

# Rehabilitation of Edentulous Arches with Fixed Prosthesis Supported by Tilted Implants: A Systematic Review

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## ABSTRACT

**Aim and objective:** The aim of this systematic review was to seek evidence and to find the favorable and unfavorable factors for the use of a minimum number of implants in complete arch rehabilitation.

**Materials and methods:** A search of electronic database limited to English language articles was conducted using the following MeSH terms; “dental implant”, “tilted implant”, “axial implant”, “edentulous patient”, “edentulous maxilla”, and “edentulous mandible”, “implant supported dental prosthesis”, “immediate loading and immediate placement”. They were used alone or in combination. Thirty-three articles were selected for the final review which were all clinical studies with human participants and had a follow-up period of 1 year or more. In all the studies included in this review, a minimum of four implants were placed in each arch and one implant placed in each arch was angulated.

**Results:** Of the 33 articles analyzed, 21 (63.63%) articles reported failure of implants. A total of 161 (1.56%) implants failed out of the 10,300 implants placed. In the 161 failed implants, 63 (39.13%) were axially placed implants and 63 (39.13%) were implants placed at an angulation. The orientation of 60 (37.27%) implants was not mentioned.

**Conclusion:** The survival rate of tilted implants at the implant and prosthetic levels is good. Tilted implants provide greater surface area for osseointegration, provide greater primary stability, reduce cantilever length, reduce bone resorption, and also reduce the need for bone grafting. The angulation of the implant which provided the most success was found to be 30°.

**Keywords:** Axial implant, Fixed implant prosthesis, Tilted implant.

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## INTRODUCTION

The life expectancy of humans has increased in the last few decades due to the improved and continuous progress in the medical field. The loss of teeth due to old age and its replacement is seen as a natural phenomenon. The complete loss of teeth during the fourth and fifth decades of life due to various lifestyle habits and diseases is more common today. The increase in the level of education and improved patient awareness has led to an increase in patients demanding higher quality treatment options. Age-related tooth loss, anatomic condition of edentulous ridges, psychological needs, decreased performance of removable prostheses, and predictable long-term results of implant-supported prostheses have increased the demand for implant-supported rehabilitation of teeth.

Traditional treatment plans typically called for a large number of implants placed in fairly vertical positions throughout the entire arch.<sup>1</sup> However, the rehabilitation of edentulous jaws with implants is often complicated by poor bone quality, especially in the posterior region, and reduced bone volume due to a long-term edentulous state.<sup>2</sup> Alveolar bone resorption and pneumatization of the maxillary sinus reduce, in many cases, the available amount of bone in both width and height for the placement of dental implants in the edentulous posterior maxilla.<sup>3</sup> In the mandible, the inferior alveolar nerve and associated structures may provide minimal bone for implant anchorage or prevent the placement of implants distal to the mental foramina altogether.<sup>1</sup> Bone grafting procedures to increase the bone volume available for implant placement is a viable treatment option but they often require demanding surgical procedures and can lead to complications, morbidity, and high costs. Therefore, patient compliance is often poor.<sup>2</sup> If posterior implants could not be placed and to compensate for

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these biologic limitations, a lengthy cantilever distal to the terminal implant was typically needed to provide patients with adequate posterior dentitions; however, extensive posterior cantilevers are biomechanically unfavorable due to increased occlusal forces.<sup>1</sup>

To overcome such limitations, different therapeutic alternatives have been proposed, such as long distal cantilever (Shackleton et al.),<sup>4,5</sup> short implants (Goené et al.,<sup>6</sup> Renouard and Nisand,<sup>7</sup> Maló et al.<sup>8</sup>) or implants placed in specific anatomical areas like, for the maxilla, the pterygoid region, the tuberosity of the zygoma (Khayat and Nader;<sup>9</sup> Venturelli;<sup>10</sup> Balshi et al.,<sup>11</sup> Brånemark et al.,<sup>12</sup> Galán Gil et al.,<sup>13</sup> Aparicio et al.,<sup>14</sup> Maló et al.<sup>15</sup>). Any of these procedures requires considerable surgical expertise and has its advantages, limitations, surgical risks, and complications involving biological and financial costs.<sup>2</sup>

In recent years, several clinical studies have reported that placement of implants at an angulation is a feasible option (Krekmanov;<sup>16</sup> Krekmanov et al.;<sup>17</sup> Aparicio et al.;<sup>18</sup> Maló et al.<sup>19,20</sup> Calandriello and Tomatis;<sup>21</sup> Capelli et al.;<sup>22</sup> Agliardi et al.<sup>23,24</sup>).<sup>2</sup> The introduction of tilted implants has provided a significant alternative for the restoration of maxillary and mandibular posterior segments without bone grafting.<sup>1</sup> Tilted implants provide several surgical and prosthetic advantages, like the possibility of placing long implants with an improvement of bone anchorage, the reduction of the need for bone grafting, the avoidance of long cantilevers, and the possibility of increasing the distance between anterior and posterior abutments, with an improvement of the load distribution.<sup>2</sup>

