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Oral rehabilitation with tilted dental implants: A metaanalysis

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Abstract

Objective: To compare the course of patients treated with tilted implants versus those treated conventionally with axial implants, analyzing the success rate and marginal bone loss.
Material and Methods: A PubMed search was made using the key words “tilted implants”, “angled implants”, “angulated implants”, “inclined implants” and “maxillary atrophy.” A review was made of the articles published between 1999-2010. The inclusion criteria were the use of tilted implants, clinical series involving at least 10 patients, and a minimum follow-up of 12 months after prosthetic loading. The exclusion criteria were isolated clinical cases, studies with missing data, and publications in languages other than English or Spanish. The metaanalysis finally included 13 articles: 7 retrospective studies and 6 prospective studies.
Results: On analyzing the success rate in the retrospective studies, two reported a higher success rate with tilted implants; one a higher success rate with axial implants; and two reported similar success rates with both implants. On analyzing the success rate in the prospective studies, two reported a higher success rate with tilted implants; two a higher success rate with axial implants; and two reported similar success rates with both implants. On examining marginal bone loss, three studies reported greater bone loss with axial implants and one with tilted implants.
Conclusions: There was no evidence of differences in success rate between tilted and axial implants in either the prospective or retrospective studies subjected to review. The marginal bone loss observed with the tilted and axial implants likewise proved very similar. It thus can be deduced that tilted implants exhibit the same evolutive behavior as axial implants.

Key words: *Axial implants, tilted implants, maxillary atrophy, tilted implants.*

Introduction

The term tilted implants refers to implants placed at an angle of normally 30 degrees or more with respect to axially or vertically positioned implants (1). According to many authors, the use of tilted implants in the posterior maxillary sector offers advantages over axial implants (2-7).

The placement of tilted implants offers both surgical and prosthodontic benefits. In effect, the combination of tilted and axial implants allows the use of longer implants, thereby increasing the osseointegration surface; improves primary stability by anchoring in more than one cortical layer; avoids cantilever extremities by placing the implants more distal and with better load distribution over the dental arch; and avoids the use of bone grafts and sinus lift procedures - with the resulting reduction in morbidity (1,8).

The present metaanalysis compares the course of patients treated with tilted implants versus those treated conventionally with axial implants, analyzing the success rate and marginal bone loss.

Material and Methods

A PubMed search was made using the key words “tilted implants”, “angled implants”, “angulated implants”, “inclined implants” and “maxillary atrophy.” A review was made of the articles published between 1999-2010. A manual search was also made, using those references to review articles considered to be important.

In selecting the publications we reviewed the titles and abstracts to identify the relevant studies, which were then retrieved in full format and assessed for the following inclusion criteria: the use of tilted implants, clinical series involving at least 10 patients, and a minimum follow-up of 12 months after prosthetic loading. The exclusion criteria in turn were: isolated clinical cases, studies with missing data, and publications in languages other than English or Spanish.

The initial search yielded 118 publications, and the first analysis based on the titles and abstracts reduced this number to 22 articles. In-depth evaluation of the full text of these papers in turn yielded 13 publications (7 retrospective studies and 6 prospective studies), which were finally included in the metaanalysis.

The differences between tilted and axial implants in terms of success rate and marginal bone loss were statistically analyzed via three metaanalyses summarized in (Table 1). In relation to success rate, two study subgroups were established according to the design involved (prospective or retrospective), and an independent metaanalysis was carried out in each of them. Metaanalysis I examined the success rate in four retrospective studies (2,3,5,9), with the exclusion of three studies (13-15) that failed to compile data on axial implants. Metaanalysis II in turn analyzed the success rate in 6 prospective studies (4,7,8, 10-12), while metaanalysis III analyzed marginal bone loss in 5 studies, though yielding QH = 11.705 for the heterogeneity test, with p = 0.019 (i.e., these were very heterogeneous studies from the statistical perspective). The source of such heterogeneity was identified as the publication by Calandriello et al. (4), which involved the smallest sample size, and reported exceptionally low marginal bone loss in tilted implants. This article was therefore excluded, leaving a final total of four studies (7, 10-12).

