

**Restoring the Edentulous Mandible: An ICOI Committee Review, Assessment and
Recommended Guidelines Regarding Number and Type of Implants for Fixed
Restorations and Overdenture Attachments for Removable Restorations**

ABSTRACT

Objectives:

The aim of this Committee Review and assessment was to recommend evidence-based guidelines in support of the long-term successful fixed restoration on tilted implants, multiple implants and type of connection for use with removable overdentures when used in the edentulous mandible.

Materials and methods:

A search of PubMed using predetermined keywords and inclusion criteria was performed. The search was limited to English language articles covering the period between 2000 and 2017. Pertinent data points were extracted and recorded regarding the study design, the follow-up period, number of patients, implant survival rates, level of bone resorption, and complications. These data points were summarized and formed the basis for the evidence-based clinical guidelines.

Results:

The literature search initially yielded 864 publications. After the review committee applied the inclusion and exclusion criteria, there were 31 significant studies which met the objectives. These 31 studies were divided into 2 types of reports: fixed implants retained denture (n=24) and removable implant overdentures using various attachment types (n=7). The committee concluded that fixed implant supported restoration is requested mainly by

younger patients (age 30-40 years), and that if bone volume is sufficient, 6 implants or more are recommended. Tilted implants are recommended in cases where bone volume is not sufficient, and usually in older patients (age 50-70 years). Overdentures are the preferred treatment option for elderly patients who lacks bone volume to support multiple implant placement. Results of the review showed that all attachment types improve denture stability. The main disadvantage of overdentures is the long-term maintenance requirement.

Conclusion:

The high survival and success rates reported in the reviewed studies confirm the predictability and efficacy of multiple implant and tilted implant treatment (all-on-four concept) for rehabilitation of completely edentulous mandibles. Minimal marginal bone loss was also reported, along with increased patient satisfaction. Different attachment systems have been successfully used with removable implant overdentures restoration and assist in preventing vertical movement of the denture, leading to increased patient satisfaction.

INTRODUCTION

The typical resorption pattern of the mandible makes rehabilitation both complex and difficult.¹ Treatment choices for edentulousness in the mandible include conventional complete dentures, implant-supported fixed restorations, and implant-retained and supported overdentures.²

Traditionally, the standard of care for edentulous patients has been complete maxillary and mandibular dentures. However, problems with mandibular dentures are frequently reported due to their high mobility, poor stability, and/or challenges with retention.³ Additionally, many patients report complications such as pain, chewing, and speech difficulties that may have both personal and social implications.³ Using implants to support complete dentures improves mastication, speech, comfort, denture stability and retention, and patient satisfaction,⁴ and implant-supported overdentures are now considered the treatment of choice for rehabilitation of the edentulous mandibles.⁴ Long-term clinical studies have shown that this type of restoration can be successful for many years.⁵ However, the cost differential between dentures and implants has prevented many edentulous patients from receiving these more technically challenging and expensive fixed treatment alternatives.

Several implant-based options exist. Implant-supported restorations can be attached to implants with screws or can be cemented to abutments that are secured to implants with screws.⁶ Options include the use of multiple implants and tilted implants (“All-on-four”). The multiple implant option is when 4 to 6 implants are considered for use in supporting mandibular full-arch prostheses.⁷ Increases in the number of supporting implants increases the treatment cost and leads to more invasive surgical procedures.⁷ However, a larger number of implants produces greater prosthetic stability and preserves the supporting peri-implant bone.⁸ The all-on-four approach is a full arch rehabilitation of edentulous jaws with

immediate function through a fixed prostheses supported by four implants – two straight anterior implants and two tilted posteriorly.⁹⁻¹² The tilted implants are placed in areas where bone height, nerve proximity, inferior alveolar canal and mental foramen prevent the placement of straight implants. They also enable the placement of longer implants, increase the inter-implant distance, decrease cantilever length, and decrease the need of bone augmentation.¹³⁻¹⁵

Mandibular implant overdentures (OVDs) offer a less costly but effective rehabilitative treatment for edentulous patients.¹⁶⁻¹⁸ Although there are numerous studies reporting implant and denture-related complications, there is a lack of knowledge on the influence of implant number and attachment type on overdenture maintenance.¹⁹ Several studies have indicated the clinical advantages of two-implant-retained overdentures in terms of retention, stability, and patient satisfaction.²⁰

Type of overdenture attachment is also a clinical consideration. In recent years, various attachments systems have been successfully used with removable implant overdentures. All available attachment systems are designed to prevent vertical movement of the denture and can be used as an isolated attachment mounted directly to an implant or attached to a bar system. The choice of the attachment is dependent upon the retention required, jaw morphology, anatomy, mucosal ridge, oral function, and patient compliance for recall.²¹ Overdentures can be attached to implants with splinted attachments such as bars or un-splinted attachments, eg, locators ball anchors or double crowns.^{21,22}

Objectives

The aim of this literature review and assessment was to evaluate and recommend evidence-based guidelines in support of the long-term successful fixed restoration on tilted implants,

multiple implants and type of connection for use with removable overdentures when used in the edentulous mandible.