The All-on-4® treatment concept was introduced by Nobel Biocare AB, Göteborg, Sweden. This protocol using only four implants has produced good short-term outcomes, with a survival rate of 98.2% and marginal bone level of 0.6 mm at 6-month follow-up. Since this first report, several other authors have reported good short- and medium-term outcomes for patients undergoing this treatment. Moreover, recent systematic reviews have confirmed these results for maxilla and mandible rehabilitation.<sup>24</sup>

The All-on-6 treatment protocol is used to minimize the length of the cantilever. It is a deviation from the All-on-4 treatment modality.

The different treatment modalities provide various advantages to the clinicians as well as to the patients. But they also come with a variety of disadvantages too. The failure rate of such treatment modalities even though is less cannot be ignored. For this treatment option to be widely advocated and used successfully, one has to sort out the factors which favor and those which are unfavorable to this treatment option. The factors which contribute to the failure of such cases cannot be assessed from the reports of a handful of patients treated by a single clinician. Therefore, one needs to extensively study and carefully assess a considerable number of cases treated.

Thus, this review aims to seek evidence and to find the factors which are favorable and unfavorable for the use of a minimal number of implants for the complete arch rehabilitation of a patient.

## MATERIALS AND METHODS

An electronic search was carried out in PubMed and Medline. The keywords used for the search were “dental implant”, “tilted implant”, “axial implant”, “edentulous patient”, “edentulous maxilla”, and “edentulous mandible”, “implant-supported dental prosthesis”, “immediate loading and immediate placement”. They were used alone or in combination.

### Inclusion Criteria

- The articles from 2005 to 2016 were included in the study.
- The articles selected were limited to *in vivo* studies involving human subjects with a minimum of 10 patients treated.
- Studies with a minimum of 4 implants and a maximum of 10 implants placed on a single arch of which at least two are tilted implants were considered.
- Articles with a minimum of 1-year follow-up and loss of study participants <10% were included.
- Use of tilted implants.
- The survival rate of tilted and upright implants should be indicated and calculable from the data provided.

### Exclusion Criteria

Multiple publications with the same pool of patients, single case reports, studies with missing data, and studies in languages other than English were excluded. Publications that did not meet the above inclusion criteria and those that were not dealing with original clinical cases (reviews and technical reports) were also excluded.

Studies dealing with orthodontic implants, mini-implants, partial rehabilitation, and removable prosthesis were excluded too.

Thirty-three articles were selected for the final review which were all clinical studies with human participants and had a follow-up period of 1 year or more. In all the studies included in this review, a minimum of four implants were placed in each arch and one implant placed in each arch was angulated. The restoration of an edentulous maxilla or mandible or both with implant retained fixed prosthesis is the best treatment option available currently with long-term patient satisfaction and comfort compared to other methods of teeth replacement.

### Outcomes

After analyzing the selected articles the following outcomes were thoroughly analyzed.

- Type of study.
- Sample size.
- Number of implants placed.
- Number of implants placed in each arch.
- Angulation of the implant placed.
- The use of surgical guides for implant placement.
- The time of implant placement.
- The loading protocol was followed.
- The length of the cantilever.
- Type of provisional restoration/prosthesis.
- Type of opposing dentition.
- Follow-up interval.
- Follow-up period.
- Bone loss.
- Patient satisfaction.

## RESULTS

A total of 75 articles were obtained through the initial screening process. Out of which 28 articles were discarded as they did not fulfill the inclusion criteria. A total of 47 articles were identified as potentially eligible articles through screening by titles and abstracts. The full-text articles were obtained and thoroughly evaluated. As a result, 33 articles fulfilled the inclusion criteria and were included in the systematic review (Table 1, Fig. 1). The distribution of the type of study was mentioned in Table 2.

The review analyzed 15 criteria from each article, which include the type of study, sample size, number of implants used, number of implants placed per arch, the angulation of the implants placed, the use of surgical guides, the surgical protocol followed, time of placement of a provisional restoration, the length and presence of cantilever, type of opposing dentition, follow-up interval, follow-up period, bone loss at the implant site, patient satisfaction and the implant failures.

