Review

Clinical success between tilted and axial implants in edentulous maxilla: A systematic review and meta-analysis

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Abstract

Aim: This systematic review and meta-analysis evaluated the clinical survival of axial and tilted implants in atrophic edentulous maxilla after three years of immediate loading and also the corresponding marginal bone loss.

Setting and Design: This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines (PRISMA).

Materials and Methods: The relevant studies were retrieved from MEDLINE(PubMed), the Cochrane Central Register of Controlled Trials (CENTRAL), Science Direct, Google Scholar databases. The search was limited to studies published in the English language with no date restrictions. A further hand search was conducted on individual journals and reference lists of studies. The risk of bias in included studies was assessed by using the Evidence Project risk of bias tool.

Statistical Analysis Used: Statistical meta-analysis was conducted using RevMan 5.4 software. The assessment for the level of evidence was done using GRADEpro software.

Results: Eleven studies were finalised. All were included in the meta-analysis for implant survival, while only seven studies were included in the meta-analysis of marginal bone loss. After three years, the meta-analysis results for implant survival showed no statistical difference between axial and tilted implants, with the forest plot neither favouring axial nor tilted implants (RR = 1.00 (95% CI: 0.98-1.01); *P*-value = 0.59). After three years, the meta-analysis results for marginal bone showed no statistical difference between axial and tilted implants, with the forest plot neither favouring axial nor tilted implants (MD = -0.02; 95% CI; -0.09-0.06; *P*-value = 0.69).

Conclusion: In the immediately loaded rehabilitation of completely edentulous atrophic maxillae, tilting of implants did not induce any significant alteration in their survival and their corresponding marginal bone loss levels compared to conventionally placed axial implants even after three years of function.

Keywords: Atrophic edentulous maxilla, axial implants, immediate loading, implant survival, marginal bone loss, meta-analysis, systematic review, tilted implants

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INTRODUCTION

For partial or total edentulism, dental implants are a safe and effective therapeutic option.[1] The potential height and the available width of the residual alveolar ridge are critical for successful implant placement. The loss of posterior teeth, especially at an early age, causes alveolar bone loss, making implant placement difficult in the preferred positions in the dental arches.[2] Since the resorption of the jaw's alveolar processes depends on the existence of teeth, alterations in their morphology are more pronounced in fully edentulous people. These variations in the shape and size of the ridge contour occur at different rates in different people and at different times in the same person.[3] The rehabilitation of atrophied edentulous ridges with endosseous implants in the posterior regions is frequently hampered by physiological issues such as bone resorption, poor bone quality, the presence of maxillary sinuses, pneumatization of maxillary sinuses, and a relative surfacing of the inferior alveolar nerve in the mandible, all of which make implant placement in the posterior region difficult.[4] The densest bone is found in the anterior-most part of the mandibular arch, and it becomes more fragile in the posterior maxilla. Maximum clinical failures are found in the posterior maxilla because of the resulting high masticatory forces and insufficient density of the supporting bone.[5]

Sinus augmentation, bone regeneration, short implants, distal cantilever pontics, or implants placed in certain areas such as the pterygoid, tuberosity, and zygomatic regions are some of the therapeutic options available to address these flaws.[4] Either of these procedures requires surgical and prosthetic expertise and present with their own set of risks, including membrane perforation, postoperative wound infection, bony sequestrum formation, hematoma, maxillary sinusitis, oro-antral fistula, wound dehiscence, bone graft loss, dental implant displacement into the maxillary sinus, longer healing time, and patient discomfort.[6] To avoid these problems, a tilt in the implant position is introduced to engage the maximum amount of accessible bone and put longer distal implants at the same time. The fundamental benefit of placing the tilted implant in the maxilla is that it allows the fixed implant-connected prosthesis to be extended more distally, reducing the length of the cantilever without the need for a sinus floor elevation treatment. Tilting distal implants have shown the same clinical effectiveness rate as axial implants. It also aids in the posterior positioning of the distal implant platform.[7-13] The region of congruity between bone and implant grows with the introduction of longer implants, providing enhanced primary stability to the implant. Anchorage from more than one cortical layer is used to produce increased primary stability.[14,15] These aids in the immediate loading of the implants, therefore shortening the treatment time.

The benefits achieved by immediately loading dental implants in the mandibular jaw have motivated many clinicians to use them in the maxillary jaw. Despite the exponential growth of dentistry, the predictability of immediately loaded implants over a long duration of function in the resorbed maxillary, particularly in the posterior region, is not studied. A meta-analysis of maxillary rehabilitations that employed tilted and axial implants were previously reported, concentrating mainly on their 1-year performance.[16] This highlighted the necessity for a more extensive follow-up period and analysis based on strong and healthy clinical evidence.