Table 1. Summary of the three metaanalyses (I, II and III).

	Analysis of success rate	Analysis of marginal bone loss
Retrospective	METAANALYSIS I N=4 (2, 3, 5, 9)	
Prospective	METAANALYSIS II N=6 (4, 7, 8, 10-12)	METAANALYSIS III N=4 (7, 10-12)

In the study of implant success rate (metaanalyses I and II) the odds ratio (OR) was used as measure of effect, since it is the most stable statistic in situations of sample size variations. The corresponding 95% confidence interval (95%CI) was reported in all cases, along with the standard error of the Naperian logarithm of the OR. In the study of marginal bone loss (metaanalysis III) we used the difference of means as the measure of effect, together with the corresponding 95%CI and the standard error of the difference of means. In both cases the random effect model was used. As calculation method we employed inverse variance of DerSimonian and Laird. The heterogeneity test was based on the QH statistic, with chi-squared distribution and k-1 degrees of freedom (k = number of studies). The global effect magnitude test was based on the distribution of the QA logit association statistic. The level of significance considered in the association and heterogeneity contrasts of the metaanalyses was 5%.

Results

Success rate

The results of metaanalysis I are presented in (Table 2). Based on the corresponding ORs, the included studies show some contradiction. In effect, the studies of Krekmanov et al. (2) and Aparicio et al. (3) point to a greater success rate with tilted implants, while in contrast the study of Maló et al. (5) reports superior results with axial implants. In the sample of Balleri et al. (9), the descriptive results were identical in both groups, and OR = 1. The heterogeneity test showed homogeneity among the studies. The total OR was 1.162, with 95%CI. The QA association statistic was 0.079, with a p-value of 0.778, allowing us to assume the existence of homogeneity in the success rate between tilted and axial implants. The Forest plot (Fig. 1) compares the different studies (measures of OR and 95%CI).

Table 2. Metaanalysis I: Success rates in retrospective studies.

Year	Study	Exposed cases	Exposed controls	Exposed total	Non-exposed cases	Non-exposed controls	Non-exposed total	TOTAL	Lower CI	Upper CI	OR	SE (LnOR)
2000	Krekmanov et al. (2)	38	2	40	91	7	98	138	0.2903	7.3589	1.4615	0.8247
2001	Aparicio et al. (3)	40	2	42	54	5	59	101	0.3417	10.0363	1.8519	0.8623
2005	Malo et al. (5)	61	3	64	64	0	64	128	0.0069	2.6917	0.1362	1.5223
2010	Balleri et al. (9)	20	0	20	20	0	20	40	0.0189	52.8490	1.0000	2.0242
TOTAL									**0.4073**	**3.3196**	**1.1628**	**0.5352**

Heterogeneity test: Qh= 2.3579, p=0.5015
Association test: QA = 0.0794, p=0.7781
CI = confidence interval; OR = odds ratio; SE(LnOR) = standard error of the Naperian logarithm of the odds ratio

