Tilted Implants for the Rehabilitation of Edentulous Jaws: A Systematic Review

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ABSTRACT

Purpose: The aim of this review was to evaluate the survival rate of upright and tilted implants supporting fixed prosthetic reconstructions for the immediate rehabilitation of partially and fully edentulous jaws, after at least 1 year of function.

Materials and Methods: An electronic search of databases plus a hand search on the most relevant journals up to December 2009 was performed. The articles were selected using specific inclusion criteria, independent of the study design.

Results: The literature search yielded 347 articles. A first screening based on the title and abstract identified 25 eligible studies. After full-text review of these studies, 10 articles were selected for analysis. Seven were prospective single-cohort studies and three had a retrospective design. A total of 462 patients have been rehabilitated with 470 immediately loaded prostheses (257 in the maxilla, 213 in the mandible), supported by a total of 1,992 implants (1,026 upright and 966 tilted). Twenty-five implants (1.25%) failed in 20 patients within the first year. All failures except one occurred in the maxilla. No significant difference in failure rate was found between tilted and upright implants, nor between maxillary and mandibular implants. No prosthesis failure was reported. Limited peri-implant bone loss was reported with no difference between upright and tilted implants. Full patients' satisfaction for function, phonetics, and esthetics was reported in three studies, based on questionnaires.

Conclusions: The use of tilted implants to support immediately loaded fixed prostheses for the rehabilitation of edentulous jaws can be considered a predictable technique, with an excellent prognosis in the short-medium term. However, randomized long-term trials are needed to determine the efficacy of this surgical approach.

KEY WORDS: dental implants, immediate loading, mandible, maxilla, tilted implants

INTRODUCTION

Implant-supported fixed prostheses represent today a common treatment for the rehabilitation of edentulous jaws. The long-established Brånemark protocol recommended the implants to be placed in an upright position, often resulting in a distal cantilever length of even 20 mm.[1–3] This may lead to high bending moments and high stress levels at both the implants and the surrounding bone,[4] which in turn may sustain marginal bone resorption, thus compromising implant survival.[5] A matter to face with when inserting dental implants in an atrophic edentulous mandible is the presence of the mandibular nerve. In this instance, bone grafting and other regenerative procedures could represent a solution in order to increase bone volume prior to implant placement. However, these types of intervention are poorly accepted by patients. With regard to the maxilla, success rates can be significantly different with respect to the mandible.[6] The rehabilitation of the edentulous maxilla with osseointegrated implants is often associated with several problems. In many cases, sufficient alveolar crest volume is found in the anterior region, while in the premolar and molar region, severe bone resorption can

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occur as a consequence of tooth loss.[7] The presence of the maxillary sinus and a limited ridge dimension must also be considered when placing implants in this region.[8,9] During the past decades, various alternative clinical procedures have been proposed to place implants in the posterior atrophic maxilla; one of them is the maxillary sinus augmentation procedure. In spite of the excellent outcomes of this procedure,[10–13] it is associated with several possible complications like morbidity at the donor site, sinusitis, fistulae, loss of the graft or the implants, and osteomyelitis. Grafting procedures are generally demanding for both clinicians and patients and are often associated with increased surgical risks and financial cost as well. Another alternative therapeutic option in case of limited available bone is represented by the use of implants of reduced length.[14,15] However, in the posterior maxilla, a minimum ridge height of 6 to 7 mm should be present for a safe placement of implants shorter than 8 mm. On the other hand, in the case of extremely atrophic posterior mandible, where superficialization of the alveolar nerve is often present, the use of short implants may be contraindicated because of the risk of violating the nerve.

The adoption of tilted implants for the rehabilitation of both edentulous mandibles and maxillae has been proposed in the recent years. In the mandible, tilting of the distal implants may prevent damage to the mandibular nerve. In the edentulous maxilla, implant tilting is an alternative to bone grafting procedures. Implants of conventional length can be placed, allowing engagement of as much cortical bone as possible, thus increasing primary stability.[16] Furthermore, increasing the interimplant distance and reducing cantilever length, a better load distribution may be achieved. Several computational studies suggested possible biomechanical advantages of implant tilting in full-arch restorations.[17–19]

Implant tilting associated with immediate loading for the treatment of partial and complete edentulism, especially in the presence of atrophic ridge, is progressively spreading among clinicians. The performance of immediately loaded dental implants supporting partial and full restorations has been evaluated in recent systematic reviews and meta-analyses.[20–22] Such reviews showed that immediate implant loading does not impair treatment success and pointed out the influence of implant micromorphology and patient selection on the treatment outcomes.

