15 mm	1 years	10/0	21/0	52/0	1/19
Agliardi et al., 2009	Prospective	20	57	Brånemark System MK IV and NobelSpeedy Groovy	oxidized	4 x 11 mm 4 x 13 mm 4 x 15 mm	27 months	11/0	73/0	32/0	4/0
Gallucci et al., 2009	Prospective	45	59.5	Straumann AG	Sandblasted and acid-etched	L = 8;10;12;14;16 mm	5 years	43/0	126/0	38/0	25/0
Johansson et al., 2009	Prospective	52	72	Brånemark System MK- III TiUnite	oxidized	D = 3.75–4.0 L = 10;11.5;13;15 mm	1 year	126/1	134/1	49/0	3/0
Sennerby et al., 2012	Prospective	90	50.6	Neoss Implant System	Sandblasted and acid-etched	D = 3.5;4.0;4.5 mm L = 7;9;11;13;15 mm	2 years	12/0	2/142	44/0	1/20
Jang et al., 2011	Retrospective	3755	65.0	paragon TSV, Camlog, Biohorizon, Astra, Replace, GS	Machined, Oxidized, acid-etched, titanium plasma sprayed, sandblasted/acid-etched	D=<3.75; 3.75–4.5, >4.5 L=<10: 10–15; > 15 mm	10 years	271/1	2690/45	3312/59	112/3
Calandriello and Tomatis, 2011	Retrospective	33	52	Brånemark System TiUniteWide Platform MK	oxidized	Wide – L = 8.5;10;11.5;13;18 mm	5 years	3/1	21/0	1/15	1/0
Galindo-moreno et al., 2012	Prospective	69	18–72	Astra Tech OsseoSpeed™ TX 3.0S	TiO2-blasted fluoride -modified	D = 3.0 mm L = 11;13;15 mm	1 years	1/0	3/61	1/32	3/0
Barewal et al., 2012	RCT	40	51.0	OsseoSpeed, Astra Tech	TiO2-blasted fluoride -modified	4 x 11 mm 4 x 13 mm	3 years	1/0	12/0	19/0	8/1
Ostman et al., 2012	Prospective	42	>18	NanoTite™ Tapered Certain	Acid-etched and CaP-coated	D = 4.1;5.0 mm L = 8.5;10;11.5;13;15 mm	1 year	3/0	46/0	58/1	32/0
Finne et al., 2012	Prospective	56	47.0	NobelDirect and NobelPerfect	oxidized	D = 3.5;4.3;5.0 mm L = 10;13;16 mm	3 years	5/0	54/1	22/0	1/0
Maló et al., 2003	Prospective	116	41	Brånemark System	Machined	L = 10;11.5;13;15;18 mm	1 year	1/0	3/49	2/57	6/0
Mangano et al., 2014	Prospective	642	51.0	Leone Implant System	Sandblasted and acid-etched	D = 3.3, 4.1, 4.8 mm L = 8.0, 10.0, 12.0, 14.0 mm	10 years	84/1	292/2	727/7	9/391
Dahlin et al., 2013	Prospective	177	Majority > 50	NEOSS implants	Sandblasted and acid-etched	D = 3.5;4;4.5;5.5 mm L = 7;9;11;13;15;17 mm	1 year	12/0	237/5	312/4	4/29
Vasak et al., 2014	Prospective	30	31–80	NobelReplace®	oxidized	D = 3.5;4.3;5.0 mm L = 8;10;13;16 mm	1 year	7/0	84/0	66/1	6/1
Mangano et al., 2014	Prospective	279	25–73	Leone implant system	Sandblasted and acid-etched	D = 3.3 mm L = 8;10;12;14 mm	10 years	26/0	75/0	154/3	69/1
Glibert et al., 2016	Prospective	48	>18	Osseotitis 2 Certain	dual-acid etched	D = 4.0;5.0 mm L = 8.5;10;11.5;13;15 mm	1 year	4/0	30/0	61/0	20/0
Han et al., 2014	Retrospective	879	NR	Nobel Biocare, Straumann, Biolok International	Machined, Oxidized, acid-etched, titanium plasma sprayed, sandblasted/acid-etched	D=<3.75, 3.75–4.5, >4.5 – L=<10, 10–15, > 15 mm	19 years	73/0	1197/19	388/5	88/5
Muelas-Jiménez et al., 2017	Retrospective	52	47.5	SwissPlus	MTX surface	D = 3.7;4.1;4.8 mm L = 10;12;14 mm	5 years	17/0	70/3	9/61	6/16
Olmedo-Gaya et al., 2016	Retrospective	142	48.49	BTI implants	Bioactive surface	D = 2.5;3.0;3.3 mm L = 7;7.5;8.5;10;11.5;13;15 mm	5 years	1/21	8/83	133/3	4/23
Díaz-Sánchez et al., 2017	Prospective	27	18–65	ELEMENT INICELL, Thommen Medical AG,	Sandblasted and acid-etched	D = 3.5;4.0;4.2;5.0 mm L = 8;9.5;11;12.25 mm	1 years	42/0	16/0	8/0	1/0

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Table 1 (*continued*)