As a result, this systematic review aimed to assess the 3-year clinical survival of axial and tilted immediately loaded implants in the atrophic edentulous maxilla, as well as the marginal bone loss associated with them. The null hypothesis assumed that when axial and tilted implants rehabilitating completely atrophic edentulous maxilla were loaded immediately, there would be a difference in implant survival and marginal bone loss levels.

METHODS

Guidelines provided by Preferred Reporting Items for Systematic Reviews and Meta-Analyses were followed for carrying out this systematic review.[17,18] The PICOS structure was used to develop the search strategy [Figure 1].

Search strategy

A thorough electronic literature search was undertaken via PubMed, the Cochrane Central Register of Controlled Trials (CENTRAL), Science Direct, and Google Scholar. The search was conducted solely in English, with no time constraints. All databases were searched using the following MeSH terms, search phrases, and combinations: Dental implants, edentulous jaws, maxilla, tilted implants, angled implants, atrophy, immediate dental implant loading, survival analysis, alveolar bone loss combined with the Boolean operators OR, AND. Relevant studies were included after hand-searching the reference list of shortlisted articles.

Domain	Description
Population/Participants	Completely edentulous atrophic maxilla
Intervention	Delayed implant placement (minimum four and maximum six) immediately loaded with fixed prostheses
Comparison	Axial and tilted implants
Outcomes	(a) Primary outcome: survival of implants (b) Secondary outcome: marginal bone loss
Study design	Clinical studies performed in humans involving randomised and non-randomised clinical trials, prospective and retrospective studies with a minimum follow-up of three years

Figure 1: PICOTS of the study

Studies that matched the following inclusion criteria were included in the current systematic review:

1. Human clinical trials having at least a 3-year follow-up period
2. Completely edentulous atrophic maxilla rehabilitated using axial and tilted implants
3. Immediately loaded after surgery (within 48 h)
4. Amount of marginal bone loss indicated or calculable from data provided for axial and tilted implants
5. Articles with a full text published in English.

This systematic review included human clinical trials, prospective clinical trials, and retrospective research. The participants in the study were not restricted by any age restrictions. The following criteria were used to assess implant survival in the studies that were included:

1. Clinical stability and function without any discomfort
2. Absence of suppuration, infection, pain at the implant site, or any other persistent pathology
3. In evident peri-implant radiolucency.

In the included studies, intra-oral periapical radiographs and panoramic radiographs were used to assess the bone levels surrounding the margins of axial and tilted implants.

Screening for selection

Two separate investigators were responsible for examining the titles and abstracts of the searched articles for their inclusion in the analysis. The investigators then got the complete texts of all potentially relevant research for independent review. A new investigator was brought in to resolve the conflict between the two investigators; if any disagreement regarding inclusion occurred.

Data extraction

Two investigators worked independently to obtain data by filling out a data extraction form. Each included trial provided data on (1) the author and year of publication, (2) the study design, (3) the type of loading and timing of prosthetic loading, (4) the number of patients treated, (5) the number of axial implants, (6) the number of tilted implants, (7) the type of definitive prosthesis, and (8) the follow-up period.

Risk of bias in individual studies

In both randomized and nonrandomized intervention trials, the Evidence Project risk of bias tool was used to assess the risk of bias.[19] Eight domains were used to assess the risk of bias: (1) cohort, (2) control or comparison group, (3) pre-post intervention data, (4) random assignment of participants to the intervention, (5) random selection of participants for assessment, (6) follow-up rate of 80% or more, (7) comparison groups equivalent on sociodemographic, and (8) comparison groups equivalent at the baseline on outcome measures.

Statistical analysis

The differences between axial and tilted implants were investigated through meta-analysis, focusing, particularly on the survival of implants and levels of bone loss around the margins after 3 years. Relative risks (RRs) were calculated for implant survival, and the differences of the mean (MD) values reported for marginal bone loss, both with 95% confidence intervals (CIs), were considered to be effective measures. If the RR values were obtained >1, the tilted implants would be failing more than the axial implants. Similarly, if the MD values were larger than 0, then the tilted implants would be presenting more marginal bone loss than axial implants. To summarize these effects and fabricate the forest plots for the presentation of the overall analysis, RevMan 5.4 software was used (Review Manager (RevMan) [computer program]. Version 5.4, The Cochrane Collaboration, 2020).

Summary of findings

The GRADE-pro software was used to assess the current systematic review and meta-analysis (GRADE-pro Guideline Development Tool [Software]. McMaster University, 2020).

RESULTS

Study selection

A total of 135 studies were found via an electronic search of databases and manual investigation. After the deletion of duplicates, 93 full-text papers were evaluated, with 56 studies being eliminated by both investigators. When the remaining 37 full-text studies were evaluated for eligibility, 26 more research were eliminated for various reasons. Finally, the current systematic review and meta-analysis included 11 studies [Figure 2].

