Review

# Survival rates of axial and tilted implants in the rehabilitation of edentulous jaws using the All-on-four™ concept: A systematic review

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## Abstract

**Aim:** The aim of this review was to evaluate the survival rate of axial and tilted implants in rehabilitation of edentulous jaws using all on four concept.

**Setting and Design:** Systematic Review.

**Materials and Methods:** A literature review was performed in MEDLINE, PubMed Central (PMC), Google scholar, Embase, Cochrane Central Register of Controlled Trials. Hand searches were conducted of the bibliographic of related journals and systematic reviews. A total of 380 articles were obtained from the intial screening process. Of these articles, 25 articles fulfilled the inclusion criteria. The authors performed evaluation of articles independently as well as data extraction and quality assessment.

**Statistical Analysis Used:** Qualitative analysis.

**Results:** The major prosthetic complication was the fracture of the acrylic prosthesis. The mean cumulative survival rate of implants (72-132 months) were 94% to 98%. The prosthesis survival rate (12 months) was between 99% to 100%. The averaged bone loss was 1.3 ±0.4 mm (12-60 months). No Significant difference was found between survival rates of axial and tilted implants nor between maxilla and mandible.

**Conclusion:** All on four concept can be employed successfully in the edentulous patients with resorbed ridges while improving their quality of life and reducing morbidity. However,randomized clinical trials with large sampling size and long term follow up should be incorporated.

**Keywords:** All-on-four™, axial implants, mandible, maxilla, tilted implants

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## INTRODUCTION

The occurrence of edentulism among elderly patients has been shown to have a negative impact on their quality of life.[1] It is a debilitating and irreversible condition leading to functional impairment and physical, psychological, and social disability. The treatment options available for these

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patients are complete dentures and removable or fixed implant-supported prosthesis.

Prosthetic rehabilitation of completely edentulous patients with implants is a reliable mode of treatment, but its success depends on the availability of good quality and quantity of bone. Patients with severe resorption of the alveolar bone require prior surgical intervention such as bone augmentation and sinus lift procedures for a successful outcome.[1,2,5] These techniques increase patient morbidity and treatment fees and can have associated complications. To overcome these disadvantages, the concept of "All-on-four™" was introduced by Paulo Malo in 2003.[70] This concept demonstrates placing two anterior implants in an axial position and two posterior implants with a tilt of up to 45° to support a full-arch fixed restoration. Bone grafting is avoided by tilting the posterior implants, thus utilizing the available bone. Advantages of tilting implants are that it eliminates the need for invasive procedures such as sinus floor augmentation and bone augmentation, preserves anatomical structures such as sinus floor in the maxilla and inferior alveolar nerve in the mandible, allows for placement of longer implants with good cortical anchorage, and increases interimplant space, thus reducing cantilever length in jaws and helping in better force distribution, thus reducing load on the implants.[1-4,6,11,13,15,18,26] Disadvantages of tilting implants include the technical sensitivity of the procedure and the need of computer-guided surgical stent for implant to be placed in an optimal position.[6,11,13,18] The purpose of this review article is to evaluate the survival rate (SR) of axial and tilted implants to rehabilitate completely edentulous maxilla and mandible.

### Objectives of the study

The objectives of the study are to evaluate the survival rates of tilted and axial implants placed in human either in the maxilla or mandible using All-on-four treatment concept, bone level changes around these implants, and survival rates of fixed dental prostheses on these implants.

## MATERIALS AND METHODS

### Search method and identification of studies

A literature review was performed in MEDLINE, PubMed Central, Google Scholar, Embase, and Cochrane Central Register of Controlled Trials.

Keywords such as "All on 4," "All-on-four," "tilted implant," "angled implant," "upright implant," "axial implant," "four implants," "edentulous patient," "edentulous mandible," and "edentulous maxilla" were used alone or in combination.

### Types of studies

Clinical trials reporting on the survival rates of axial and tilted implants, survival rates of full-arch fixed prosthesis, and changes in the bone levels around implants with a minimum follow-up period of 1 year were considered.

The following articles were excluded:

- Systematic reviews
- Case reports
- Biomechanical trials
- Finite-element analyses and
- Trials including more than four implants, zygomatic implants, and pterygoid implants.

### Types of participants

Studies involving only human subjects were included.

### Types of outcome measurements and data collection

For each study, the following data were collected: name of the authors, type of study design, number of jaws investigated, total number of implants, number of implants in the maxilla and mandible, implant survival rates, prosthesis survival rates, and marginal bone loss.