The purpose of the present review was to evaluate the prognosis of immediately loaded prostheses supported by both upright and tilted implants, after at least 1 year of function. A further aim was to compare the survival rate of upright and tilted implants for the immediate rehabilitation of partially and fully edentulous arches.

MATERIALS AND METHODS

Search Methods

The following electronic databases were searched: MEDLINE (with a time limit from 1990 to March 2009); Embase (from 1990 to December 2009); Cochrane Central Register of Controlled Trials (December 2009). Keywords such as "dental implant,*" "tilted implant,*" "angled implant,*" "angulated implant,*" "offset implant,*" "upright implant,*" "axial implant,*" "edentulous patient,*" "edentulous mandible," "edentulous maxilla," "immediate loading," and "immediate function" were used alone or in combination. Furthermore, the following journals in the field of implant dentistry were hand-searched for further articles not detected by the electronic search (from January 2000 to December 2009): *Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, Implant Dentistry, European Journal of Oral Implantology, International Journal of Oral and Maxillofacial Surgery, International Journal of Prosthodontics, Journal of Implantology, Journal of Oral and Maxillofacial Surgery, Journal of Periodontology, Journal of Prosthetic Dentistry, The International Journal of Oral & Maxillofacial Implants, The International Journal of Periodontics & Restorative Dentistry.* Finally, the authors of the included studies were contacted to know whether further unpublished or ongoing studies were available to be included in the present review.

Inclusion Criteria

The search was limited to studies involving human subjects. Restrictions were not placed regarding the study design and the language usage. Further inclusion criteria were a minimum of 10 patients treated, loading applied within 48 hours of implant surgery, a minimum follow-up duration of 1 year, fewer than 10% patients lost during follow-up, survival rate for tilted and upright implants clearly indicated or calculable from data provided.

Publications that did not meet the above inclusion criteria and those that were not dealing with original clinical cases (eg, reviews, technical reports) were excluded. Multiple publications of the same pool of patients were also excluded from the database. When papers from the same group of authors, with very similar databases of patients, materials, methods, and outcomes were identified, the authors were contacted for clarifying if the pool of patients was indeed the same. In case of multiple publications relative to consecutive phases of the same study, only the most recent data (those with the longer follow-up) were considered.

Outcomes

The following outcomes were extracted from each study, where available: type of study design; number of patients; gender; age; proportion of smokers; total number of implants; number, type, and location of the prostheses; follow-up duration; number of tilted and upright implants; number of failed implants and details (time after loading, location, reason for failure); prosthesis success rate; bone loss around tilted and upright implants; soft tissue outcomes; occurrence of complications. The effect of implant location (maxilla or mandible) and angulation (tilted or upright) on the outcomes was evaluated.

Statistical Analysis

The estimates of the effects of an intervention were expressed as risk ratio (RR) together with 95% confidence intervals (CI). The statistical evaluation was conducted considering both the implant and the patient as the analysis unit. Comparisons among studies were performed by meta-analysis. When sufficient homogeneity was detected, RRs were combined using a random-effects model. Pearson's chi-square analysis was used to investigate the effect of implant location and angulation on the treatment outcome; $p = .05$ was considered as the significance level.

RESULTS

The electronic search yielded a total of 347 articles. After a first screening of the titles and abstracts, 24 articles were selected, which reported results of clinical studies in which edentulous patients have been rehabilitated using prostheses supported by upright and tilted implants. The results of two further unpublished studies were provided by the authors of an included study. After examining the full text of the 26 articles, 16 of them were excluded from the review (Table 1).[3,16,23–36] Of the 10 remaining articles, 7 reported the results of prospective studies and 3 of retrospective studies (Table 2).[37–46] The main outcomes of these studies are reported in Table 3. A total number of 1,992 implants, of which 11 (0.55%) with machined surface, were inserted in 462 patients rehabilitated with 12 partial and 458 full fixed prostheses (257 in the maxilla, 213 in the mandible). Of the placed implants, 1,026 were upright and 966 tilted.