Study characteristic

There were eleven included researches, which were published between 2007 and 2017. The research comprised eight prospective clinical studies (73%) and three retrospectives, nonrandomized comparative trials (27%). In total, 351 patients had 1545 implants placed in their maxilla. There were 648 titled implants (41.94%) and 897 axial implants (58.06%) among these implants. All eleven articles published data on implant survival after 3 years of implantation. Only 1148 implants were documented after the 3rd year of follow-up, with 510 (44.42%) being titled implants and 638 (55.58%) being axial implants [Table 1].

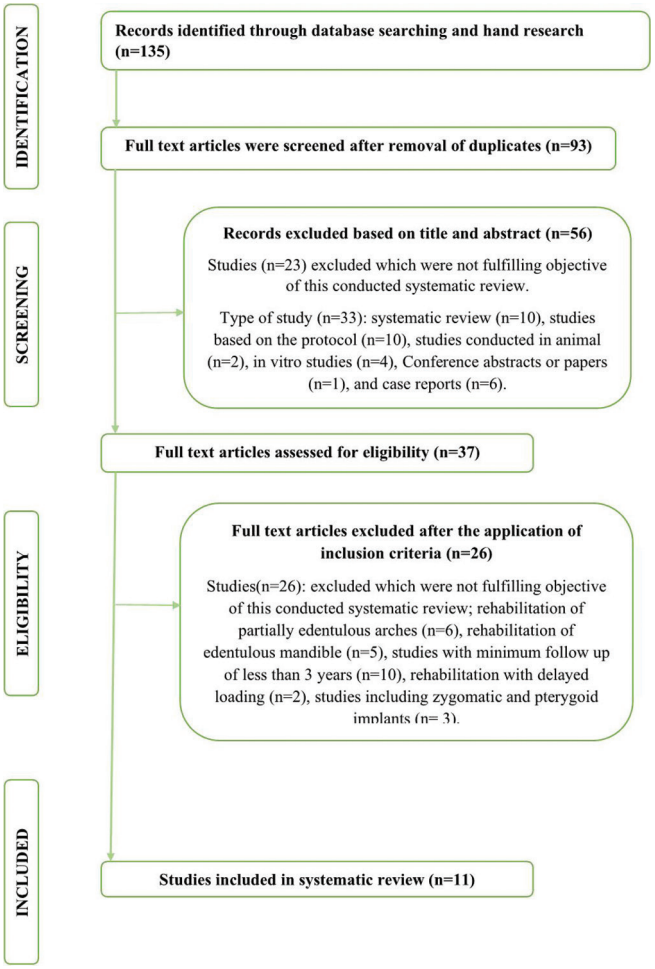

Figure 2: Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for the identification and selection of studies

Figure 3: Graphical presentation of risk of bias assessment

Risk of bias within studies

Three studies[20,21,23] (27%) have a moderate risk of bias, according to the Evidence Project's risk of bias tool. The remaining eight studies (73%) revealed a low risk of bias.[22,24-30] The included studies indicated a low risk of bias in the cohort domain, control or comparison group domain, and pre-/post-intervention data domain. Except for one,[25] all of the studies demonstrated a high risk of bias in the assessment domain's random selection of participants. In a follow-up rate of 80% or more domain, there was a low risk of bias in eight studies,[22,24-30] and a high risk of bias in three studies.[20,21,23] [Table 2 and Figure 3].

Meta-analysis 1: Survival of axial and tilted implants

One thousand one hundred and forty-eight implants were reported for follow-up after 3 years of placement. Among them, 510 (44.42%) were titled implants, and 638 (55.58%) were axial implants. Studies performed by Roberto Crespi[25] and Enrico L. Agliardi[28] had reported failure of tilted implants. Roberto Crespi *et al*.[25] reported failure of only one tilted implant out of 48 tilted implants due to periimplantitis. Similarly, Enrico L. Agliardi *et al*.[28] also reported failure of two tilted implants out of 128 tilted implants owing to periimplantitis only after 6 months of loading.

A total of three titled implants had failed, while no failure of the axial implant was reported. There was survival of 507 implants (99.41%) out of 510 implants for titled implants and 638 implants (100%) out of 638 implants for axial implants.

Figure 4 has illustrated a forest plot depicting meta-analysis comparing tilted and axial implant survival rates after 3 years of function. An insignificant difference was obtained between titled and axial implants (RR = 1.00; 95 % CI: 0.98-1.01; *P*-value = 0.59). Heterogeneity was not found between the studies included (I^2 = 0%).

Meta-analysis 2: Levels of bone loss around the margins of axial and tilted implants

Values for marginal bone loss following a 3-year follow-up period were obtained from seven out of eleven trials.