## RESULTS

The electronic search yielded a total of 380 articles. The search results were combined, and articles including the words "case report," "literature review," and "finite element analysis" in the title were excluded and seventy papers were considered. Of these, 45 trials were excluded after reading full texts for the initial screening process [Tables 1-3], and 25 articles fulfilled the inclusion criteria. Fourteen studies reported were prospective studies and 11 studies reported were retrospective studies [Tables 2 and 4].

**Table 1: Search results**

Search Results

| All-on-4 | All on four | Tilted implants | Angled implants | Axial implants | Upright implants | Four implants |
|---|---|---|---|---|---|---|
| 32 | 12 | 14 | 8 | 11 | 14 | 289 |

Total articles=380

↓

(Analysis of titles and abstracts)

↓

70 articles

↓

(Analysis of Full texts)

↙ ↘

45 articles Eliminated

25 articles Included

14-Prospective studies

11-Retrospective studies

### Outcomes of the studies

During the follow-up period, it was seen that the majority of implant failures were seen within 12 months of surgical placement. The reasons for failure were reported to be lack of osseointegration and infections.

There was no significant difference in the outcome of tilted versus axial implants in the maxilla and the mandible. In addition, no significant difference was found between tilted and axial implants in their respective jaws [Table 4].

The most common prosthesis-related problem reported was fracture of the provisional acrylic prosthesis. Other problems reported were wear patterns in the opposing dentition and prosthetic screw loosening in the cases of bruxers.

In all the studies, bone-level changes were evaluated based on the measurements of the distance between the implant neck and the first sign of bone-to-implant contact radiographically. Marginal bone loss level was reported separately for both tilted and axial implants in 15 trials. It was found that there was no significant difference for bone loss values for both tilted and axial implants and also for maxillary and mandibular implants.

## DISCUSSION

The "All-on-4" concept to support fixed full-arch prostheses has been gaining popularity because it offers a predictable treatment option to rehabilitate edentulous patients while eliminating regenerative procedures and complications inherent to these procedures. The patient is benefitted by the provision of a fixed full-arch prosthesis on the day of the surgery, a shorter treatment time due to elimination of time-consuming bone-grafting procedures, and the low cost of the treatment compared to conventional implant treatment modalities.

**Table 2: Included studies**

| Author | Title |
|---|---|
| Agliardi *et al*.[1] | Immediate loading of full-arch fixed prostheses supported by axial and tilted implants for the treatment of edentulous atrophic mandibles |
| Agliardi *et al*.[2] | Immediate rehabilitation of the edentulous jaws with full-arch fixed prostheses supported by four implants: Interim results of a single cohort prospective study |
| Babbush *et al*.[3] | The All-on-four immediate function treatment concept with NobelActive® implants: A retrospective study |
| Butura *et al*.[4] | Mandibular All-on-four therapy using angled implants: A 3-year clinical study of 857 implants in 219 jaws |
| Capelli *et al*.[5] | Immediate rehabilitation of the completely edentulous jaw with fixed prostheses supported by either upright or tilted implants: A multicenter clinical study |
| Crespi *et al*.[6] | A clinical study of edentulous patients rehabilitated according to the "All-on-four" immediate function protocol |
| Francetti *et al*.[7] | Immediate rehabilitation of the mandible with fixed full-arch prosthesis supported by axial and tilted implants: Interim results of a single cohort prospective study |
| Francetti *et al*.[8] | Bone-level changes around axial and tilted implants in full-arch fixed immediate restorations. Interim results of a prospective study |
| Hinze *et al*.[9] | Immediate loading of fixed provisional prostheses using four implants for the rehabilitation of the edentulous arch: A prospective clinical study |
| Landázuri-Del Barrio *et al*.[10] | A prospective study on implants installed with flapless-guided surgery using the All-on-four concept in the mandible |
| Maló *et al*.[11] | The use of computer-guided flapless implant surgery and four implants placed in immediate function to support a fixed denture: Preliminary results after a mean follow-up period of 13 months |
| Weinstein *et al*.[12] | Immediate rehabilitation of the extremely atrophic mandible with fixed full-arch prosthesis supported by four implants |
| Maló *et al*.[13] | "All-on-4" immediate-function concept for completely edentulous maxillae: A clinical report on the medium- (3 years) and long-term (5 years) outcomes |
| Galindo *et al*.[14] | Immediately loaded mandibular fixed implant prosthesis using the All-on-four protocol: A report of 183 consecutively treated patients with 1 year of function in definitive prostheses |
| Maló *et al*.[15] | All-on-4 immediate function concept with Branemark system implants for completely edentulous edentulous maxilla: A 1-year retrospective clinical study |
| Balshi *et al*.[16] | A retrospective analysis of 800 Branemark system implants following the All-on-Four™ Protocol |
| Di *et al*.[17] | The All-on-Four implant therapy protocol in the management of edentulous Chinese patients |
| Malo *et al*.[18] | A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up |
| Agliardi *et al*.[19] | Immediate fixed rehabilitation of the edentulous maxilla: A prospective clinical and radiological study after 3 years of loading |
| Cavalli *et al*.[20] | Tilted implants for full-arch rehabilitations in completely edentulous maxilla: A retrospective study |
| Lopes *et al*.[22] | The NobelGuide® All-on-4 treatment concept for rehabilitation of edentulous jaws: A prospective report on medium- and long-term outcomes |
| Browaeys *et al*.[23] | Ongoing crestal bone loss around implants subjected to computer-guided flapless surgery and immediate loading using the all-on-4 concept |
| Maló *et al*.[26] | All-on-4 treatment concept for the Rehabilitation of the completely edentulous mandible: A 7-year clinical and 5-year radiographic retrospective case series with risk assessment for implant failure and marginal bone level |
| Krennmair *et al*.[27] | Clinical outcome and peri-implant findings of four-implant-supported distal cantilevered fixed mandibular prostheses: 5-year results |
| Maló *et al*.[70] | "All-on-Four" immediate function concept with Branemark system implants for completely edentulous mandibles: A retrospective clinical study |