Author	study type	Patients	mean age	implant system	Surface	Diameter and Length	follow-up	Placed/Failed implants Type I	Type II	Type III	Type IV
				Waldenburg, Germany							
Andersson et al., 2019	Retrospective	334	52.0	neoss implant	Sandblasted and acid-etched	D = 3.5–5.5 mm L = 7–17 mm	5 years	37/0	392/11	263/8	50/1
Eskandarloo et al., 2019	Retrospective	22	42.6	NR	NR	NR	30 months	3/0	35/0	44/0	01/18
Singh et al., 2020	Retrospective	826	NR	NR	NR	D=< 3.75 mm; 3.75–4.5 mm; >4.5 mm x L= < 10 mm; 10–11.5 mm; >11.5 mm	10 years	648/52	412/38	210/24	150/31
Thome et al., 2020	Retrospective	101	59.17	Helix Acqua GM, Neodent	Sandblasted and acid-etched surfaces with hydrophilic properties	D = 3.5;3.75;4.0;4.3;5.0;6.0 mm L = 8;10;11.5;13;16;18	2 years	49/0	98/1	116/0	25/0
Wang et al., 2021	Retrospective	827	44.11	Straumann® Dental Implant System	Sandblasted and acid-e tched	D = 3.3; 4.1; 4.8 mm L = 8;10 mm	9 years	2/26	531/20	843/14	149/4

and 2661 in bone type IV. The follow-up period ranged from 1 to 19 years. The diameter of the implants ranged from 3.3 to 6.0 mm and the length ranged from 7 to 20 mm. Most studies used implants of the Brånemark System type.

3.2. Risk of bias

For randomized clinical trials, the Cochrane scale was used only one study was assessed by this scale (Barewal et al., 2012), the risk of bias was considered low for the following outcomes: random sequence generation, blinding of participants and raters, incomplete outcomes, report of selective outcome and other sources of bias, the outcome allocation concealment was assessed with uncertain risk of bias. All prospective and retrospective studies evaluated using the NOS scale demonstrated a low risk of bias, as they obtained more than six stars, as specified in Table 2.

3.3. Meta-analysis

All 49 articles could be included in the meta-analysis. When comparing the number of installed/failed implants between type I and type IV bone, there was a statistically significant difference in favor of type I bone ($p < 0.00001$; RR: 1.92; 95 %CI: 1.52–2.43) (Fig. 2) and when compared bone types II and IV, being significantly favorable to bone type II ($p < 0.00001$; RR: 1.89; 95 %CI: 1.59–2.24) (Fig. 3). Furthermore, there was a statistically significant difference when comparing type III and IV bone, favorable to type III bone ($p < 0.00001$; RR: 1.50; 95 %CI: 1.27–1.76) (Fig. 4).

4. Discussion

Although the survival rate of dental implants over a 10-year observation period was reported as greater than 90 % (Alghamdi, 2018), implants do fail in some patients. In this study, the null hypothesis that implants placed in bone type IV have the same success rates as those in types I, II, and III was rejected, since according to the meta-analysis, a significant difference in the survival rate was observed when other bone types were compared with type IV.

This systematic review presents results in agreement with those of Goiato et al. (2014), who showed that implants inserted in bone type IV had a lower success rate than that of other types, and that implants with surface treatments showed a higher success rate than that of machined implants. However, the current review adds improvements such as the use of a meta-analysis to acquire data, the inclusion of a greater number of new articles, and the assessment of the risk of bias. In addition, new data were acquired in the meta-analysis showing equal performance of implants installed in bone types I and II.

Preoperative bone evaluation is critical for implant treatment planning as it improves the accurate determination of prognosis and increases the implant success rate (Eskandarloo et al., 2019). Various factors are important for long-term implant success, including good bone quality around the implant and a solid bone/implant interface (Linetskiy et al., 2017), implant design and shape (Thomé et al., 2020), and local and systemic patient-related factors (Mohajerani et al., 2017).

Bone quality was suggested by Díaz-Sánchez et al. (2017) as one of the main factors related to the success of implant therapy. Their study showed that implants installed in bone types III and IV were more likely to fail, whereas the highest survival rates were achieved in bone types I and II, which have a higher density (Muelas-Jiménez et al., 2015) and superior primary stability. A high primary stability is a prerequisite for implant survival (Glibert et al., 2016). Dense and spongy compact bones are favorable because they hold the implant firmly in the bone. In contrast, porous and trabecular bones decrease implant stability (Kate et al., 2016) leading to micromovements at the bone-implant interface during healing, which in turn stimulates soft tissue formation fibrosis rather than bone repair (Andersson et al., 2019). In their 5-year analysis, Jaffin and Berman (1991) reported a 35 % failure of implants installed in bone type IV, with 36 failures in a total of 102 installed implants due to thin cortical bone. In the same study, 952 implants were placed in bone types I, II, and III, of which 29 failed (3 %). Andersson et al. (2019) reported a lower survival rate of implants with low stability than that of implants with greater stability.

A decrease in the cortical bone leads to an increase in local bone stress, which may increase the micromovement of the *peri*-implant bone, impairing primary stability. Primary stability is critical for improving the success rate of dental implants (Chou et al., 2014). The studies by Andersson et al. (2019), Barewal et al. (2012), and Sennerby et al. (2012) reported implant stability quotient (ISQ) values acquired using the Osstell device immediately after implant installation in different bone types. Bone type IV revealed the lowest mean primary stability values, i.e., 58 (Barewal et al., 2012), 63.8 (Andersson et al., 2019), and 60–65 (Sennerby et al., 2012). The bone type I values were 72 (Barewal et al., 2012), 76.5 (Andersson et al., 2019), and 75–80 (Sennerby et al., 2012), the bone type II values were 72 (Barewal et al., 2012), 75 (Sennerby et al., 2012), and 75.2 (Andersson et al., 2019), and finally, the type III bone values, were 70 (Barewal et al., 2012), 70–75 (Sennerby

Table 2
Detailed Newcastle-Ottawa Scale of each included cohort study.