TABLE 1 Excluded Studies and Reasons for Exclusion

Excluded Studies	Reason for Exclusion
Mattsson, 1999[23]	Delayed loading
Krekmanov, 2000[3]	Delayed loading
Krekmanov, 2000[24]	Delayed loading
Aparicio et al., 2001[16]	Delayed loading
Aparicio et al., 2002[25]	Delayed loading
Fortin et al., 2002[26]	Delayed loading
Malò et al., 2003[27]	Inadequate report
Koutouzis and Wenstrom, 2007[28]	Inadequate report, delayed loading
Malò et al., 2007[29]	Inadequate report, redundant publication
Rosén and Gynther, 2007[30]	Delayed loading
Bedrossian et al., 2008[31]	Case report (2 patients)
Bilhan, 2008[32]	Case report (1 patient)
Khatami et al., 2008[33]	Case report (1 patient)
Testori et al., 2008[34]	Redundant publication
Agliardi et al., 2009[35]	Redundant publication
Pomares, 2009[36]	Inadequate report; delayed loading of some implants

TABLE 2 Characteristics of the Included Studies

Articles	Study Type	No. of Patients	Men (%)	Women (%)	Age	Smokers (%)	No. of Implants	No. Maxillary Prostheses (Implants)	No. Mandiblular Prostheses (Implants)	Type of Restoration	Follow-Up Duration, Months (Range)
Calandriello and Tomatis, 2005[37]	Prospective	18	38.89	61.11	64 (51–76)	Heavy smokers excluded	60	19 (60)	–	12 partial and 7 full	12
Malò et al., 2005[38]	Retrospective	32	53.13	46.88	55.1 (NR)	NR	128	32 (128)	–	Full	12
Malò et al., 2006[39]	Retrospective	46	36.96	63.04	52.2 (32–78)	34.78	189	44 (166)	9 (23)	Full	12
Capelli et al., 2007[40]	Prospective	65	33.85	66.15	59.2 (28–83)	15.38	342	41 (246)	24 (96)	Full	55 (33–82)
Malò et al., 2007[41]	Retrospective	23	NR	NR	NR	NR	92	18 (72)	5 (20)	Full	13 (6–21)
Agliardi et al., 2008[42]	Prospective	21	57.14	42.86	58 (44–68)	38.10	126	21 (126)	–	Full	20 (4–35)
Francetti et al., 2008[43]	Prospective	62	45.16	54.84	56 (35–77)	40.32	248	–	62 (248)	Full	22.4 (6–43)
Tealdo et al., 2008[44]	Prospective	21	52.38	47.62	58	NR	111	21 (111)	–	Full	20 (13–28)
Agliardi et al., in press[45]	Prospective	154	46.10	53.90	58 (35–80)	27.8	616	61 (244)	93 (372)	Full	27 (12–55)
Weinstein et al., in press[46]	Prospective	20	40	60	60 (47–77)	20	80	–	20 (80)	Full	30.1 (20–48)

NR = not reported.

A total number of 25 implants (1.25%) failed in 20 patients during the first year of function. The reason for failure was infection ($n = 10$, 40%) or lack of osseointegration ($n = 7$, 28%), while for eight of them (32%) no reason was reported. Two implant failures were reported to occur later than 1 year but before 18 months of function. Of the implants failed within 12 months, 11 were upright and 14 tilted, and all but one were placed in the maxilla. Two of them had machined surface.[37] One-year implant survival was 97.9% and 99.9% for the maxilla and the mandible, respectively. No prosthesis failure was reported in any of the evaluated studies. Given such an outcome, no further analysis was performed at prosthesis level.

The results of the random effects meta-analyses for implant failures at 1 year are presented as forest plot in Figures 1–4. Considering the outcome of tilted versus upright implants in both jaws, no significant difference (RR = 1.46, 95% CI: 0.63, 3.39) and no heterogeneity was found (Figure 1). No significant difference (RR = 2.49, 95% CI: 0.64, 9.64) and no heterogeneity was found when considering maxillary versus mandibular implants in the four studies that included both jaws (Figure 2). For this comparison, on a patient basis, no significant difference nor heterogeneity was found (RR = 3.00, 95% CI: 0.79, 11.35) (Figure 3). As most of the failed implants were located in the maxilla, a further meta-analysis was conducted, excluding mandibular implants. Again, no significant difference (RR = 1.58, 95% CI: 0.66, 3.78) and no heterogeneity was found when considering maxillary tilted versus upright implants (Figure 4).