**Table 3: Excluded studies and reasons for the exclusion**

| Excluded studies | Reason for exclusion |
|---|---|
| Arvidson *et al*.[21] | Number of implants (more than four implants) |
| Arvidson *et al*.[24] | Number of implants |
| Astrand *et al*.[25] | Overdentures |
| Agliardi *et al*.[28] | Number of implants |
| Ata-Ali *et al*.[29] | Literature review |
| Bedrossian[30] | Zygoma implants |
| Bedrossian[31] | Zygoma implants |
| Butura *et al*.[32] | Case reports |
| Cannizzaro *et al*.[33] | Study design |
| Degidi *et al*.[34] | Number of implants |
| Del Fabbro *et al*.[35] | Literature review |
| Di *et al*.[36] | Language |
| Ekelund *et al*.[37] | Number of implants |
| Eccellente *et al*.[38] | Removable prosthesis |
| Friberg and Jemt[39] | Implants not tilted |
| Ferreira *et al*.[40] | Case report |
| Graves *et al*.[41] | Zygoma implants |
| Graves *et al*.[42] | Zygoma implants |
| Heschl *et al*.[43] | Removable prosthesis |
| Jensen *et al*.[44] | Case report |
| Jensen *et al*.[45] | Case report |
| Jensen *et al*.[46] | Case report |
| Jensen *et al*.[47] | Case report |
| Jensen and Adams[48] | Case report |
| Krekmanov *et al*.[49] | Number of implants |
| Khatami and smith[50] | Case report |
| Li *et al*.[51] | Number of implants |
| Menini *et al*.[52] | Literature review |
| Orentlicher and Abboud[53] | Letter |
| Oyama *et al*.[54] | Study design |
| Penarrocha *et al*.[55] | Overdentures |
| Peñarrocha *et al*.[56] | Zygoma implants |
| Pomares[57] | Number of implants |
| Penarrocha-Oltra *et al*.[58] | Literature review |
| Pomares[59] | Number of implants |
| Parel and Philips[60] | Number of implants |
| Osen and Gynther[61] | Number of implants |
| Romanos *et al*.[62] | Removable prosthesis |
| Wu *et al*.[63] | Study design |
| Christopher *et al*.[64] | Study design |
| Babbush *et al*.[65] | Case report |
| Maló *et al*.[66] | Study design |
| Molina *et al*.[67] | Case report |
| Niedermaier *et al*.[68] | Study design |
| Sannino *et al*.[69] | Study design |

Out of 380 publications, only 25 papers provided substantial information about the all-on-4 concept to evaluate the SR of axial and tilted implants, fixed prostheses, and marginal bone-level changes.

Most of the studies reported were of retrospective or prospective. None of the studies were designed as a randomized controlled trial (RCT).