Study	Selection				Comparability		Outcome			total quality score
	Representativeness of exposed cohort	Selection of nonexposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Adjust for the most important risk factors	Adjust for other risk factors	Assessment of outcome	follow-up length	Loss to follow-up rate	
De Bruyn & Collaert, 1994	★	★	★	★	★	★	★	★	★	9
Becker et al., 1995	★	★	★	★	★	★	★	★	★	9
Bergendal & Engquist, 1998	★	★	★	★	★	★	★	★	★	9
Becker et al., 1999	★	★	★	★	★	★	★	★	★	9
Lekholm et al., 1999	★	★	★	★	★	★	★	★	0	8
Balshi et al., 1999	0	★	★	★	★	★	★	★	★	8
Friberg et al., 1999	★	★	★	★	★	★	★	★	★	9
Truhlar et al., 2000	★	★	★	★	★	★	★	★	★	9
Orenstein et al., 2000	★	★	★	★	★	★	★	★	★	9
Glauser et al., 2001	★	★	★	★	★	★	★	★	★	9
Morris et al., 2001	★	★	★	★	★	★	★	★	★	9
Cochran et al., 2002	★	★	★	★	★	★	★	★	0	8
Engquist et al., 2002	★	★	★	★	★	★	★	★	★	9
Calandriello et al., 2003	★	★	★	★	★	★	★	★	★	9
Raghoebar et al., 2003	★	★	★	★	★	★	★	★	★	9
Tawil & Younan, 2003	★	★	★	★	★	★	★	★	★	9
Friberg et al., 2005 A	★	★	★	★	★	★	★	★	0	8
Herrmann et al., 2005	★	★	0	0	★	★	★	★	★	7
Noguerol et al., 2006	★	★	★	★	★	★	★	★	★	9
Romeo et al., 2006	★	★	★	★	★	★	★	★	★	9
Becktor et al., 2007	★	★	★	★	★	★	★	★	0	8
Siddiqui et al., 2008	★	★	★	★	★	★	★	★	★	9
Fischer et al., 2009	★	★	★	★	★	★	★	★	★	9

(continued on next page)

Table 2 (*continued*)

Study	Selection				Comparability		Outcome			total quality score
	Representativeness of exposed cohort	Selection of nonexposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Adjust for the most important risk factors	Adjust for other risk factors	Assessment of outcome	follow-up length	Loss to follow-up rate	
Ostman et al., 2010	★	★	★	★	★	★	★	★	★	9
Agliardi et al., 2009	★	★	★	★	★	★	★	★	★	9
Gallucci et al., 2009	★	★	★	★	★	★	★	★	★	9
Johansson et al., 2009	★	★	★	★	★	★	★	★	★	9
Sennerby et al., 2012	★	★	★	★	★	★	★	★	★	9
Jang et al., 2011	★	★	★	★	★	★	★	★	★	9
Calandriello and Tomatis, 2011	★	★	★	★	★	★	★	★	★	9
Galindo-moreno et al., 2012	★	★	★	★	★	★	★	★	★	8
Ostman et al., 2012	★	★	★	★	★	★	★	★	★	9
Finne et al., 2012	★	★	★	★	★	★	★	★	0	8
Maló et al., 2003	0	★	★	★	★	★	★	★	★	8
Mangano et al., 2013	★	★	★	★	★	★	★	★	★	★
Dahlin et al., 2013	★	★	★	★	★	★	★	★	★	9
Vasak et al., 2014	★	★	★	★	★	★	★	★	★	9
Mangano et al., 2014	★	★	★	★	★	★	★	★	★	9
Glibert et al., 2016	★	★	★	★	★	★	★	★	★	9
Han et al., 2014	★	★	★	★	★	★	★	★	★	9
Muelas-Jiménez et al., 2017	★	★	★	★	★	★	★	★	★	9
Olmedo-Gaya et al., 2016	★	★	★	★	★	★	★	★	★	9
Díaz-Sánchez et al., 2017	★	★	★	★	★	★	★	★	★	9
Andersson et al., 2019	★	★	★	★	★	★	★	★	★	9
Eskandarloo et al., 2019	★	★	★	★	★	★	★	★	★	9
Singh et al., 2020	★	★	★	★	★	★	★	★	★	9

(continued on next page)

Table 2 (*continued*)

Study	Selection				Comparability		Outcome			total quality score
	Representativeness of exposed cohort	Selection of nonexposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Adjust for the most important risk factors	Adjust for other risk factors	Assessment of outcome	follow-up length	Loss to follow-up rate	
Thome et al., 2020	★	★	★	★	★	★	★	★	★	9
Wang et al., 2021	★	★	★	★	★	★	★	★	★	9

et al., 2012), and 72 (Andersson et al., 2019). In addition, despite being identified as an important factor in achieving final osseointegration, introducing implants with high installation torque resulted in bone resorption due to impairment of the vascularized bone caused by increased tension in the bone walls (Galindo-Moreno et al., 2012).

De Bruyn et al. (1994), Friberg et al. (1999), Tawil et al. (2003), and Jang et al. (2011) reported higher failure rates in the maxilla than in the mandible. According to Andersson et al. (2019), an analysis of resonance frequency (RFA) showed that the stability of maxillary implants was lower than that of mandibular implants. In addition, the implant stability quotient (ISQ) values were significantly higher in the mandible, and the author speculated that this finding was due to the bones in the maxilla commonly being of lower density than those in the mandible. In addition to bone quality, the main factors that influenced primary stability are the implant design and surgical procedure (Huang et al., 2014).