MATERIALS AND METHODS

A search through the databases of PubMed using the following key words was performed: multiple implants, implant number, edentulous mandible, ball attachment, bar attachment, locator, telescopic attachment, attachments, mandibular overdenture, tilted implants (All-on-4), two implants, fixed prosthesis, double crown, fixed restorations, conventional denture, number of implants, marginal bone loss, survival rate, and mechanical complications.

The search was limited to English language articles covering the period between 2000 and 2017. Two evaluators performed each step of the literature search.²³ The following inclusion criteria was applied for the data extraction process:

Inclusion Criteria

1. Human studies with at least 10 patients treated
2. A follow-up time of at least 3 years
3. Patients treated with fixed implant reconstructions, with either multiple or tilted implants OR patients treated with removable denture on implants AND where different connectors are discussed.
4. Publication contained detailed information on the implant-abutment connections (internal or external)

Exclusion Criteria

1. Case reports
2. Literature reviews
3. In vitro studies
4. Non-clinical studies

After the publications were selected based on the above criteria, they were reviewed and assessed by the review committee. Pertinent data points were extracted and recorded regarding the study design, the follow-up period, number of patients, implant survival rates, level of bone resorption, and complications. These data points were summarized and formed the basis for the recommended clinical guidelines.

RESULTS

The literature search initially yielded 864 publications. After the committee (authorship team) applied the inclusion and exclusion criteria for the data extraction objectives, there were 31 publications remaining. These 31 studies were divided into groups:

1. Fixed implants-retained denture, using either multiple or tilted implants (n=24 publications). Few complications were reported including screw loosening and acrylic and metal frame-work fractures (Table 1).
2. Removable implant overdentures using various attachment types (n=7 publications). This group presented with a high rate of prosthetic complications. The majority of the cases which experienced adverse events had fracture of the acrylic teeth and soft tissue inflammation (Table 2).

The qualifying publications were qualitatively analyzed by subgroup, with notable findings summarized below:

Fixed Implants Retained Denture

Numerous studies have reported high survival rates of implant-supported mandibular overdentures with minimal marginal bone loss, regardless of the loading protocol. Technical complications were few.²⁴⁻²⁸ Patients reported satisfaction with the phonetics, esthetics and functional aspects once treatment was completed.

Multiple implants

A retrospective study on this topic included 156 completely edentulous patients. The patients were rehabilitated with fixed prostheses on either 4 or 6 screw-shaped titanium implants. The implant survival rate for prostheses on 6 implants was 93.2%.²⁹

Two significant retrospective studies which were performed by the same research group assessed the 1-year outcome of 3 different treatment procedures treating the edentulous mandible. They reported a 1-year CSR of 97.5% and mean marginal bone resorption of 0.4mm.³⁰ The outcomes of this study were compared with a previous study that used the two-stage implant surgical technique.³¹ The study included 68 patients treated with 338 turned Branemark System implants. 5, 60 and 3 patients received 4, 5 and 6 implants each. The CSR was 99.7% and there was no difference in marginal bone resorption between the two surgical procedures. In 2007 the authors retrospectively evaluated the 1-year treatment outcome of one stage surgery and early loading using 450 TiUnite implants.³¹ The study involved 90 patients, each patient received 5 implants. They reported a CSR of 100% and mean marginal bone resorption of 0.49 mm. Similar studies reported long-term survival rates in the same study group regardless of the loading protocol and length of distal cantilever.^{28, 32, 33}

Tilted Implants (All-on-four)

A prospective study evaluated the clinical and radiographic outcome of 4 implant-supported fixed mandibular prostheses (4-ISFMP). The study included 41 patients; all patients received 2 anterior axial implants and 2 posterior either axial or tilted implants. Based on the placement directions of the distal implants, patients were divided into two groups: an axial group with 21 patients and 84 implants and a tilted group with 21 patients and 80 implants. Patients were followed annually for 3 years presenting no implant loss (100% survival). The marginal bone resorption (MBR) at year 1, 2 and 3 was 1.11 ± 0.4 mm, 1.26 ± 0.42 mm and 1.40 ± 0.41 mm, respectively. MBR did not differ between anterior and posterior regions in both groups or between them. Also, biological complications for implants (mucositis, gingival hyperplasia, fistulas and recessions) showed no difference between the groups over the follow-up period.³⁴