Of the 33 articles analyzed, 21 (63.63%) articles reported failure of implants. A total of 161 (1.56%) implants failed out of the 10,300 implants placed. In the 161 failed implants, 63 (39.13%) were axially placed implants and 63 (39.13%) were implants placed

Table 1: Master chart

S. no.	Authors/ Journal	Type of study	Sample size	No. of implants	No. of implants in each arch	Angulation of implants (°)	Surgical guide/ freehand implant placement	Time of implant placement	Loading protocol	Length of cantilever	Type of provisional prosthesis	Type of opposing dentition	Follow-up interval	Follow-up period	Bone loss	Patient satisfaction
1	Agliardi et al. COIR 2010	Prospective study	173	692	4	30-45	Nil	Immediate	Immediate loading		Acrylic prosthesis	Mandible: Removable partial denture-50 Fixed prosthesis on natural teeth-15 Natural teeth and fixed prosthesis on natural teeth-12 Implant-supported bridge-9 Natural teeth and two implant-supported bridge-4 Maxilla: Implant-supported fixed prosthesis-25 Removable prosthesis-22 Natural teeth-9 Fixed prosthesis on natural teeth-5	Once a week 6 months	For 1 month For 5 years	Maxilla: 0.9 ± 0.7 Mandible: 1.2 ± 0.2	NA
2	Weinstein et al.	Prospective study	20	80	4	30	Nil	Immediate	Immediate loading	15.2 ± 1.4	Acrylic prosthesis	Removable prosthesis-11	6 months	For 2 years	Axial:	Esthetic: excellent and very good by 66.70% of patients

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever	Type of prosthesis	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion
	Clinical Implant Den- tistry and Related Research 2012									Natural teeth and fixed prosthesis on natural teeth-4 Implant- supported prosthesis-5	1 year	For 5 years	0.6 ± 0.3	Phonet- ics and mastica- tion: ex- cellent and very good by 77.80 and 88.90%
3	Malo et al.	Retro- spective study	32	4	30	Used	Immedi- ate	Imme- diate loading	NA	All acrylic prosthesis	6 months	1 year	Tilted: 0.7 ± 0.4 0.9 mm	NA
	Clinical Implant Den- tistry and Related Research 2005									Natural teeth-11 Combination-6				
4	Malo et al.	Clinical report	242	4	45	Used	Immedi- ate	Imme- diate loading	NA	All acrylic prosthesis	6 months	5 years	1.52 mm after 3 years	NA
	Clinical Implant Den- tistry and Related Research 2011									Natural teeth-68			1.95 mm after 5 years	
										Combina- tion-60				

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever mm	Type of prosthesis	Type of oppos- ing dentition	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion
5	Capelli et al.	Clinical study	65	Max-6	Max- 30-35	Nil	Immedi- ate	Imme- diate loading	NA	Acrylic resin teeth	Removable prosthesis-7	3 months	5 years	Maxilla: 0.95 ± 0.44 mm	Satisfied with the esthet- ics, phonet- ics, and function
	The Inter- national Journal of Oral and Maxil- lofacial Implants 2007			Mand-4	Mand- 25-35							6 months		Axial- 0.95 ± 0.44 mm	
6	Krenn- mair et al.	Prospec- tive study	41	Max- 160	Angula- tion-40	Nil	Conven- tional	Delayed loading	Group I: 15.7 ± 2.1	Acrylic veneered teeth	Group I: Natural teeth-3	1 year	3 years	Mandi- ble: Axial- 0.82 ± 0.64 mm Tilted- 0.75 ± 0.55 mm At 1 year: 1.1 ± 0.4	NA
	Clinical Implant Den- tistry and Related Research 2016			Mandi- ble-4					Group II: 13.7 ± 2.1					At 2 years: 1.26 ± 0.42	





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12	Agliardi etal.	Prospective cohort study	32	192	6 per arch	30-45	NA	Immedi- ate and delayed	Imme- diate loading	NA	Screw retained metal re- inforced, acrylic resin interim restora- tion	6 months	3 years	Axial: 1.55 ± 0.31	Satisfied with both esthet- ics and function
13	Clinical Implant Den- tistry and Related Research 2012 Malo et al.	Pre- liminary result	23	92	4 per arch	NA	Surgical template	Delayed	Imme- diate loading	NA	Fixed all acrylic com- plete denture	10 days	2 years	Tilted: 1.46 ± 0.19 Maxilla: 2 mm	NA
14	The Journal of Prosthetic Dentistry 2007 Balshi et al. The American College of Prosthodontists 2014	Retro- spective analysis	152	800	4 per arch	NA	NA	Immedi- ate and delayed	Imme- diate loading	NA	Screw retained all acrylic resin	3 months	5 years	Mandible: 1.7 mm	NA