Table 1: Demographic data and characteristics of the included studies

Number	Author and year	Study design	Loading	Number of patients (maxilla)	Number of axial implants	Number of tilted implants	Implant system	Defintive prosthesis	Follow-up period (years)
1	Capelli *et al*.[20]	A multicentre clinical study	Immediate	41	164	82	Osseotite NT; Biomet/3i, West palm beach, FL	Hybrid titanium with acrylic resin teeth	3
2	Agliardi *et al*.[21]	Prospective	Immediate	61	122	122	Branemark Systems Mk IV or Nobel speedy Groovy S, Nobel Biocare AB, Goteborg, Sweden	Hybrid titanium with acrylic resin teeth	Up to 5
3	Francetti *et al*.[22]	Prospective	Immediate	16	32	32	Nobel Biocare Ab, Göteborg, Sweden	Hybrid titanium with acrylic resin teeth	3
4	Agnini *et al*.[23]	Single cohort study	Immediate	30	165	37	Zimmer Dental Inc., Carlsbad, Ca, USA)	Hybrid titanium with acrylic resin teeth or all ceramic crowns or composite teeth	Up to 5
5	Cavalli *et al*.[24]	Retrospective	Immediate	34	68	68	Branemark systems Mk IV or nobel-speedy Groovy, Nobel Biocare AB, Goteborg, Sweden	Hybrid titanium with composite teeth	Up to 5
6	Crespi *et al*.[25]	Clinical study	Immediate	24	48	48	Pad system, Sweden-Martina	Hybrid titanium or acrylic resin framework with acrylic resin teeth	3
7	Malo *et al*.[26]	Retrospective	Immediate	70	140	57	Nobel Biocare	Hybrid titanium with acrylic resin teeth or all ceramic crowns	3
8	Lopes *et al*.[27]	Prospective	Immediate	18	36	36	Nobelspeedy Groovy; Nobel Biocare	Hybrid titanium with acrylic resin teeth or all ceramic crowns	5
9	Agliardi *et al*.[28]	Prospective	Immediate	32	64	128	Nobel Biocare Ab, Göteborg, Sweden	Hybrid titanium with acrylic resin teeth	3
10	Browaeys *et al*.[29]	Prospective	Immediate	9	18	18	Nobel Biocare Ab, Göteborg, Sweden	Hybrid titanium with acrylic resin teeth	3
11	Wentaschek *et al*.[30]	Retrospective	Immediate	10	40	20	Bluesky™ Implants, Bredent Gmbh, Senden, Germany	Hybrid titanium with acrylic resin teeth	Up to 5

Mk IV: Implant system used by author in study

Table 2: Summary of risk of bias for the nonrandomized studies included in the systematic review

Study	Cohort	Control or comparison group	Pre/post intervention data	Random assignment of the participants to the intervention	Random selection of participants for assessment	Follow-up rate of 80% or more		Comparison groups equivalent on sociodemographic	Comparison groups equivalent at baseline on disclosure	Risk of Bias
Capelli *et al*.[20]	Yes	Yes	Yes	NA	No	No	54	NA	NA	Medium
Agliardi *et al*.[21]	Yes	Yes	Yes	NA	No	No	64	NA	NA	Medium
Francetti *et al*.[22]	Yes	Yes	Yes	NA	No	Yes	100	NA	NA	Low
Agnini *et al*.[23]	Yes	Yes	Yes	NA	No	No	70	NA	NA	Medium
Cavalli *et al*.[24]	Yes	Yes	Yes	NA	No	Yes	80	NA	NA	Low
Crespi *et al*.[25]	Yes	Yes	Yes	NA	Yes	Yes	100	NA	NA	Low
Malo *et al*.[26]	Yes	Yes	Yes	NA	No	Yes	87	NA	NA	Low
Lopes *et al*.[27]	Yes	Yes	Yes	NA	No	Yes	89	NA	NA	Low
Agliardi *et al*.[28]	Yes	Yes	Yes	NA	No	Yes	100	NA	NA	Low
Browaeys *et al*.[29]	Yes	Yes	Yes	NA	No	Yes	80	NA	NA	Low
Wentaschek *et al*.[30]	Yes	Yes	Yes	NA	No	Yes	95	NA	NA	Low

NA: Not applicable

For maxilla, these studies[22,23,25,26,28-30] showed separate results of marginal bone loss that occurred for an implant placed with tilt (n = 274) as well as the implant placed axially (n = 293).

A nonsignificant mean difference (MD = −0.02; 95% CI; −0.09–0.06; P value = 0.69) was discovered between tilted and axial implants [Figure 5]. There was some heterogeneity between trials (I^2 = 23%), which was discovered. However, there was no difference in the outcomes of fixed and random-effects models.