Tapered dental implants demonstrate superior mechanical stability compared to cylindrical dental implants (Romanos et al., 2014). In addition, primary stability is influenced by implant dimensions (length and diameter), surface characteristics (rough or smooth), number of threads on the implant surface (Romanos et al., 2020), and pitch, shape, and thread depth (Alghamdi, 2018), as the presence of threads increases the surface area for osseointegration (Sykaras et al., 2000).

Various implantation techniques have been proposed to promote a high degree of implant stability without removing additional bone, particularly in situations where bone density is limited (Alghamdi, 2018). Studies have shown good results in less-dense bones, which may be the result of modified surgical techniques, such as the use of self-threading implants, conical implants, and final drills with a smaller diameter than the diameter of the implant (Fischer et al., 2009). Lateral compression of the recipient bed has been successfully used in implant dentistry (Tabassum et al., 2013). Lateral compression is achieved by placing an implant in a bone cavity that is considerably smaller in diameter than the diameter of the implant itself, resulting in greater insertion torque, which is an indicator of high primary stability (Tabassum et al., 2013). Although the posterior regions, especially the maxilla, are considered more challenging because of the presence of less-dense bone, stability can be achieved using undermilling techniques (Gehrke et al., 2018; Ostaman et al., 2010).

Recent advances in dentistry have revolutionized the use of dental implants. Thomé et al. (2020) reported survival rates ranging from 99 % to 100 % for different bone types (I–IV) with a 2-year followup. This result may be explained by the conical design of the evaluated hybrid implants using the protocol of a suitable drill, allowing compaction of the trabecular bone in the middle and cervical portions, and promoting better results regardless of the type of bone site.

Osseointegration may be impaired in patients with diabetes *mellitus* (Mombelli and Cionca, 2006) and osteoporosis (Giro et al., 2015), and in those treated with radiotherapy (Koudougou et al., 2020). Jang et al. (2011) reported that the failure rate tends to increase with patient age due to decreasing bone density. This is because over time, the rate of bone resorption is greater than that of bone production. Thus, the cortical bone was thinner and the porosity of the cancellous bone increased, highlighting the need for surface modifications that accelerated osseointegration after implant insertion (Sekar et al., 2019).

The surface of the implants and speed of bone apposition around the implantation site are key factors in bone-implant contact (Mohajerani et al., 2017). In a previous report, surface microtopography significantly influenced the osseointegration of titanium implants due to an increase in surface roughness leading to greater bone apposition and decreased healing time (Ding et al., 2020). Topographically modified titanium implant surfaces, such as sandblasted, acid-etched (SLA), and chemically modified hydrophilic SLA surfaces, have shown promising results when compared to polished titanium surfaces (Chakravorty et al., 2017). Studies revealed that implants with modified surfaces showed a higher success rate than that of superficial implants machined in compromised bone situations (Del Fabbro et al., 2006; Del Fabbro et al., 2008; Smeets et al., 2016).

The heterogeneity identified in meta-analyses comparing the number of installed vs. failed implants among different bone types is considered low (Higgins and Green, 2011). A limitation of the present meta-analysis is that the studies did not determine the length and width of each implant installed in each bone type, nor did they determine the type of connection used. These factors may interfere with the biomechanics of implant-supported prostheses, and consequently, with the success of rehabilitation. Therefore, conducting new randomized clinical trials including standardization of implant length and width, type of connection, and surface treatment is warranted.

In order to achieve higher success rates for implants placed in bone type IV, the clinician must take into account various features including systemic factors related to the patient, the diameter and length of the implant, properties related to the thread of the implant (pitch, shape, and depth), surface treatment, and the use of surgical techniques that preserve the bone in the recipient site. In addition, a less traumatic surgical procedure, two-stage approach, and adequate healing time are important (Gehrke et al., 2018; Jang et al., 2011).

5. Conclusion

Dental implants installed in bone types I, II, and III had a significantly higher survival rate than implants installed in bone type IV. To reduce implant failure rates, it is clinically important, when selecting an implant, to consider bone density, as it is a critical factor for achieving high insertion torque. Therefore, it is advisable to adapt drilling protocols according to the bone density of the rehabilitated area. In situations involving type IV bone, the use of additional drills, such as thread male drills and cortical drills, is strongly discouraged, as such practices may compromise the success of the treatment entirely.