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever	Type of prosthesis	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion
15	Tealdo etal.	Pilot study	21	111	Maxilla 111	NA	NA	Immedi- ate and delayed	Imme- diate loading	NA	Screw retained fixed acrylic resin	6 months	1 year	Mesial site: 1.39	NA
	The Journal of Prosthetic Dentistry 2008				4-6 per arch						Natural teeth and fixed implant- supported prosthesis-3 Complete arch fixed implant- supported prosthesis-6 Natural teeth and RPD-3			Distal site: 1.35	
16	Francetti etal.	Retro- spective investi- gation	53	212	4 per arch	NA	NA	Immedi- ate and delayed	Imme- diate loading	NA	NA	1 year	5 years	At 1 year: 0.9 ± 0.5	NA
	Journal of Periodon- tal and Implant Science 2015														
17	Malo et al.	Retro- spective study	324	1296	4 per arch			Delayed	Imme- diate loading	Used only in the final prosthesis	Acrylic resin with a titanium cylinder	6 months	7 years	At 5 years: 1.81 mm	Average: 1.74 mm
	Clinical Implant Den- tistry and Related Research 2015										Natural teeth-40				

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever mm	Type of prosthesis	Type of oppo- sition	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion	
18	Di et al.	NA	69	4 per arch	45	NA	Immedi- ate	Imme- diate loading	</+ 8 mm	Acrylic resin	NA	3 months	5 years	Axial: 0.7 ± 0.2	Satisfied with the function and es- thetics	
19	Sannino et al.	Retro- spective study	51	4 per arch	30	NA	Immedi- ate and conven- tional	Imme- diate loading	≤ 10 mm	Acrylic resin	Implant-sup- ported restora- tion-11	6 months	2 years	Maxilla: Axial- 1.07 ± 0.33 Tilted- 1.10 ± 0.32	NA	
	The Inter- national Journal of Prosthodontics 2013										Fixed prosthesis over natural teeth-26 Combination of natural teeth and implant-supported fixed prosthesis-38 Removable prosthesis-81					
	The American College of Prosthodontists 2015										Maxillary CD-17 Natural teeth-12			Mandible: Axial- 1.08 ± 0.40 Tilted- 1.12 ± 0.39		

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever mm	Type of prosthesis	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion
22	Najafi et al.	Prospective study	30	156	4 per arch	45	NA	Immediate and conventional	Delayed loading	NA	Fixed metal resin	6 months	1 year	0.84 ± 0.15	NA
	Journal of Dentistry 2016										Implant-supported prosthesis-23 Removable prosthesis-4				
23	Hinze et al.	Prospective clinical study	37	148	4 per arch	30	NA	Immediate and conventional	Immediate loading	Right side: 12.47 ± 1.48 Left side: 12.28 ± 1.36	Acrylic resin	6 months	5 years	Axial: 0.82 ± 0.31	NA
	The American College of Prosthodontists 2010										FPD on natural teeth-11			Tilted: 0.76 ± 0.49	
24	Mozzati et al.	Retrospective analysis	50	200	4 per arch	30	NA	Immediate	Immediate loading	NA	Acrylic resin	1 month	For 6 months	After 1 year: 1.33 ± 0.36	Patients were satisfied
	Clinical Implant Dentistry and Related Research 2012										Implant-supported fixed partial denture-14 Full arch implant-supported prosthesis-5	6 months	For 2 years	After 2 years: 1.48 ± 0.39	

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants	No. of implants in each arch	Angulation of implants (°)	Surgical guide/ freehand implant placement	Time of implant placement	Loading protocol	Length of cantilever	Type of provisional prosthesis	Type of opposing dentition	Follow-up interval	Follow-up period	Bone loss	Patient satisfaction
25	Galindo et al.	Retrospective study	183	732	4 per arch	30	NA	Immediate and conventional	Immediate loading	NA	Acrylic resin	NA	10 days	1 year	<1 mm	NA
26	The International Journal of Oral and Maxillofacial Implants 2012 Browaeys et al.	Prospective study	20	80	4 per arch	20–40	Computer-guided surgery Surgical template	Conventional	Immediate loading	NA	Acrylic resin	NA	1 year 6 months	3 years	After 1 year: 1.13 mm After 3 years: 1.61 mm	NA
27	Clinical Implant Dentistry and Related Research 2014 Francetti et al.	Prospective study	62	248	4 per arch	30	Freehand placement	Immediate and conventional	Immediate loading	Right side: 7.23 ± 1.27 (immediate)	Acrylic resin	Removable prosthesis-27	6 months	For 2 years	Axial: 0.7 ± 0.4	NA
	Clinical Implant Dentistry and Related Research 2008											Natural teeth-8	1 year	For 5 years	Tilted-0.7 ± 0.5	
										14.46 ± 1.68 (final)		Natural teeth and fixed prosthesis on natural teeth-3				