Survival of prostheses

The fracture of provisional and/or definitive prosthesis[21,22,24-27] and prosthetic screw-loosening[24-27] were the most commonly observed complications. Agnini *et al*.[23] and Cavalli *et al*.[24]

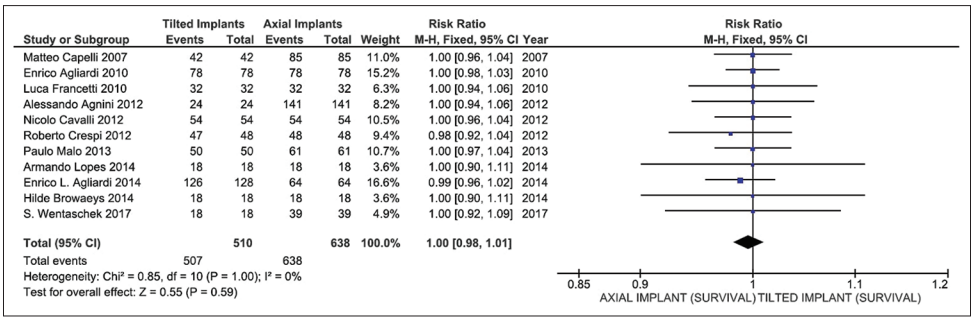

Figure 4: Forest plot for survival of axial and tilted implants

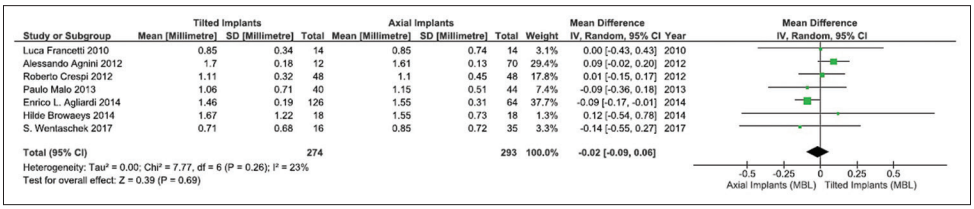

Figure 5: Forest plot for levels of bone loss around the margins of axial and tilted implants

reported breaking of esthetic veneering of the provisional prosthesis. Paulo Malo *et al*.[26] and Armando Lopes *et al*.[27] proposed that fracture of the provisional and definitive prosthesis could be resolved by repairing the fracture, followed by adjusting the occlusion and simultaneously providing an occlusal night guard to the patient.

The number of implants used, provisional and definitive prosthetic materials used, prosthesis design, use of a surgical template, performing surgery with a flap retraction, or performing a flapless surgery were some of the differences in the methods followed in different studies.

Most studies employed four implants (two axial implants placed anteriorly, two tilted implants placed distally). Whereas only two studies[20,30] used more than one axial implant per quadrant, with one distally tilted implant. Depending on the availability of bone and proximity to vital tissues, Agnini *et al*.[23] used four implants (two axial implants placed anteriorly, two tilted implants placed distally) or six implants (four axial implants placed anteriorly, two tilted implants placed distally) for the maxillary arch. While Agliardi *et al*.[28] placed two anterior axial and four posterior tilted implants at the same time.

Two of the eleven studies[27,29] employed computer-guided stents for performing flapless surgery and documented positive results. Patients with insufficient mouth opening (<50 mm) to accommodate the surgical equipment were excluded from these investigations.

All researchers[20-30] suggested achieving a primary torque of minimum 30 Ncm to exercise immediate loading.

Three authors[20,23,28] documented the use of a provisional prosthesis for the complete arch with a metal substructure and veneering acrylic resin. In contrast, the remaining authors provided an all-acrylic full-arch provisional prosthesis to their patients.[21,22,24,26,27,30] Within 24 h of implant insertion, Crespi *et al*.[25] advocated using the screw-retained full-arch definitive prosthesis. Five investigations[21,23,24,29,30] reported the use of a fixed provisional prosthesis without distal cantilevers. On the other hand, the other six investigations had not mentioned the use of a distal cantilever.

The use of screw-retained definitive prosthesis was reported in all included articles.[20-30]

Summary of findings

The standard of evidence generated was assessed using GRADEpro software and was very low for implant survival and low for marginal bone loss [Figure 6]. The quality of evidence was initially good, but it was then downgraded to poor due to a lack of randomization and blinding, and later to very low due to imprecision. This suggested that more well-controlled research should be conducted in the future to affect the result of the current review.

DISCUSSION

This systematic review and meta-analysis aimed to identify axial and tilted implant's 3-year clinical survival rate and the resulting marginal bone loss when they were immediately rehabilitated. Studies that matched the following criteria were included in this systematic review: Clinical studies in humans with a minimum 3-year follow-up, rehabilitation

Outcomes	Anticipated absolute effects* (95% CI) Risk with Axial Implants	Risk with Tilted Implants	Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)	Comments
Survival of Implants	1,000 per 1,000	**1000 per 1,000** (980 to 1,000)	**RR 1.00** (0.98 to 1.01)	1184 (11 observational studies)	⨁◯◯◯ VERY LOW [a]	
Marginal bone loss	The mean marginal bone loss was **0**	MD **0.02 lower** (0.09 lower to 0.06 higher)	-	567 (7 observational studies)	⨁⨁◯◯ LOW	

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **RR:** Risk ratio; **MD:** Mean difference

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. Imprecise due to confidence intervals included the potential for important harm or benefit.