Malo *et al*.[18] reported the results of implant SR up to 132 months (cumulative survival rate [CSR] 94.8%) and a SR up to 72 months (CSR 98%). In this review, no statistically significant difference was observed in the SR of axial and tilted implants. Due to the absence of RCT, the efficacy of immediate rehabilitation supported by axial and tilted implants cannot be evaluated definitely, However, based on the included studies in the review, it is seen that prognosis of the implant is excellent.[1-20,22,23,26,27]

Regarding marginal bone level changes, no significant difference was found between axial and tilted implants. Most of the included studies reported limited marginal bone loss on an average of <1.5 mm for axial and tilted implants for a follow-up period of 12 months.[1,2,5-17,19,22,23,26,27] The studies by Maló *et al*.[26] and Krennmair *et al*.[27] reported limited marginal bone loss of 1.74 mm and 1.17 mm for axial implants and 1.76 mm and 1.24 mm for tilted implants, respectively, for a follow-up period of 5 years. Only one study defined success criterion for bone loss as no more than 1.5 mm by the end of the 1st year of functional loading or 0.2 mm/year in the subsequent years.[5]

In addition, when comparing either the maxilla and mandible, no statistically significant differences were found in the SR of implants.

The above-mentioned studies suggest that the placement of implant in the jaws (maxilla/mandible) or angulation of implant using the "All-on-4" concept does not affect the bone levels.

The prostheses were incorporated within 48 h after the surgery in all the included studies. The most common complication reported was the fracture of the acrylic prosthesis. This was mainly seen in bruxers due to progressive wear of the resin material. Therefore, it is recommended to reinforce definitive prostheses with cast metal frameworks.

### Limitations

This review is based only on prospective and retrospective studies which gave limited information on the prognosis of the All-on-4 technique for a short term. To determine the efficacy of this, RCTs with large sample size and long-term follow-up should be incorporated.

## CONCLUSION

The All-on-four treatment concept seems to be an approach for edentulous jaws according to the common demand of a cost-effective treatment concept, decreased treatment times, and higher patient quality of life compared to extended surgical approaches. The results obtained from the studies indicate an

**Table 4: Summary of the included studies**

| Study | Study design | Number of jaws | Total number of implants | Number of implants in maxilla | Number of implants in mandible | Implant Survival Rate (SR) | Prosthesis Survival Rate (SR) | Bone loss/follow up (mm/months) |
|---|---|---|---|---|---|---|---|---|
| Agliardi *et al.*[1] | Prospective | 24 | 96 | 96 | - | CSR 100% | CSR 100% | Axial implants ( 0.9±0.4/12) Tilted implants (0.8±0.5/12) |
| Agliardi *et al.*[2] | Prospective | 173 | 692 | 288 | 404 | CSR 98.36% maxilla CSR 99.73% mandible | Not reported | 0.9±0.7/12 maxilla 1.2±0.9/12 mandible No significant difference reported between tilted and axial implants |
| Babbush *et al.*[3] | Retrospective | 177 | 708 | 436 | 272 | CSR 99.3% maxilla CSR 100% mandible | CSR 100% | Not reported |
| Butura *et al.*[4] | Retrospective | 219 | 876 | - | 876 | Axial SR 99.54% Tilted SR 99.7% CSR 99.77% | SR 100% | Not reported |
| Capelli *et al.*[5] | Prospective | 24 | 96 | - | 96 | CSR 100% | SR 100% | Axial implants (0.82±0.64/12) Tilted implants (0.75±0.55/12) |
| Crespi *et al.*[6] | Prospective | 44 | 176 | 96 | 80 | Axial SR 100% Tilted SR 96.59% | SR 100% | Axial implants Axial implant in maxilla in mandible 1.02±0.35/12 1.04±0.30/12 1.08±0.41/24 1.04±0.35/24 1.10±0.45/36 1.06±0.41/36 Tilted implants Tilted implants in Mandible in Mandible 1.05±0.29/12 1.05±0.32/12 1.07±0.46/24 1.09±0.29/24 1.11±0.32/36 1.12±0.12/36 |
| Francetti *et al.*[7] | Prospective | 62 | 248 | - | 248 | CSR 100% | SR 100% | Axial implants (0.7±0.4/12) Tilted implants (0.7±0.5/12) |
| Francetti *et al.*[8] | Prospective | 16 | 64 | 64 | - | CSR 100% | SR 100% | Axial implants Tilted implants 0.40±0.27/12 0.32±0.28/12 0.44±0.37/24 0.63±0.38/24 0.85±0.74/36 0.85±0.34/36 |
| Hinze *et al.*[9] | Prospective | 37 | 148 | 76 | 72 | SR in maxilla 96.6% SR in mandible 98.7% | SR 100% | Axial implants (0.82±0.31/12) Tilted implants (0.76±0.49/12) |
| Landazuri-Del Barrio *et al.*[10] | Prospective | 16 | 64 | - | 64 | SR 100% | SR 93.75% | 0.13±0.03/0 0.83±0.14/12 |
| Malo *et al.*[11] | Prospective | 23 | 92 | 72 | 20 | CSR in maxilla 97.2% CSR in mandible 100% | - | 0.2±0.7/0 1.9±0.9/12 |
| Weinstein *et al.*[12] | Prospective | 20 | 80 | - | 80 | CSR 100/24 CSR 100/36 CSR 100/48 | CSR 100 | Axial implants 0.6±0.3/12 Tilted implants 0.7±0.4/12 |
| Malo *et al.*[13] | Retrospective | 242 | 968 | 242 | 968 | CSR 98.3/12 CSR 98.0/48 CSR 98.1/24 CSR 98.0/60 CSR 98.0/36 CSR 98.0/72 | Not clear | Axial implants 1.52±0.31/36 Tilted implants 1.95±0.44/60 |
| Galindo *et al.*[14] | Retrospective | 183 | 732 | - | 732 | SR 99.86% | SR 97.27% | On average: less than 1/12 |
| Malo *et al.*[15] | Retrospective | 32 | 128 | 128 | - | SR 97.6% | Not clear | 0.9±1.02/12 Axial implants 1.01±1.0/12 Tilted implants 0.9±1.1/12 |
| Balshi *et al.*[16] | Retrospective | 200 | 800 | 300 | 500 | CSR in maxilla 96.3% CSR in mandible 97.8% | CSR 99.0 | - |
| Di *et al.*[17] | Prospective | 86 | 344 | 152 | 192 | CSR 96.2/33.7 | CSR 96.5% | Axial implants 0.7±0.2 mm Tilted implants 0.8±0.4 mm |