Marginal bone level was reported separately for both tilted and upright implants in seven trials (see Table 3).[37,40,42–46] Bone loss values were rather homogenous for both upright and tilted implants as well as for maxillary and mandibular implants, with the exception of Calandriello and Tomatis,[37] where lower bone loss values for tilted implants were found, as compared with upright ones.

Fracture of the temporary acrylic prosthesis and screw loosening were the most common complications described (see Table 3). No significant relation with the arch was found for these complications. Some authors observed wear patterns in the opposing dentition.[41] Most of patients that experienced prosthesis fracture or prosthetic screw loosening were reported as being bruxers[38,40] or having a short face morphotype.[43,45]

TABLE 3 Main Outcomes of the Included Studies after 1 Year of Function

Articles	Inserted Implants		Failures		PSR (%)	Location of Failed Implants	Bone Loss, mm (n of Implants)		Complications
	Upright	Tilted	Upright	Tilted			Upright	Tilted	
Calandriello and Tomatis, 2005[37]	33	27	1	1	100	Maxilla	0.82 ± 0.86 ($n = 32$)	0.34 ± 0.76 ($n = 26$)	Fracture of the acrylic bridge (1 patient) that probably leads to implant failure
Malò et al., 2005[38]	64	64	0	3	NR	Maxilla	No details by implant type		Fracture of prosthesis in 4 bruxing patients, of whom 2 were patients who lost 1 implant each
Malò et al., 2006[39]	93	96	0	2	100	Maxilla	No details by implant type		Prosthetic screw loosening in 6 patients (bruxers)
Capelli et al., 2007[40]	212	130	2	1	100	Maxilla	0.95 ± 0.44 (maxilla; $n = 84$); 0.82 ± 0.64 (mandible; $n = 32$)	0.88 ± 0.59 (maxilla; $n = 42$); 0.75 ± 0.55 (mandible; $n = 32$)	None reported
Malò et al., 2007[41]	46	46	1	1	100	Maxilla	No details by implant type		Fracture of acrylic resin complete denture (8 patients); abutment screw loosening (2 patients); 2 implants in 2 patients presented peri-implant pathology
Agliardi et al., 2008[42]	42	84	0	0	100	–	0.8 ± 0.4 ($n = 28$)	0.9 ± 0.5 ($n = 56$)	None reported
Francetti et al., 2008[43]	124	124	0	0	100	–	0.7 ± 0.4 ($n = 60$)	0.7 ± 0.5 ($n = 60$)	Light ipoesthesia on the left side of the lower lip after surgery, resolved after 6 months (1 patient); fracture of the acrylic prosthesis (7 patients)
Tealdo et al., 2008[44]	64	47	3	5	100	Maxilla	0.62 mesial ($n = 61$); 0.86 distal ($n = 42$)	0.92 mesial ($n = 61$); 1.04 distal ($n = 42$)	None reported
Agliardi et al., in press[45]	308	308	4	1	100	Mandible (1) maxilla (4)	0.9 ± 0.7 (maxilla; $n = 204$); 1.2 ± 0.9 (mandible; $n = 292$)	0.9 ± 0.7 (maxilla; $n = 204$); 1.2 ± 0.9 (mandible; $n = 292$)	Fracture of the acrylic prosthesis (23 patients)
Weinstein et al., in press[46]	40	40	0	0	100	–	0.6 ± 0.3 ($n = 36$)	0.7 ± 0.4 ($n = 36$)	None reported

NR = not reported; PSR = prosthesis success rate.