Figure 6: Summary of findings according to the GRADE approach

of completely edentulous maxilla supported by axial and tilted implants, immediate loading within 48 h after surgery, marginal bone loss post 3 years for axial and tilted implants indicated or calculable from data provided, full-text articles published in the English language only. The literature search revealed eleven papers that matched the criteria for inclusion. There were no randomized clinical trials found; eight of the included papers were prospective clinical studies (73%), and the remaining three were retrospective, nonrandomized comparative studies (27%). In this systematic review and meta-analysis, the following information was compiled from the findings of eleven studies [Table 3].

Type 3 and type 4 bone morphology, residual ridge resorption, maxillary sinus pneumatization, and the existence of nasal cavities generally limit traditional implant placement axially in the completely edentulous atrophic maxilla.[31] To give the patient enough chewing capacity in the molar region, prostheses with a long distal cantilever are required. Cantilever lengths above 15 mm, on the other hand, are linked to a higher likelihood of implant failure.[32] To resolve these issues, bone augmentation techniques and nongrafting techniques are proposed in the literature. Grafting techniques include sinus lift procedure, ridge split technique, and block grafting procedures. Whereas nongrafting techniques include placement of zygomatic implants, pterygoid implants, short implants, and tilted implants.[33]

Grafting methods have a high rate of complications, a high risk of morbidity, high expenses, and a longer time for prosthetic rehabilitation due to which patient acceptance is low.[34] When compared to implants placed in the grafted bone, Widmark *et al*.[35] found that maxillary implants implanted in native bone have a higher success rate (87%) after 5 years (74%). Other options for rehabilitating atrophic maxilla include zygomatic and pterygoid implants, which have success rates but need extensive surgical competence and are associated with greater morbidity.[36,37] Furthermore, adequate bone height (7–8 mm) and a superior bone density of bone become mandatory when planning for short implant placement.[38]

According to the intuitive concepts, dental implants must be placed in the axial plane to achieve and sustain adequate osseointegration. The primitive concept advocated the use of implant placement that was "in-line" or perpendicular to occlusal stresses and claimed that tilted implants would lose bone and eventually "de-osseointegrate."[39] However, an appealing technique for treating atrophic edentulous maxilla using titled implants was discovered to be a feasible therapeutic option because of technological advancements.[40] Its goal was to get maximum cortical bone involved for support.[41] It has several advantages, including strong primary stability even with low bone volume, longer implant length for more bone to implant contact, more anterior-posterior spread, minimally invasive approach without bone grafting, and ability to place implants close to anatomical structures.[42,43] Using titled distal implants rather than distal cantilever units has proven biomechanical advantage. The resulting full-arch fixed prosthesis has a bilateral cantilever length of up to 20 mm attributable to distally tilted implants.[44]

Compared to previous grafting treatments, this philosophy of placing implants in preexisting bone applied the therapeutic idea of taking maximum advantage of the naturally available bone, resulting in a simple, more predictable, less expensive, and faster rehabilitation. According to a finite element analysis undertaken by Bevilacqua *et al*., an individual tilted implant posed higher stress on the surrounding bone than an implant positioned axially straight.[45] However, it was proven that splinting tilted and axial implants with a single unit fixed prosthetic structure reduced peri-implant bone stress significantly when rehabilitating the complete arch.[46,47] Bevilacqua *et al*.[47] used different implant inclinations and cantilever