*Contd..*

**Table 4: Contd...**

| Study | Study design | Number of jaws | Total number of implants | Number of implants in maxilla | Number of implants in mandible | Implant Survival Rate (SR) | Prosthesis Survival Rate (SR) | Bone loss/follow up (mm/months) |
|---|---|---|---|---|---|---|---|---|
| Malo *et al*.[18] | Prospective | 245 | 980 | - | 980 | CSR 98.3/12 CSR 96.3/96 CSR 98.3/24 CSR 94.8/108 CSR 98.6/36 CSR 94.8/120 CSR 98.5/48 CSR 94.8/132 CSR 98.4/60 CSR 98.1/72 CSR 97.9/84 | CSR 99.2% | Not reported |
| Aligardi *et al*.[19] | Prospective | 32 | 192 | 192 | - | CSR 98.96% | CSR 100% | Axial implants 1.55±0.31mm Tilted implants 1.46±0.19mm |
| Cavalli *et al*.[20] | Retrospective | 34 | 136 | 136 | - | CSR 100% | Not clear | Not reported |
| Lopes *et al*.[22] | Prospective | 23 | 92 | 72 | 20 | CSR 96.6% | 100% | 1.7mm/1yr 1.7mm/2yrs 1.9mm/3yrs |
| Browaeys *et al*.[23] | Prospective | 20 | 80 | 36 | 44 | CSR 100% | 100% | Axial Tilted implants implants 1.13±0.71/1 yr 1.55±o.73 1.55±0.73/3yrs 1.67±1.22 |
| Krennmair *et al*.[27] | Retrospective | 38 | 152 | - | 152 | CSR 100% | - | Axial implants 1.17±0.26mm/5 yrs Tilted implants 1.24±0.8mm/5 yrs |
| Malo *et al*.[26] | Retrospective | 324 | 1296 | - | 1296 | CSR 95.4% | CSR 99.7% | Axial implants 1.74mm/5 yrs Tilted implants 1.76mm/5yrs |
| Malo *et al*.[70] | Retrospective | 14 | 56 | - | 56 | CSR 98.2% | CSR 100% | 0.6±0.6/? |

implant SR of 98% to 94.8% for a follow-up period of 72–132 months. The marginal bone loss of 1.5 mm to 1.7 mm for axial and tilted implants was reported for a follow-up period of 12–60 months. The prosthesis SR was reported between 99% and 100% for the follow-up period of 12 months. Proper patient selection, thorough evaluation of patients, and good surgical skills of the operator are important to establish predictable treatment outcomes.

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## Conflicts of interest

There are no conflicts of interest.

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