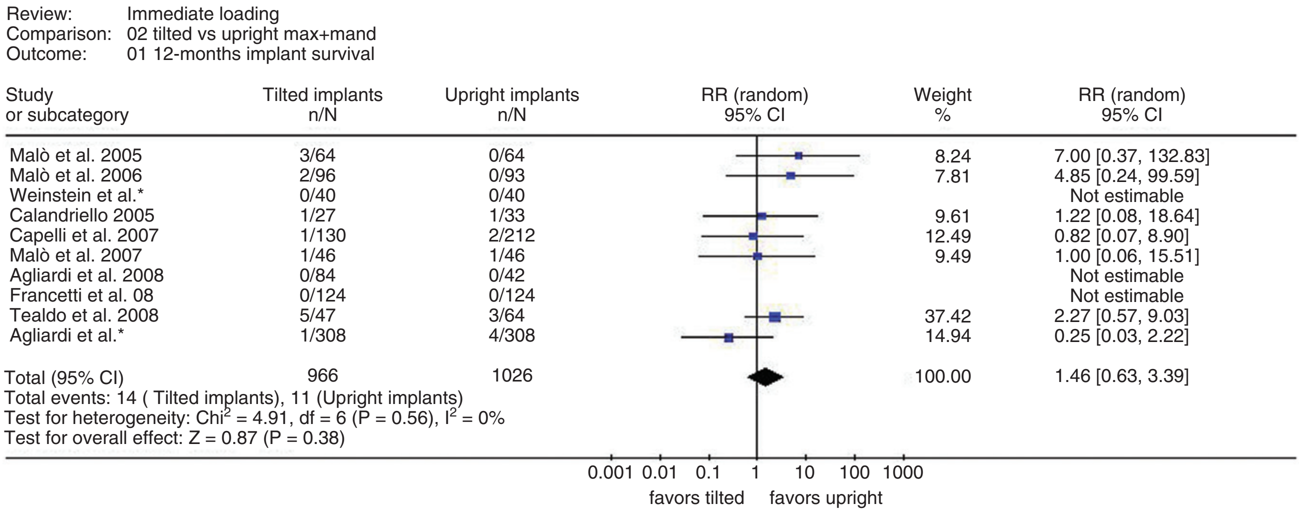

Figure 1 Forest plot for the comparison between tilted and upright implants in both arches. (CI = confidence interval; *df* = degrees of freedom; RR = risk ratio.)

Plaque and bleeding scores progressively improved during the first year.[42,43,45,46] High level of patients' satisfaction for function, phonetics, and esthetics after 1 year of loading was reported by a few studies.[42,43,46]

DISCUSSION

In this review, no statistically significant difference in implant success was observed considering tilted versus upright implants. Because of the absence of randomized controlled clinical studies, definitive conclusions cannot be drawn on the efficacy of immediate rehabilitation supported by a combination of upright and tilted implants. However, based on the available included studies, the present review suggests that the prognosis of such therapeutic approach is excellent as only 1.25% of the implants was lost during the first year of loading, while only two failures were recorded thereafter. Such value is in line with a previous systematic review on immediate loading, in which implants with rough surface displayed a survival rate of 99.1% and 98.68% for fixed mandibular and maxillary full-arch rehabilitations, respectively.[21] It has to be considered that two of the articles included in the present study[37,38] were also selected for the previous systematic review, though their weight on the overall analysis of that study was practically negligible.

From the failure analysis, some trends can be observed. Immediate-loaded maxillary implants appear to be at higher risk of failure than mandibular implants. This finding, however, did not reach statistical significance. Only four studies reporting on both jaws were considered for this comparison, and they accounted for

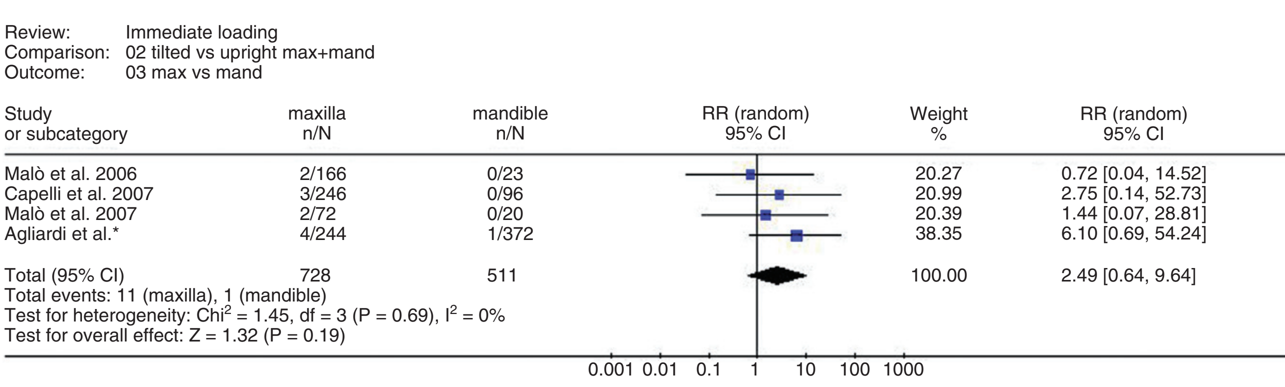

Figure 2 Forest plot for the comparison between maxillary and mandibular implants independent of their angulation. (CI = confidence interval; *df* = degrees of freedom; RR = risk ratio.)