Study or Subgroup	BONE IV Events	BONE IV Total	BONE I Events	BONE I Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Agliardi et al., 2009	0	4	0	11		Not estimable
Andersson et al., 2019	1	50	0	37	0.7%	2.24 [0.09, 53.37]
Balshi et al., 1999	24	217	0	2	1.1%	0.67 [0.05, 8.70]
Barewal et al., 2012	1	8	0	1	0.9%	0.67 [0.04, 11.07]
Becker et al., 1995	0	6	0	3		Not estimable
Becker et al., 1999	0	5	4	77	0.7%	1.44 [0.09, 23.78]
Becktor et al., 2007	1	17	1	38	0.7%	2.24 [0.15, 33.67]
Bergendal & Engquist, 1998	1	18	0	4	0.9%	0.79 [0.04, 16.59]
Calandriello and Tomatis, 2011	0	1	1	3	1.1%	0.67 [0.04, 10.05]
Calandriello et al., 2003	0	4	0	5		Not estimable
Cochran et al., 2002	0	57	0	30		Not estimable
Dahlin et al., 2013	4	29	0	12	0.8%	3.90 [0.23, 67.31]
De Bruyn & Collaert, 1994	0	71	1	38	2.2%	0.18 [0.01, 4.33]
Dı´az-Sa´nchez et al., 2017	0	1	0	42		Not estimable
Engquist et al., 2002	0	24	4	16	6.1%	0.08 [0.00, 1.31]
Eskandarloo et al., 2019	0	18	0	3		Not estimable
Finne et al., 2012	0	1	0	5		Not estimable
Fischer et al., 2008	1	3	0	1	0.8%	1.50 [0.10, 22.62]
Friberg et al., 1999	2	72	0	7	1.0%	0.55 [0.03, 10.44]
Friberg et al., 2005 A	0	10	0	12		Not estimable
Galindo-moreno et al.,2012	0	3	0	1		Not estimable
Gallucci et al.,2009	0	25	0	43		Not estimable
Glauser et al., 2001	11	38	1	8	1.9%	2.32 [0.35, 15.48]
Glibert et al., 2014	0	20	0	4		Not estimable
Han et al., 2014	5	88	0	73	0.6%	9.15 [0.51, 162.70]
Herrmann et al., 2005	12	49	2	18	3.3%	2.20 [0.55, 8.90]
Jang et al., 2011	3	112	1	271	0.7%	7.26 [0.76, 69.04]
Johansson et al., 2009	0	3	1	126	0.1%	10.58 [0.51, 221.67]
Lekholm et al., 1999	6	65	0	6	1.0%	1.38 [0.09, 21.98]
Maló et al., 2013	0	6	0	1		Not estimable
Mangano et al., 2013	9	391	1	84	1.9%	1.93 [0.25, 15.06]
Mangano et al., 2014	1	69	0	26	0.8%	1.16 [0.05, 27.54]
Morris et al., 2001	5	95	1	163	0.8%	8.58 [1.02, 72.34]
Muelas-Jime´nez et al., 2015	6	16	0	17	0.6%	13.76 [0.84, 226.13]
Noguerol et al., 2006	7	79	4	58	5.2%	1.28 [0.39, 4.18]
Olmedo-Gaya et al., 2016	4	23	1	21	1.2%	3.65 [0.44, 30.12]
Orenstein et al., 2000	19	238	14	238	15.9%	1.36 [0.70, 2.64]
Ostman et al., 2012	0	32	0	3		Not estimable
Ostman et al.,2008	1	19	0	10	0.7%	1.65 [0.07, 37.18]
Raghoebar et al., 2003	4	7	0	13	0.4%	15.75 [0.97, 256.33]
Romeo et al., 2006	5	51	1	42	1.2%	4.12 [0.50, 33.89]
Sennerby et al., 2010	1	20	0	12	0.7%	1.86 [0.08, 42.27]
Siddiqui et al., 2008	1	8	0	10	0.5%	3.67 [0.17, 79.54]
Singh et al.,2020	31	150	52	648	22.2%	2.58 [1.71, 3.87]
Tawil & Younan, 2003	2	27	0	3	1.0%	0.71 [0.04, 12.35]
Thome et al., 2020	0	25	0	49		Not estimable
Truhlar et al., 2000	22	231	16	242	17.7%	1.44 [0.78, 2.67]
Vasak et al.,2014	1	6	0	7	0.5%	3.43 [0.16, 71.36]
Wang et al., 2020	4	149	2	26	3.9%	0.35 [0.07, 1.81]
Total (95% CI)		**2661**		**2570**	**100.0%**	**1.92 [1.52, 2.43]**
Total events	195		108			

Heterogeneity: $Chi^2 = 30.14$, df = 34 (P = 0.66); $I^2 = 0\%$
Test for overall effect: Z = 5.45 (P < 0.00001)