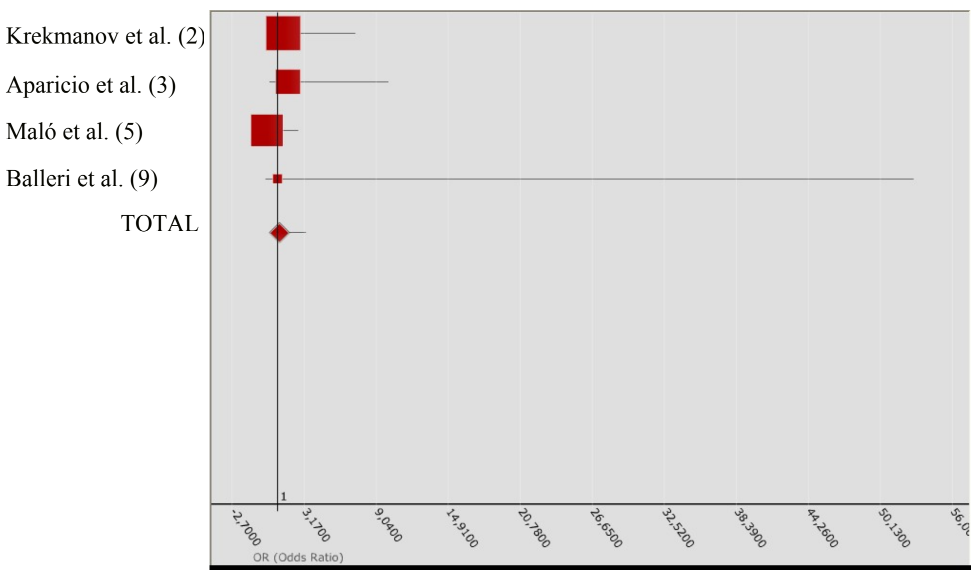

Fig. 1. The Forest plot compares the different studies included in the metaanalysis I (measures of OR and 95%CI).

In metaanalysis II (Table 3), the individualized ORs again indicated slightly conflicting tendencies. The studies of Agliardi et al. (8,10) indicated a greater success rate with tilted implants. In contrast, Calandriello et al. (4) and Testori et al. (7) reported superior results with axial implants. In the samples analyzed by Hinze et al. (11) and Francetti et al. (12), the descriptive results were identical, with no failures in balanced groups of tilted and axial implants (hence OR = 1). The recorded QH = 1.089 for the heterogeneity test, with p = 0.9550, indicates that the studies were quite homogeneous from the statistical perspective. The total OR was 1.137, with 95%CI. The QA association statistic was 0.071, with a p-value of 0.789, allowing us to assume the existence of homogeneity in the success rate between tilted and axial implants. The Forest plot (Fig. 2) compares the different studies (measures of OR and 95%CI).

Marginal bone loss

Metaanalysis III relating to marginal bone loss in prospective studies yielded QH = 7.601 for the heterogeneity test, with p = 0.055. The results are shown in (Table 4), while (Fig. 3) presents the Forest plot comparing the studies included in this metaanalysis. The studies can be taken to be homogeneous, though the work of Francetti et al. (12) proved relatively heterogeneous with respect to the rest. The differences in weighted means obtained for each individual study proved negative for the first three publications (indicating increased losses with axial implants) and positive only for the study by Francetti et al. (12). The global difference in weighted means was -0.029, with a 95%CI that clearly contained the value zero, i.e., no effect was recorded. In turn, QA = 2.457 with p = 0.117, which leads us to the same con-

Table 3. Metaanalysis II: Success rates in prospective studies.

Year	Study	Exposed cases	Exposed controls	Exposed total	Non-exposed cases	Non-exposed controls	Non-exposed total	TOTAL	Lower CI	Upper CI	OR	SE(LnOR)
2005	Calandriello et al. (4)	26	1	27	32	1	33	60	0.0484	13.6271	0.8125	1.4386
2008	Testori et al. (7)	78	2	80	157	3	160	240	0.1220	4.5522	0.7452	0.9233
2009	Agliardi et al. (8)	121	1	122	119	3	122	244	0.3129	29.7417	3.0504	1.1619
2009	Agliardi et al. (10)	80	0	80	40	0	40	120	0.0387	102.0049	1.9877	2.0093
2010	Hinze et al. (11)	35	3	38	35	3	38	76	0.1887	5.2988	1.0000	0.8508
2010	Francetti et al. (12)	32	0	32	32	0	32	64	0.0193	51.9333	1.0000	2.0153
TOTAL									**0.4408**	**2.9365**	**1.1377**	**0.4838**

Heterogeneity test: Qh= 1.0895, p=0.9550
Association test: QA = 0.0711, p=0.7898
CI = confidence interval; OR = odds ratio; SE(LnOR) = standard error of the Naperian logarithm of the odds ratio