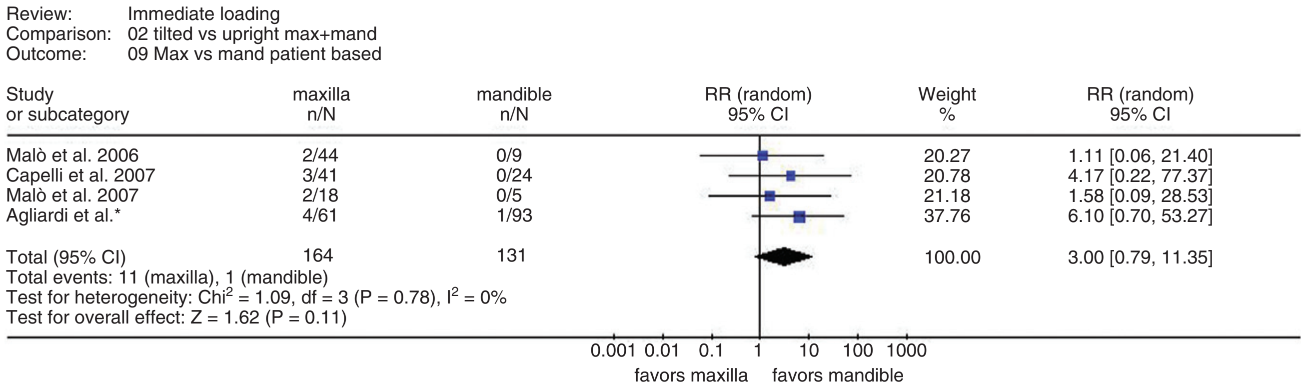

Figure 3 Forest plot for the comparison at patient level between maxillary and mandibular prostheses. (CI = confidence interval; *df* = degrees of freedom; RR = risk ratio.)

less than half of the failures. Immediate-loaded tilted implants placed in the maxilla did not present a higher risk of failure as compared with upright ones. Regarding peri-implant bone loss, no significant difference between upright and tilted implants was reported, except for the study of Calandriello and Tomatis,[37] which also included partial prostheses. In that study, lower bone loss values for tilted implants were recorded, as compared with upright ones. The authors suggested that this could be related to the position of the implant neck relative to bone crest: mesially, the neck was in a supracrestal position, while distally, it was positioned subcrestally, resulting in a favorable soft tissue seal.[37] It should be considered that in the study by Calandriello and Tomatis,[37] partial and full restoration were analyzed together, even though a different performance could be expected given the biomechanical differences between full and partial prosthetic rehabilitations.

In all the included studies, limited peri-implant bone loss was observed over a follow-up period of 1 year. No studies were found reporting long-term evaluation of peri-implant bone loss when using tilted implants.

The improvement in oral hygiene reported in some studies might reflect the easy maintenance of this type of rehabilitation, in which the distance between fixtures is relatively wide. Another factor that might be related for such a good compliance is the high level of satisfaction about this treatment, as reported by patients.[42,43,46]

The use of posterior tilting of the implants presents various biomechanical advantages as compared with the configuration based on fairly upright position for all implants. The distalization of the implant platform reduces the moments of force and improves the load distribution.[18,19,23,38] One limitation to the widespread use of this technique is the relative difficulty in the insertion of the posterior tilted fixtures that must be placed