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever mm	Type of prosthesis	Type of oppo- sition dentition	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion
						Left side: 6.84 ± 1.62 (im- mediate) 14.65 ± 1.72 (final)				Implant- supported prosthesis-9 Natural teeth and 2 implant- supported bridge-4					
28	Francetti et al.	Prospective study	47	196	4 per arch	30	Free- hand place- ment	Immedi- ate and conven- tional	NA	Acrylic resin	Removable prosthesis-23	6 months	For 2 years	At 1 year: 1.1 ± 1.1	NA
	Clinical Implant Den- tistry and Related Research 2010														
29	Li et al.	Prospective study	17	80	4 per arch	30-40	Free- hand place- ment	Immedi- ate loading	<8 mm	Heat cure acrylic resin	Natural teeth- 11 Natural teeth and fixed prosthesis on natural teeth-9 Implant- supported bridge-2 Natural teeth and 2 implant- supported bridge-2	1 week	For 1 year	After 1 year: 0.8 ± 0.4	NA
	Clinical Implant Den- tistry and Related Research 2017														
												3-6 months	For 7 years	After 7 years: 1.2 ± 0.3	
												1 year			

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants	No. of implants in each arch	Angulation of implants (°)	Surgical guide/ freehand implant placement	Time of implant placement	Loading protocol	Length of cantilever	Type of provisional prosthesis	Follow-up interval	Follow-up period	Bone loss	Patient satisfaction
30	Agliardi et al.	Prospective study	20	120	6 per arch	30-45	Freehand placement	Immediate and conventional	Immediate loading	NA	Acrylic resin	6 months	For 2 years	After 1 year:	Excellent esthetics, phonetics, and mastication
	The International Journal of Oral and Maxillofacial Implants 2009										Removable prosthesis-4	1 Year	For 5 years	Axial-0.8 ± 0.4	
											Natural teeth and fixed prosthesis on natural teeth-3				
											Natural teeth-4			Tilted-0.9 ± 0.5	
											Fixed prosthesis on natural teeth-5				
											Natural teeth and 2 implant-supported prosthesis-4				
31	Malo et al.	Prospective study	16	68	4 per arch	45	Freehand placement	Immediate and conventional	Immediate loading	NA	Acrylic resin	10 days	2 years	At 6 months: 0.58 mm	NA
	Clinical Implant Dentistry and Related Research 2015										Implant-supported prosthesis-4	6 months		After 1 year: 0.85 mm	
											Natural teeth-2				
											Combination of both-10				

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S. no.	Authors/ journal	Type of study	Sample size	No. of implants in each arch	Angula- tion of implants (°)	Surgical guide/ freehand implant place- ment	Time of implant place- ment	Loading protocol	Length of cantilever mm	Type of prosthesis	Type of oppo- sition	Follow- up interval	Follow- up period	Bone loss	Patient satisfac- tion
32	Piano et al.  Clini- cal Oral Implant Research 2015	Prospect- ive study	21	4 per arch	<30	Surgical guide	Immedi- ate and conven- tional	Imme- diate loading	<15 mm	Acrylic resin	Natural teeth with partial removable prosthesis-6 Natural teeth supporting fixed partial prosthesis-3	1 year	2 years	0.34 mm	NA
33	Marcello et al.  Implant Dent. 2015		17	4 per arch	30-45	NA	Immedi- ate and conven- tional	NA	NA	Acrylic resin	Natural teeth-10 Implant- supported bar-retained overdenture-3 CD-7	NA	3 years	NA	NA
											Implant- supported prosthesis-7				



**Table 2:** Distribution of the type of study

S. no.	Type of study	Number	Percentage
1	Prospective Clinical Cohort	14	42.42
2	Retrospective Pilot Investigation Comparative	11	33.33
3	Clinical report	1	3.03
4	Clinical study	1	3.03
5	Clinical trial	1	3.03
6	Preliminary report	1	3.03
7	Pilot study	1	3.03
8	Longitudinal study	1	3.03
9	Not mentioned	1	3.03

**Table 3:** Angulation of implants used

S. no.	Implant angulation (°)	No of articles	Percentage
1	30	12	44.44
2	45	6	22.22
3	20–30	1	3.70
4	20–40	1	3.70
5	25–35	1	3.70
6	30–35	2	7.40
7	30–40	2	7.40
8	30–45	5	18.51

at an angulation. The orientation of 60 (37.27%) implants was not mentioned.

In the maxillary arch, 93 implants (57.76%) failed, out of which 19 (11.80%) implants were axially placed, and 38 (23.60%) implants were tilted. The angulation of the remaining 36 (22.36%) implants was not mentioned.