Table 3: Summary of evidence

Author and Year	Study design	Number of axial implants	Number of tilted implants	Type of defintive prosthesis	Follow-up period (years)	Outcome
Capelli *et al*.[20]	A multicentre clinical study	164	82	Hybrid titanium with acrylic resin teeth	3	Placing implants in preexisting bone enables avoidance of more complex surgical procedures such as maxillary sinus floor augmentation. According to their study, immediate rehabilitation of the completely edentulous atrophic maxilla with fixed prostheses supported by either axial or tilted implants aimed at combining an optimized use of available bone with the benefits of immediate loading. According to the author's experience, these methods led to more simple, more predictable, less expensive, and less time-consuming treatment compared to maxillary sinus augmentation
Agliardi *et al*.[21]	Prospective	122	122	Hybrid titanium with acrylic resin teeth	Up to 5	A combination of axially placed and tilted implant for the immediate rehabilitation of edentulous atrophic maxilla leads to excellent clinical outcomes. The advantages of the immediate loading procedure, the reduced morbidity, the high patient's satisfaction and the relatively low costs of this surgical technique should be taken into account when a decision among the alternative therapeutic options have to be made
Francetti *et al*.[22]	Prospective	32	32	Hybrid titanium with acrylic resin teeth	3	The use of tilted implants in the immediate loading procedures is safe and is not associated with a higher marginal bone loss as compared to axially placed implants
Agnini *et al*.[23]	Single cohort study	165	37	Hybrid titanium with acrylic resin teeth or all ceramic crowns or composite teeth	Up to 5	Immediate loading of axial and tilted implants provides a viable treatment modality for the rehabilitation of edentulous atrophic maxilla
Cavalli *et al*.[24]	Retrospective	68	68	Hybrid titanium with composite teeth	Up to 5	The high cumulative implant survival rate indicates that tilted implants for full-arch rehabilitation in completely edentulous atrophic maxilla could be considered a viable treatment option. An effective recall program is important to early intercept and correct prosthetic and biological complications to avoid implant and prosthetic failures
Crespi *et al*.[25]	Clinical study	48	48	Hybrid titanium or acrylic resin framework with acrylic resin teeth	3	Favorable clinical outcomes were obtained in the rehabilitation of completely edentulous atrophic maxilla using All-on-4 treatment concept
Malo *et al*.[26]	Retrospective	140	57	Hybrid titanium with acrylic resin teeth or all-ceramic crowns	3	The high survival rate registered at patient and implant level indicates that the outcome of immediately loaded tilted implants for the rehabilitation of edentulous atrophic maxilla to avoid sinus lift procedures is a viable treatment
Lopes *et al*.[27]	Prospective	36	36	Hybrid titanium with acrylic resin teeth or all-ceramic crowns	5	All-on-4 treatment concept for rehabilitation of completely edentulous atrophic maxilla is safe and predictable with good long-term outcomes
Agliardi *et al*.[28]	Prospective	64	128	Hybrid titanium with acrylic resin teeth	3	Four tilted implants that engaged the posterior and the anterior sinus walls and two axial anterior implants could be considered a predictable and cost- and time-effective alternative approach for the immediate restoration of the edentulous atrophic maxilla, avoiding bone grafting procedures, even after 3 years of loading
Browaeys *et al*.[29]	Prospective	18	18	Hybrid titanium with acrylic resin teeth	3	The implant and prosthetic survival were 100%, and patients benefited from the use of the All-on-4 treatment concept. However, unacceptable ongoing bone loss may be a warning sign of future problems and needs clinical attention. Overloading and surgery-related aspects need to be further investigated as possible explanations

Contd...

Table 3: Contd...

Author and Year	Study design	Number of axial implants	Number of tilted implants	Type of defintive prosthesis	Follow-up period (years)	Outcome
Wentaschek *et al*.[30]	Retrospective	40	20	Hybrid titanium with acrylic resin teeth	Up to 5	Immediate loading in the edentulous atrophic maxilla with tilted implants is less time-consuming and less invasive, when very limited bone is available in the atrophic maxilla

lengths to test load transmission to maxillary cortical peri-implant bone (von mises forces). When the distal axial implant was splinted with a fixed denture to the mesial axial implant, the maximum stress observed was 75 MPa. On the contrary, maximum stresses measured for distally tilted implants were lowered to 39.4 MPa (tilt of 30°) and 19.9 MPa, respectively (tilt of 45°).[47] Metal-reinforced prosthetic rehabilitation was indicated to give solid support for the implants and to reduce mechanical problems.[20,23,28] Due to improved precision and convenience, computer-guided flapless surgery for implant insertion utilizing stereolithographic templates is becoming increasingly popular among clinicians.[48] The minimally invasive aspect of this surgical technique and the accuracy of implant placement has decreased postsurgical discomfort and shortened the duration of surgical operation.[48] The prosthetic treatment for axially inserted implants can get complicated if a tilt is introduced during the surgical placement, especially for a posterior implant. This tilt can be easily adjusted with the use of angulated abutments.[49]

Since the tilted implants engage the maximum cortical bone, they are considered to have strong primary stability, which helps in loading them immediately. An implant-supported restoration placed into a function within 48 h of implant implantation is known as immediate loading.[50] Within the limitations of previous evidence (up to 2 years), the immediately loaded implant was proven to have a predictable high survival rate.[50] In terms of patient comfort and esthetics, the immediate loading approach reduced the waiting period required to install a functional prosthesis. This particular gain of reduced duration of the treatment proved to be a financial benefit, particularly for professionally and socially engaged patients. From the aspect of a clinician, the immediate loading approach saved chairside time and lowered treatment costs.[51,52] The evidence on the performance of axial and tilted implants in function for at least 3 years has been summarized in this systematic review. After 3 years of function, no significant difference in implant survival was observed between axial and tilted implants, according to the meta-analysis findings ($P = 0.59$). Both implants had a commendable success rate. At the 3rd-year follow-up, three tilted implants failed, whereas 0 axial implants failed out of a total of 1148 implants. Similarly, there was no difference between axial and tilted implants in peri-implant marginal bone loss levels ($P = 0.69$). As a result, the null hypothesis was rejected in the current systematic review and meta-analysis.