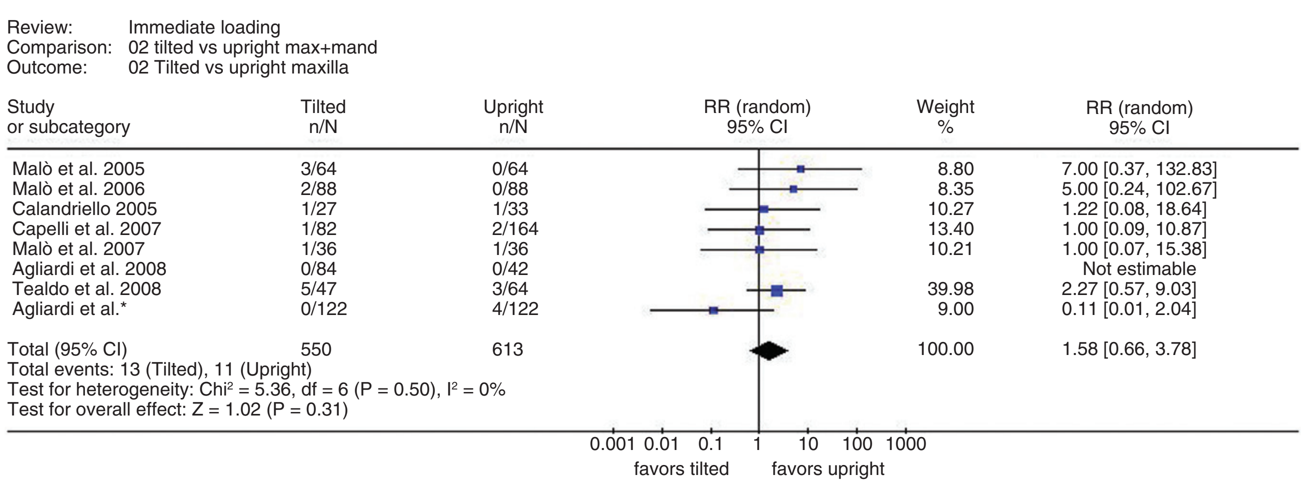

Figure 4 Forest plot for the comparison between tilted and upright implants in the maxilla. (CI = confidence interval; *df* = degrees of freedom; RR = risk ratio.)

with a precise angulation in order to engage as much cortical bone as possible. The latter is important for achieving primary implant stability, which is a prerequisite for immediate implant loading. With computer-guided implant planning and the use of an appropriate surgical template, however, the placement of tilted implants became easier in the recent years.

The most frequent complication reported by the included studies was the fracture of the acrylic prosthesis. One of the reasons addressed for such inconvenience was the progressive shift from a soft diet to a diet including hard food, as well as the wear of the resin due to repeated deglutition and mastication cycles.[42,43,46] Furthermore, some authors pointed out that most fractures of the prosthesis occurred close to the temporary abutments of the anterior implants, which can be considered a relatively weak region.[43,45] In the study by Tealdo and colleagues,[44] the provisional and definitive prostheses were made of cast metal (palladium-alloy) frameworks. Metal reinforced frameworks, as suggested by these authors, are significantly stronger than all-acrylic resin frameworks since they provide increased rigidity and could represent a solution for reducing the incidence of such complication.

The current review presents some limitations that deserve to be discussed. First of all, the follow-up duration for most studies is relatively short (see Table 2). As a matter of fact, immediate loading of prostheses supported by tilted implant is a recent technique, which started to spread among clinicians during the last 10 years. Besides, different implant-supported prosthetic designs that differ in terms of total number of implants as well as the number and angulation of tilted implants were considered all together, thus neglecting any possible different performance. It should also be considered that the minimum angulation required to define an implant as tilted has not yet been established. In the included studies, the inclination of the distal fixtures in the full-arch rehabilitations ranged from about 25° to 30° for the mandible and from 30° to 45° for the maxilla, with respect to the occlusal plane. Only in the study by Calandriello and Tomatis a higher inclination was reported (45° to 75° relative to the occlusal plane).[37] In some studies, the angulation was standardized, while in most cases of extreme atrophy, it was individually chosen according to the available bone.[37,42,46] Most of the studies were performed in private practice settings by experienced surgeons. This suggests that the external validity of the results of this review is rather high, provided that the surgical operators are adequately skilled. The most consistent limitation, however, is represented by the low level of evidence for publications on this technique to date. This review, in fact, was based only on retrospective and single-cohort prospective studies, which provided indications on the prognosis of the technique in the short-medium term. However, in order to determine the efficacy of tilted implants as an alternative to grafting techniques or to the use of short implants for the rehabilitation of edentulous atrophic jaws, randomized clinical trials with large sample size and long-term follow-up are urgently needed.

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