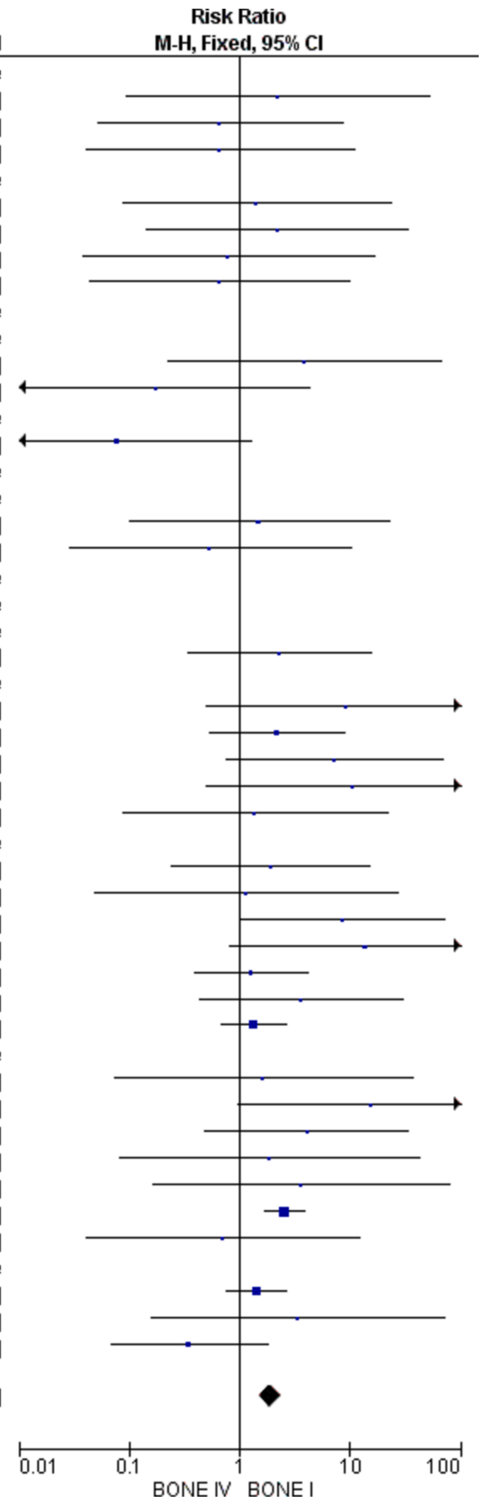

Fig. 2. Meta-analysis comparing the failure rate of implants installed in type I x IV bone. By meta-analysis, implants installed in bone type I had a significantly higher survival rate than implants installed in bone type IV.

Study or Subgroup	BONE IV Events	BONE IV Total	BONE II Events	BONE II Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Agliardi et al., 2009	0	4	0	73		Not estimable
Andersson et al., 2019	1	50	11	392	1.7%	0.71 [0.09, 5.40]
Balshi et al., 1999	24	217	2	26	2.4%	1.44 [0.36, 5.74]
Barewal et al., 2012	1	8	0	12	0.3%	4.33 [0.20, 94.83]
Becker et al., 1995	0	6	0	6		Not estimable
Becker et al., 1999	0	5	4	151	0.2%	2.81 [0.17, 46.55]
Becktor et al., 2007	1	17	12	227	1.1%	1.11 [0.15, 8.06]
Bergendal & Engquist, 1998	1	18	0	38	0.2%	6.16 [0.26, 144.17]
Calandriello and Tomatis, 2011	0	1	0	21		Not estimable
Calandriello et al., 2003	0	4	0	17		Not estimable
Cochran et al., 2002	0	57	1	163	0.5%	0.94 [0.04, 22.81]
Dahlin et al., 2013	4	29	5	237	0.7%	6.54 [1.86, 22.98]
De Bruyn & Collaert, 1994	0	71	6	84	4.0%	0.09 [0.01, 1.58]
Dı´az-Sa´nchez et al., 2017	0	1	0	16		Not estimable
Engquist et al., 2002	0	24	2	128	0.6%	1.03 [0.05, 20.85]
Eskandarloo et al., 2019	0	18	0	35		Not estimable
Finne et al., 2012	0	1	1	54	0.1%	9.17 [0.52, 162.14]
Fischer et al., 2008	1	3	0	29	0.1%	22.50 [1.09, 463.74]
Friberg et al., 1999	2	72	11	236	3.5%	0.60 [0.14, 2.63]
Friberg et al., 2005 A	0	10	1	150	0.1%	4.58 [0.20, 105.88]
Galindo-moreno et al.,2012	0	3	3	61	0.3%	2.21 [0.14, 35.88]
Gallucci et al.,2009	0	25	0	126		Not estimable
Glauser et al., 2001	11	38	4	43	2.5%	3.11 [1.08, 8.96]
Glibert et al., 2014	0	20	0	30		Not estimable
Han et al., 2014	5	88	19	1197	1.8%	3.58 [1.37, 9.36]
Herrmann et al., 2005	12	49	7	155	2.3%	5.42 [2.26, 13.01]
Jang et al., 2011	3	112	45	2690	2.4%	1.60 [0.51, 5.07]
Johansson et al., 2009	0	3	1	134	0.1%	11.25 [0.54, 235.71]
Lekholm et al., 1999	6	65	6	70	3.9%	1.08 [0.37, 3.17]
Maló et al., 2013	0	6	3	49	0.6%	1.02 [0.06, 17.74]
Mangano et al., 2013	9	391	2	292	1.6%	3.36 [0.73, 15.44]
Mangano et al., 2014	1	69	0	75	0.3%	3.26 [0.13, 78.65]
Morris et al., 2001	5	95	21	601	3.9%	1.51 [0.58, 3.90]
Muelas-Jime´nez et al., 2015	6	16	3	70	0.8%	8.75 [2.44, 31.32]
Noguerol et al., 2006	7	79	13	449	2.6%	3.06 [1.26, 7.43]
Olmedo-Gaya et al., 2016	4	23	8	83	2.4%	1.80 [0.60, 5.46]
Orenstein et al., 2000	19	238	77	1260	16.6%	1.31 [0.81, 2.12]
Ostman et al., 2012	0	32	0	46		Not estimable
Ostman et al.,2008	1	19	0	21	0.3%	3.30 [0.14, 76.46]
Raghoebar et al., 2003	4	7	4	93	0.4%	13.29 [4.19, 42.11]
Romeo et al., 2006	5	51	3	122	1.2%	3.99 [0.99, 16.06]
Sennerby et al., 2010	1	20	2	142	0.3%	3.55 [0.34, 37.39]
Siddiqui et al., 2008	1	8	0	32	0.1%	11.00 [0.49, 247.77]
Singh et al.,2020	31	150	38	412	13.8%	2.24 [1.45, 3.47]
Tawil & Younan, 2003	2	27	2	79	0.7%	2.93 [0.43, 19.77]
Thome et al., 2020	0	25	1	98	0.4%	1.27 [0.05, 30.26]
Truhlar et al., 2000	22	231	93	1294	19.1%	1.33 [0.85, 2.06]
Vasak et al.,2014	1	6	0	84	0.1%	36.43 [1.63, 813.86]
Wang et al., 2020	4	149	20	531	5.9%	0.71 [0.25, 2.05]
Total (95% CI)		**2661**		**12434**	**100.0%**	**1.89 [1.59, 2.24]**
Total events	195		431			