In the mandibular arch, a total of 60 (37.27%) implants failed, out of which 5 (3.11%) implants were axially placed and 10 (6.21%) implants were tilted. The angulation of 45 (27.95%) implants was not specified.

The position and angulation of 8 (4.97%) implants were not specified (Table 3).

## DISCUSSION

### Article Type

Out of the 75 articles obtained 33 were selected which fulfilled all the inclusion criteria.

Fourteen<sup>2,23,25–36</sup> articles (42.424%) were prospective studies of which one (7.14%) was a clinical study<sup>30</sup> and one (7.14%) a cohort study.<sup>27</sup> Eleven articles<sup>1,20,24,37–43</sup> (33.33%) were retrospective studies including one (9.09%) pilot study,<sup>38</sup> one (9.09%) investigation<sup>41</sup> and one (9.09%) comparative study.<sup>39</sup> There was also a clinical report (3.03%),<sup>44</sup> clinical study (3.03%),<sup>22</sup> clinical trial (3.03%),<sup>3</sup> preliminary report (3.03%),<sup>45</sup> pilot study (3.03%),<sup>46</sup> and a longitudinal study

(3.03%).<sup>47</sup> Two (6.060%) articles did not mention the type of study conducted.<sup>48,33</sup> The majority of the articles selected for this review were prospective studies as these types of studies help the clinician to accurately catalog the progress of the treatment.

### Study Population

A total of 2,398 patients were studied of which 967 (40.681%) were males and 1,235 (51.956%) were females. One hundred and ninety-six (8.17%) did not identify the gender of the patients. An average of 72.67 participants was present in each study. The highest sample size was found to be 324 in the article by Paulo Maló, Miguel de Araújo Nobre, Armando Lopes, Ana Ferro, Inês Gravito<sup>24</sup> and the lowest was 12 by Bassi, Andrisani, Lico, Ormanier, Arcuri.<sup>3</sup> The highest number of male participants in a single study was found to be 130<sup>24</sup> and the lowest was 4.<sup>33</sup> The highest number of female participants in a single study was 194<sup>24</sup> and the lowest 7.<sup>3,33,35</sup> The oldest participant was aged 89 years old and the youngest was 23 years old. The average age of the patients was 57.98 years, which shows that the full mouth implant rehabilitation is not necessarily indicated just for the geriatric or younger age group but can be applied to all age groups. The large sample size helps to get statistically significant results and authenticate the treatment protocol.

### Number of Implants Placed

A total of 10,300 implants were placed of which 3,489 (33.87%) were placed in the maxillary arch and 6,045 (58.68%) in the mandibular arch. The location of the remaining 766 (7.44%) implants placed were not specified. A total of 5,069 implants (49.21%) were tilted and 5,116 (49.66%) were axial. The maximum number of implants placed in a single study was 1,296 (12.58%)<sup>24</sup> and the minimum number of implants placed was 48 (0.46%).<sup>3</sup> The maximum number of implants placed in the maxillary arch in a single study was 968 (0.093%) and 1,296 (12.58%)<sup>24</sup> in the mandibular arch. The minimum number of implants used in a study was 36 (0.35%) in the maxillary arch and 4 (0.04%) in the mandibular arch.

### Number of Implants Placed Per Arch

Twenty-eight (84.84%) authors<sup>1–3,20,23–26,28–33,35–39,41–45,47,33</sup> placed four implants per arch, two (6.06%) articles<sup>22,46</sup> placed four to six implants, and one (3.03%) article<sup>40</sup> placed five implants per arch. These 31 (93.93%) authors placed two implants at an angulation. Additionally, two (6.06%) authors<sup>27,34</sup> placed six implants per arch of which four implants were tilted.

### Implant Angulation

The articles used in this review placed the implants in axial positions as well as in different angles. Few studies placed the implants in multiple angles and few used a specific angle for the implant placement. Twelve (44.44%) articles<sup>20,23–25,30–32,36,38,42,43</sup> placed the implants at 30° and six (22.22%) articles<sup>29,35,37,38,44,48</sup> placed the implants at 45°. One (3.70%) article<sup>40</sup> placed the implants at angulations between 20 and 30°, one (3.70%) article<sup>31</sup> between 20 and 40, one (3.70%) article<sup>22</sup> between 25 and 35, two (7.40%) articles<sup>22,28</sup> between 30 and 35, two (7.40%) articles<sup>33,39</sup> between 30 and 40, and five (18.51%) articles<sup>2,27,34,47,33</sup> between 30 and 45. Six (22.22%) articles<sup>1,3,26,41,45,46</sup> did not mention the angulation at which the implants were placed. The placement of implants in

different angulations is an important factor that helps to identify the most favorable angulation which is to be used for the success of the all-on-4 and all-on-6 treatment protocols.