The fracture of the acrylic provisional restoration appeared to be the most prevalent problem. Other complications included:

- The loosening of a prosthetic screw
- Chipping off of the provisional prosthesis's esthetic veneering
- Detachment of one or more resin teeth.

Only three trials employed a full-arch provisional prosthesis with a metal framework rather than an all-acrylic prosthesis.[20,23,28] A metal framework is essential for enhancing the structure's stiffness and rigidity for splinting the implants, contributing to a more favorable occlusal force distribution, allowing for osseointegration.

In 2010, Del Fabbro *et al*.[53] published a meta-analysis on the effects of tilted implants in immediately loaded rehabilitations. It comprised papers that have been published as recently as March 2009. One study[20] was included in the current review, which was also included by Del Fabbro *et al*. The current systematic review focused on rehabilitation of completely edentulous atrophic maxilla with a minimum 3-year follow-up period, which was one of the major contrasts between the two systematic studies. Del Fabbro *et al*., on the other hand, included both maxillary and mandibular arch rehabilitation in their study, with only an 1-year follow-up. Del Fabbro also failed to include a quality and bias assessment of the research he included. A meta-analysis of marginal bone loss surrounding implants was also performed in the present systematic review.

Menini *et al*.[16] reported a meta-analysis of tilted implant outcomes in immediate loading rehabilitation in 2012. It comprised papers that were published up to August 2011. Three studies[20-22] that were also included by Menini *et al*. were included in the current review. The current systematic review focused on rehabilitating completely edentulous

atrophic maxilla with a minimum of 3-year follow-up period, one of the major contrasts between the two systematic studies. In contrast, Menini *et al*. focused on rehabilitation of completely edentulous atrophic maxilla over 1 year. Furthermore, unlike the current review, Menini *et al*. did not provide a summary of evidence.

In 2021, Gaonkar *et al*.[54] conducted a systematic review to establish the success rate of axial and tilted implants implanted in edentulous jaws using the All-on-4 technique. There was no meta-analysis done. Six papers were included in the current review,[20,21,22,25,27,29] which were also included by Gaonkar *et al*., on the other hand, did not specify the research's inclusion criteria and arbitrarily chose 25 from the literature up to 2015. For every given period, the quantity of marginal bone loss was not specified. There was also no mention of the variation in implant survival rates between the maxillary and mandibular jaws. In addition, the effects of immediately loaded axial and tilted implants were not addressed.

The effects of distally tilted versus mesial axial implant survival were compared in this study. The minimum angulation required to classify an implant as tilted has yet to be determined. Seven of the eleven studies[21-24,26-28] observed angulation angles ranging from 30° to 45° degrees. According to Roberto Crespi *et al*.,[25] the degree of angulation for a distally inclined implant is between 30° and 35°. The degree of angulation for a distally inclined implant, according to Luca Francetti *et al*.[22] and Hilde Browaeys *et al*.[29] might be up to 30°. A mesiodistal angulation concerning the vertical axis might be defined as implant inclination (perpendicular to the occlusal plane).[55] However, the linguobuccal or palatobuccal inclination, which may significantly impact implant biomechanics and impacts on the surrounding hard and soft tissues, is not included in this description.

Data on the survival of prostheses have been published in several studies with appropriate conclusive findings. Randomized controlled trials on studies using only restorations supported by either axial or tilted implants should be done to provide credible data. When axial and tilted implants are utilized in the same restoration, confounding variables may be added.

However, no randomized control experiment was found in the existing literature on this topic. It was highlighted that solely clinical judgment was used to assess implant survival results in all eleven investigations. More reliable approaches such as resonance frequency analysis and the reverse torque method should be used to collect data to verify implant stability.[50,56,57]

CONCLUSION

The current systematic review derived that the rehabilitation of completely edentulous atrophic maxilla with tilting of implants and immediately loading them produced similar results compared to conventional axially placed implants. When the parameters of implant survival and marginal bone loss levels around the implants were studied in the meta-analysis, no significant difference was obtained in contrast to axial implants even after 3 years of function. The impact made on the quality of life of the patients by this alternative treatment modality is tremendous. Hence, it was concluded that tilted implants for restoring completely edentulous atrophic maxilla are a viable therapeutic option with no significant differences in outcome compared to conventional implantology. In future, further randomized clinical trials should be carried out to assess the efficacy of tilted implants as a replacement for grafting procedures, short implants, or implants in specific anatomic areas.

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