Heterogeneity: Chi² = 61.38, df = 39 (P = 0.01); I² = 36%
Test for overall effect: Z = 7.16 (P < 0.00001)

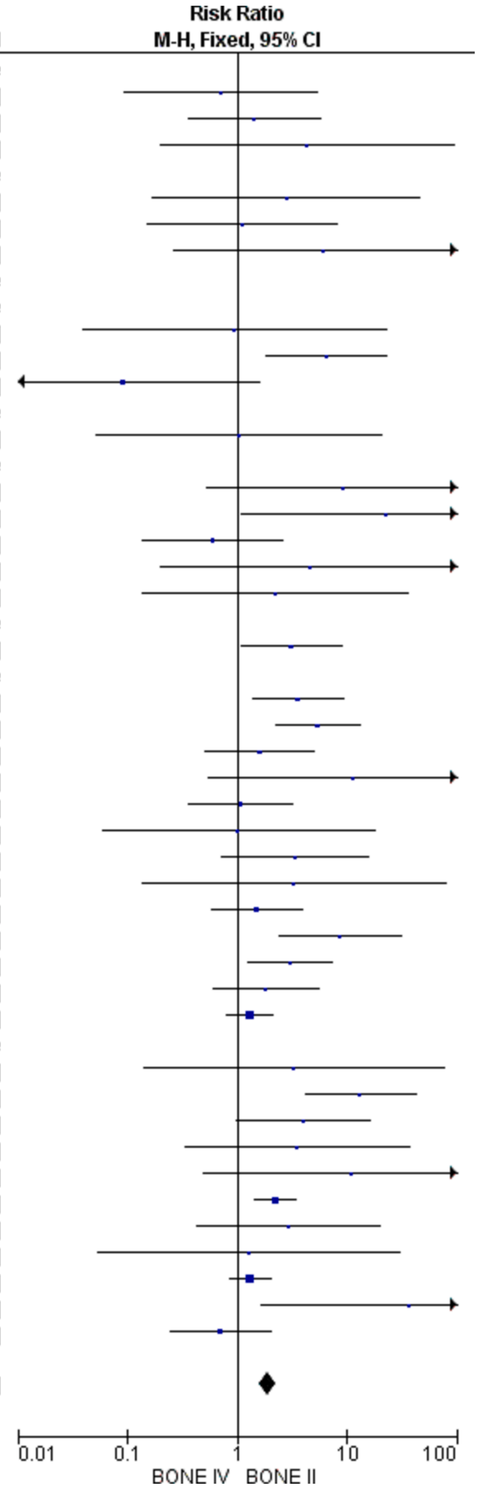

Fig. 3. Meta-analysis comparing the failure rate of implants placed in type II x IV bone. By meta-analysis, implants installed in bone type II had a significantly higher survival rate than implants installed in bone type IV.