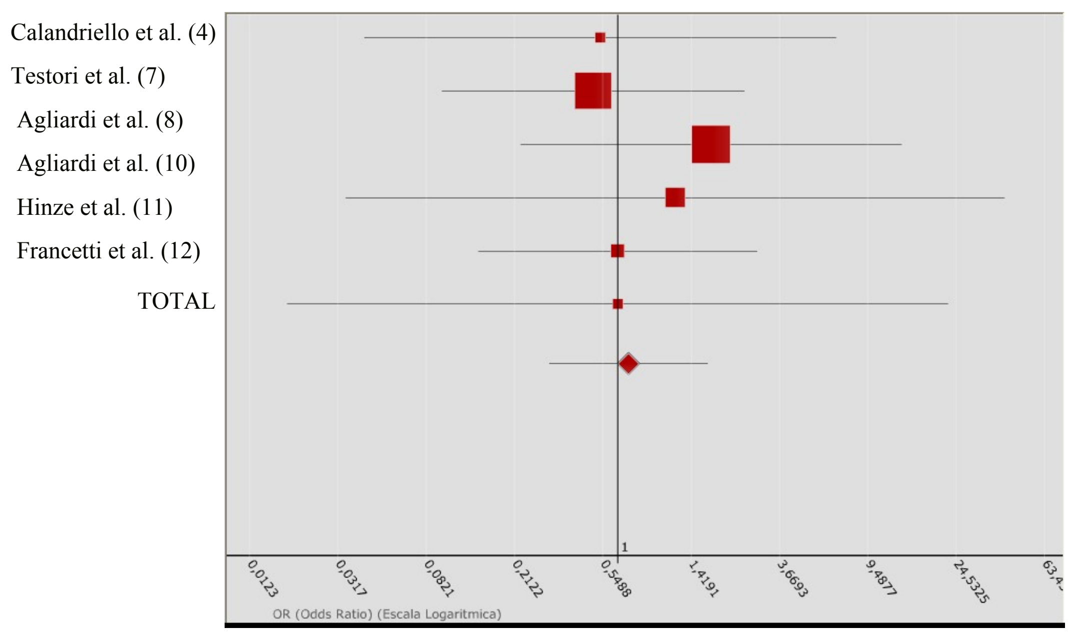

Fig. 2. The Forest plot compares the different studies included in the metaanalysis II (measures of OR and 95%CI).

Table 4. Metaanalysis III: Marginal bone loss in prospective studies.

Year	Study	Treated Number	Treated Mean	Treated SD	Non-treated Number	Non-treated Mean	Non-treated SD	Lower CI	Upper CI	DWM	SE(DWM)
2008	Testori et al. (7)	80	0.8	0.5	160	0.9	0.4	-0.3172	0.1172	-0.1000	0.0597
2009	Agliardi et al. (10)	80	0.8	0.4	40	0.9	0.5	-0.3467	0.1467	-0.1000	0.0844
2010	Hinze et al. (11)	38	0.76	0.31	38	0.82	0.31	-0.2901	0.1701	-0.0600	0.0711
2010	Francetti et al. (12)	32	0.63	0.38	32	0.44	0.37	-0.0694	0.4494	0.1900	0.0938
TOTAL								**-0.1474**	**0.0893**	**-0.0290**	**0.0369**

Heterogeneity test: Qh= 7.6011, p=0.0550
Association test: QA = 0.231, p=0.6308
SD = standard deviation; CI = confidence interval; DWM = difference in weighted mean; SE( ) = standard error ( )