### Use of Surgical Guide

Four (12.12%) studies<sup>31,37,39,45</sup> used a surgical template for surgery using a flapless approach and three (9.09%) studies<sup>35,17,20</sup> used a surgical template with the flap elevation technique. Twenty-six (78.78%) studies did not use surgical templates and employed a freehand implant placement approach.

### Time of Implant Placement

Immediate, delayed, and a combination of the two were practiced. Two (6.06%) authors<sup>33,43</sup> used an immediate placement of implants into the arch after extraction and five (18.51%) authors<sup>24,26,31,37,45</sup> used a delayed protocol for the placement of the implants. A combination of delayed and immediate implant placement was done by 26 (78.78%) authors.

### Loading Protocol

The loading protocol followed by all the authors were different. Six (18.18%) authors<sup>1,3,37,39,42,45</sup> loaded the implants immediately after surgery. Four (12.12%) authors<sup>2,20,25,27</sup> loaded the implants 3 hours after surgery, four (12.12%) authors<sup>35,38,43,47</sup> after 2–3 hours, two (6.06%) authors<sup>27,34</sup> after 4 hours, and two (6.06%) authors<sup>45,48</sup> after 6 hours. One article<sup>30</sup> (3.03%) loaded the implants within 24 hours after surgery and two (6.06%) articles loaded 24 hours after the surgery. One article (3.03%) loaded implants within 48 hours<sup>31</sup> and seven (21.21%) after 48 hours.<sup>22,23,25,32,36,40,41</sup> One article (3.03%) loaded the implants between 8 hours and 48 hours after the surgery, one article (3.03%) after 3 days of surgery,<sup>29</sup> and one (3.03%) 2 months after the surgery.<sup>26</sup> A single article (3.03%) loaded the implants on the same day of the surgery.<sup>24</sup> One article<sup>33</sup> (3.03%) did not mention the loading protocol followed.

### Presence and Length of Cantilever

The use of cantilever was assessed and it was found that 21 (63.63%) articles<sup>1,2,20,22–26,28,30,32,33,36,39,40,42–44,46–48</sup> declared the use of cantilever during restoration and 12 (36.36%) did not use cantilever during restoration.<sup>3,27,29,31,34,35,37,38,41,43,45,33</sup> The longest cantilever used was of 15.20 mm in length<sup>25</sup> and the shortest was of 6.84 mm in length.<sup>23</sup> The use of cantilever should be avoided in complete arch replacement or should be kept to not >2 times the anteroposterior spread or a maximum of 20 mm.

### Type of Provisional Restoration/Prosthesis

The type of provisional or temporary restoration was taken into consideration. Eleven (33.33%) articles gave an acrylic resin prosthesis. Five (15.15%) articles gave an acrylic prosthesis, three (9.09%) articles gave a screw-retained acrylic prosthesis and two (6.06%) articles gave acrylic prosthesis without a metal framework. Three (9.09%) studies placed all-acrylic prostheses. One (3.03%) study gave acrylic resin teeth to the patients and another gave acrylic veneered teeth. Acrylic dentures were given in one study and fixed acrylic resin complete denture was given in another study. One study had given acrylic resin with titanium cylinder. Acrylic resin prosthesis with the screw-retained bar-retained restoration was placed in one study. Fixed metal resin prosthesis was placed in

an article and heat-cured acrylic resin prosthesis in another study. The type of provisional restoration placed influences the load on the implants which has an impact on the success of the implant treatment.

### Type of Opposing Dentition

When the type of opposing dentition was considered it was found that in 311 cases the prosthesis was opposed by the natural dentition. Thirty-nine cases had a combination of natural teeth and fixed prosthesis on the natural dentition. Three hundred and twenty-seven cases had a removable prosthesis opposing the implant-supported prosthesis and 513 cases had implant-supported prosthesis itself on the opposite arch. Eighty-five cases had fixed prosthesis on natural teeth, three had natural teeth supporting fixed partial prosthesis, and five had natural teeth and implant-supported fixed partial prosthesis. Fifty-six cases reported to have a complete denture in the opposing arch and three cases had an implant-supported bar-retained overdenture. In 154 cases, the opposing arch was a combination of natural teeth and implant-supported prosthesis. Nineteen cases had had implant-supported/retained prosthesis. Fixed partial dentures were present in 40 cases and implant-supported bridge in 11 cases. Four cases presented with a combination of natural teeth and 2 implant-supported fixed partial dentures and 10 cases a combination of natural teeth with 2 implant-supported bridges. A combination of removable partial dentures supported by natural teeth was found in 13 cases. Eight cases had fixed partial dentures or removable partial dentures which were not specified by the authors. The type of opposing dentition influences the treatment plan taken for the patient. The forces acting on the implant-supported prosthesis depend on the condition of the opposing dentition. The presence of natural teeth or fixed prosthesis on the opposing arch requires the use of a short cantilever and an increased number of implants. A removable prosthesis on the opposing arch creates a minimum bite force.