Study or Subgroup	BONE IV Events	BONE IV Total	BONE III Events	BONE III Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Agliardi et al., 2009	0	4	0	32		Not estimable
Andersson et al., 2019	1	50	8	263	1.3%	0.66 [0.08, 5.14]
Balshi et al., 1999	24	217	16	131	10.5%	0.91 [0.50, 1.64]
Barewal et al., 2012	1	8	0	19	0.2%	6.67 [0.30, 148.34]
Becker et al., 1995	0	6	0	9		Not estimable
Becker et al., 1999	0	5	11	49	1.3%	0.36 [0.02, 5.40]
Becktor et al., 2007	1	17	8	122	1.0%	0.90 [0.12, 6.74]
Bergendal & Engquist, 1998	1	18	2	55	0.5%	1.53 [0.15, 15.87]
Calandriello and Tomatis, 2011	0	1	1	15	0.2%	2.67 [0.16, 45.78]
Calandriello et al., 2003	0	4	0	24		Not estimable
Cochran et al., 2002	0	57	2	133	0.8%	0.46 [0.02, 9.47]
Dahlin et al., 2013	4	29	4	312	0.4%	10.76 [2.84, 40.79]
De Bruyn & Collaert, 1994	0	71	3	51	2.1%	0.10 [0.01, 1.95]
Dı´az-Sa´nchez et al., 2017	0	1	0	8		Not estimable
Engquist et al., 2002	0	24	11	152	1.7%	0.27 [0.02, 4.37]
Eskandarloo et al., 2019	0	18	0	44		Not estimable
Finne et al., 2012	0	1	0	22		Not estimable
Fischer et al., 2008	1	3	0	20	0.1%	15.75 [0.77, 321.68]
Friberg et al., 1999	2	72	1	105	0.4%	2.92 [0.27, 31.57]
Friberg et al., 2005 A	0	10	1	230	0.1%	7.00 [0.30, 162.20]
Galindo-moreno et al.,2012	0	3	1	32	0.2%	2.75 [0.13, 56.79]
Gallucci et al.,2009	0	25	0	38		Not estimable
Glauser et al., 2001	11	38	6	38	3.1%	1.83 [0.75, 4.45]
Glibert et al., 2014	0	20	0	61		Not estimable
Han et al., 2014	5	88	5	388	1.0%	4.41 [1.30, 14.90]
Herrmann et al., 2005	12	49	15	265	2.5%	4.33 [2.16, 8.67]
Jang et al., 2011	3	112	59	3312	2.0%	1.50 [0.48, 4.72]
Johansson et al., 2009	0	3	9	49	0.7%	0.66 [0.05, 9.36]
Lekholm et al., 1999	6	65	22	320	3.9%	1.34 [0.57, 3.18]
Maló et al., 2013	0	6	2	57	0.3%	1.66 [0.09, 31.14]
Mangano et al., 2013	9	391	7	727	2.6%	2.39 [0.90, 6.37]
Mangano et al., 2014	1	69	3	154	1.0%	0.74 [0.08, 7.03]
Morris et al., 2001	5	95	22	543	3.4%	1.30 [0.50, 3.35]
Muelas-Jime´nez et al., 2015	6	16	9	61	2.0%	2.54 [1.06, 6.09]
Noguerol et al., 2006	7	79	31	493	4.5%	1.41 [0.64, 3.09]
Olmedo-Gaya et al., 2016	4	23	3	133	0.5%	7.71 [1.85, 32.22]
Orenstein et al., 2000	19	238	83	1026	16.4%	0.99 [0.61, 1.59]
Ostman et al., 2012	0	32	1	58	0.6%	0.60 [0.02, 14.22]
Ostman et al.,2008	1	19	0	52	0.1%	7.95 [0.34, 187.20]
Raghoebar et al., 2003	4	7	3	57	0.3%	10.86 [3.03, 38.84]
Romeo et al., 2006	5	51	6	115	1.9%	1.88 [0.60, 5.88]
Sennerby et al., 2010	1	20	0	44	0.2%	6.43 [0.27, 151.29]
Siddiqui et al., 2008	1	8	0	19	0.2%	6.67 [0.30, 148.34]
Singh et al.,2020	31	150	24	210	10.5%	1.81 [1.11, 2.95]
Tawil & Younan, 2003	2	27	8	160	1.2%	1.48 [0.33, 6.61]
Thome et al., 2020	0	25	0	116		Not estimable
Truhlar et al., 2000	22	231	93	1007	18.2%	1.03 [0.66, 1.60]
Vasak et al.,2014	1	6	1	66	0.1%	11.00 [0.78, 154.58]
Wang et al., 2020	4	149	14	843	2.2%	1.62 [0.54, 4.84]
Total (95% CI)		**2661**		**12240**	**100.0%**	**1.50 [1.27, 1.76]**
Total events	195		495			

Heterogeneity: $Chi^2 = 64.44$, $df = 39$ ($P = 0.006$); $I^2 = 39\%$
Test for overall effect: $Z = 4.84$ ($P < 0.00001$)

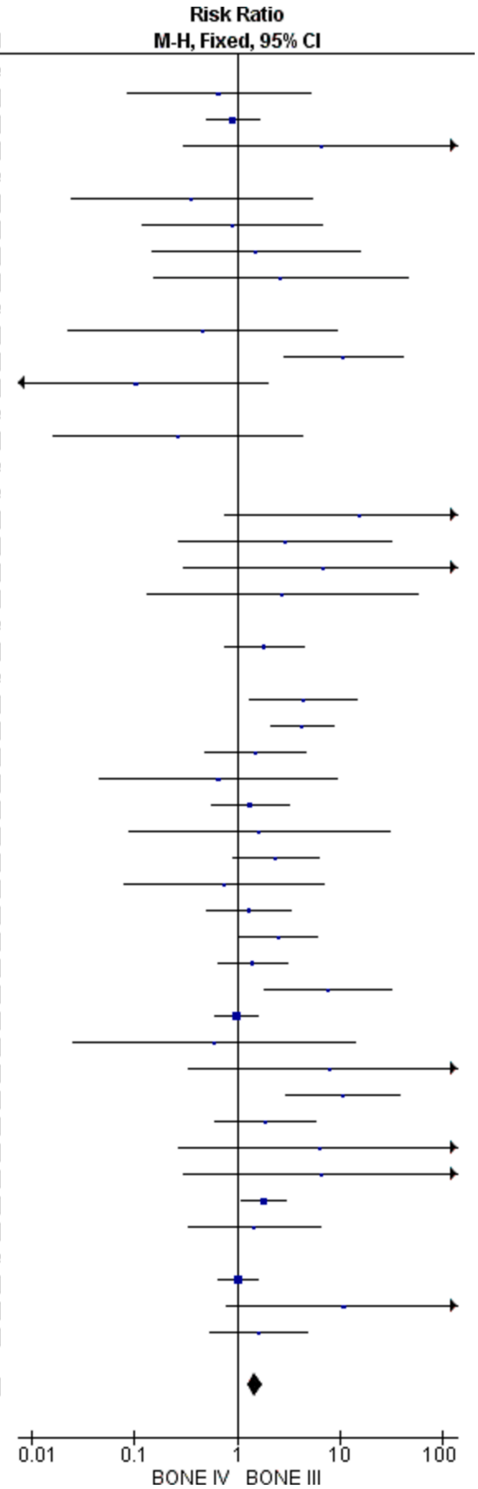

Fig. 4. Meta-analysis comparing the failure rate of implants installed in type III x IV bone. By meta-analysis, implants installed in bone type III had a significantly higher survival rate than implants installed in bone type IV.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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