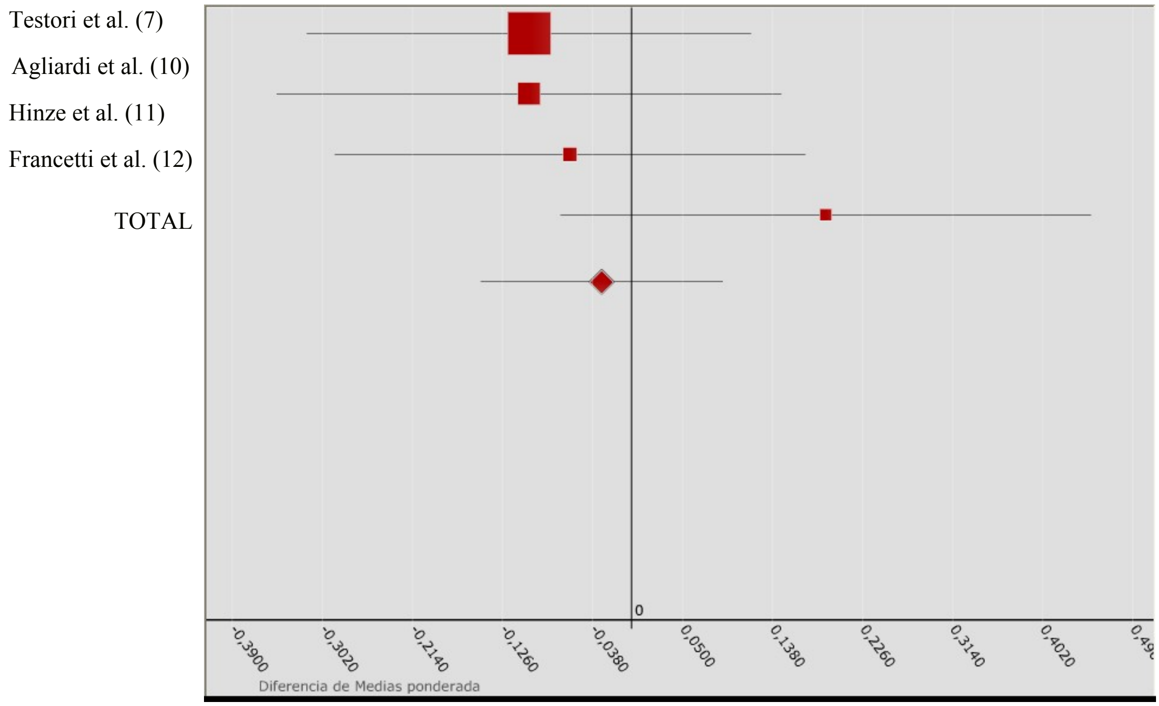

Fig. 3. Presents the Forest plot comparing the studies included in this metaanalysis III.

clusion: tilted implants show the same behavior as axial implants in terms of marginal bone loss.

Discussion

In the present study it has been assumed that the analytical units in the different studies are the implants, not the randomization units (i.e., the patients). The results therefore would also indicate widening of the confidence intervals, and thus reinforcement of the conclusion regarding the homogeneity between tilted and axial implants.

Prosthetic rehabilitation of the edentulous maxilla includes the placement of tilted implants as a relatively recent option. The advantages of tilted implants are: (a) the use of longer implants, thereby increasing the contact (osseointegration) surface; (b) improved primary stability by anchoring in more than one cortical layer; (c) the avoidance of cantilever extremities by placing the implants more distal and with better load distribution over the dental arch; and (d) avoidance of the use of bone grafts and sinus lift procedures - with the resulting reduction in morbidity (1,8).

It has been considered that loaded tilted implants can fail due to the presence of unfavorable forces applied to the bone surrounding the implants. However, this theory was rejected by Celleti et al. (16) whom used these implants splinted so as to adequately distribute prosthetic loading.

In the year 2009 Agliardi et al. (10) published the largest series to date, with 61 rehabilitated maxillas in which four implants were placed: two more anterior in an axial position and two more posterior in a tilted position parallel to the anterior wall of the maxillary sinus. The success rate was 100% for both the axial and the angled implants, after a mean follow-up of 27.2 months. Peñarrocha et al. (15) in turn rehabilitated 10 patients with overdentures on four tilted implants. Only one implant failed, after 12 months of follow-up, the corresponding success rate being 97.7%.

Maló et al. (5) published a study of 32 patients with the placement of 128 dental implants (64 angled and 64 axial), the reported success rate being 95.3% and 100%, respectively. The marginal bone loss was 0.9 mm on average, with no differences between the tilted implants and the axial implants. Rosen and Gynther (14), in a study involving follow-up for as long as 12 years, with the placement of 103 tilted implants, recorded a success rate of 97%. Their mean marginal bone loss was 1.2 mm. These authors concluded that angled implants placed in the extremities of atrophic maxillas constitute a viable and evidence-based treatment option, and may be viewed as an alternative to bone grafting.

Based on the findings of our metaanalysis, there is no evidence of differences in success rate between tilted and axial implants in either the prospective or retrospective studies subjected to review. The marginal bone loss observed with the tilted and axial implants likewise proved very similar. It thus can be deduced that tilted implants exhibit the same evolutive behavior as axial implants.

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