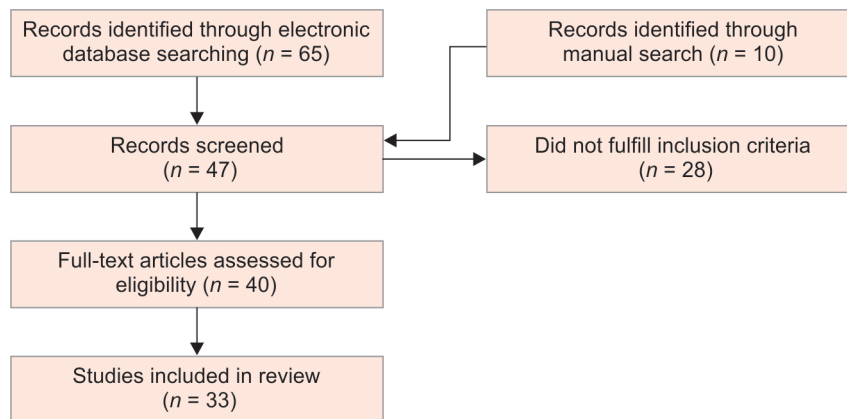
### Follow-up Interval

Most of the studies followed the cases at equal time intervals. Few studies followed-up the subjects at short intervals immediately after the treatment and at a longer interval period after some time. Nine (27.27%) studies followed-up with their patients at an interval of less than a month. Twelve (36.36%) articles followed-up with their patients at an interval of 1–3 months. Twenty (60.60%) articles also had a follow-up interval of 4–6 months and 22 (66.67%) of the studies had followed up the patients at an interval between 7 months and 12 months. The follow-up interval used by few articles is not singular. Few studies had shorter follow-up intervals in the initial few months to a year of the beginning of the treatment which was subsequently increased to extended intervals in the subsequent years. A follow-up interval of 1 month for the initial year of treatment is reasonable. The interval in the subsequent years can be of a longer duration of 6 months to 1 year.

### Follow-up Period

The articles selected for this study had a follow-up period of not less than a year. Eleven (33.33%) studies<sup>3,20,29,35,36,38,42,43,45,46</sup> followed up their patients for a period of 1 to 2 years after implant placement. Seven (21.21%) articles<sup>26–28,31,39,40,33</sup> had followed up their cases for up to 4 years and 11 (33.33%) articles<sup>1,2,22,23,25,30,32,34,41,44,48</sup> followed up their cases for 5–6 years following implant placement. About

Flowchart 1: Article search methodology



four (12.12%) studies<sup>24,33,37,47</sup> maintained patient follow-up for 7 or more years. Patient follow-up helps to carefully evaluate the time of implant failure. The failure of the implant is not a time dependent factor, but most of the implants which failed in the studies did so in the first 6 months after placement (Flowchart 1).

### Bone Loss

An implant is said to be a failure if the peri-implant bone loss is >1 mm in the first year after the placement of an implant. The bone loss in the subsequent years should not be >0.2 mm per year. Twenty-five (0.24%) implants reported a peri-implant bone loss of >1 mm. In the maxillary arch, five (20.00%) implants that lost >1 mm peri-implant bone were axially placed and five (20.00%) were placed at an angulation. In the mandibular arch, six (24.00%) implants showed bone loss >1 mm in which two (8.00%) were axially placed implants and two (8.00%) were tilted implants showed bone loss >1 mm. The angulation and location of nine (36.00%) implants were not mentioned in the articles.

### Patient Satisfaction

All-on-4 and all-on-6 treatment protocol is one of the widely accepted treatment protocols for the rehabilitation of edentulous patients with high levels of patient satisfaction. Six (18.18%) of the articles assessed patient satisfaction.<sup>4,25,27,34,44,46</sup> The patients were completely satisfied with the esthetic and functional outcome of the prosthesis. The ultimate aim of all prosthodontic treatments is patient satisfaction in terms of their appearance, functionality, and comfort of the prosthesis.

### CONCLUSION

The following conclusions were derived from the findings of this review:

- The survival rate of tilted implants at the implant and prosthetic levels is good.
- There is no significant difference between the survival rate of tilted and axial implants at implant and prosthetic levels.
- Tilted implants provide greater surface area for osseointegration, provide greater primary stability, reduce cantilever length, reduce bone resorption, and also reduce the need for bone grafting.

- The angulation of the implant which provided the most success was found to be 30°.

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