A retrospective study assessed the clinical outcomes of treating the edentulous maxilla and mandible with a fixed implant-supported prostheses utilizing a graft-less approach. A total of 34 patients were included in the study. Twenty-one mandibles and 10 maxillae were rehabilitated with the all-on-four protocol; 43 tilted and 42 axial implants were inserted in the mandible. The study presented an overall implant clinical survival rate (CSR) of 98.2% and a CSR of 96.9% and 98.0% for tilted and axial implants, respectively. The implant CSR of each jaw was not reported in the study. However, only one tilted implant failed in the mandible.¹²

A review of these and other studies found that the reported survival rate varied between 94%-97%, and the marginal bone loss was not different from non-tilted implants^{1, 9, 11, 12, 26, 34, 35}. In the reviewed studies, the technical complications or maintenance requirements were inconsistently reported. Additionally, patients were satisfied with their phonetics, esthetics and function.^{36, 37}

Removable Implant Overdentures using Various Attachment Types

Implant-retained overdentures improve masticatory ability and patient perception of functions related to mastication,^{38, 39} especially for patients with resorbed mandibles.³⁹ In addition, implant-retained overdentures enhance maximum bite force^{39, 40} and increase patient satisfaction and comfort during mastication. The improvement of oral function may depend on the type of connectors used for implant overdentures.^{39, 41, 42}

All available attachment systems are designed to prevent vertical movement of the denture, and can be used as an isolated attachment mounted directly to the implant or attached to a bar system.²¹ The choice of the attachment is dependent upon the retention required, jaw morphology, anatomy, mucosal ridge, oral function, and patient compliance for recall.^{43, 44}

Overdentures can be attached to the implants with splinted attachments as casted bars or non-splinted attachments: locators, ball anchors, double crowns, and magnets.^{20, 45} The ball attachments are considered to be the simplest type of attachments for clinical application with tooth-or implant-supported overdentures.²⁰ However, it is also well documented that O-rings gradually lose retention, and must be replaced periodically.^{21, 46} Single ball attachments require significantly more postoperative care during the follow-up period from splinted bar constructions.^{45, 47}

In the last decade, locator attachments have become more popular. These attachments are resilient^{20, 48, 49} and self-aligning, have dual retention, and are available in different colors (clear, pink, blue, green, orange, red) with different retention values.²⁰ When the inter-arch distance or the height of the denture is inadequate for placing ball attachments, several problems may occur. These problems can include fractured teeth adjacent to the attachments, over-contoured prostheses, separation of attachments from the denture, and excessive occlusal dimension. Locator attachments can be a suitable alternative to ball attachments in these situations, because of locator attachments' low profile.^{20, 48, 50}

Past reports have shown that double crown and round casted bars show adequate resistance to vertical dislodgment.^{39, 40, 51, 39, 44, 45, 52-58} Studies of ball and telescopic attachment have shown several findings, and technical complications and maintenance requirements have been addressed in some studies. Results show a high percentage of matrix fractures, relining and rebasing procedures, and matrix activation or replacements have been reported, reflecting the difficulties of various systems with no clear advantage of any system.^{21, 39, 59-61} Studies comparing ball and locator attachments have shown no differences in marginal bone resorption. A study by Krennmair et al showed no significant differences for general satisfaction, comfort, speech, esthetics, chewing ability, or denture stability between the two options.⁶²

DISCUSSION

The review committee assessed and evaluated 31 publications, and distilled the key findings into recommendations by subgroup. Qualitative analysis of the review results were the foundation for these evidence-based clinical guidelines.

Fixed Implants Retained Denture: Recommendations for Clinical Guidelines

The committee concludes that fixed implant supported restoration is requested mainly by younger patients (age 30-40 years). Based on this review, the recommendation is that if bone volume is sufficient, 6 implants or more are recommended. Tilted implants are recommended in cases where bone volume is not sufficient, usually in older patients (age 50-70 years). When using tilted implants, 4 implants are the minimum number, but the clinical recommendation is 5-6 implants for 10-12 crown units.

Removable Implant Overdentures using Various Attachment Types: Recommendations for Clinical Guidelines

Overdentures are the preferred treatment option for the elderly patient who lacks bone volume to support multiple implant placement. Results of the review showed that all attachment types improve denture stability. The main disadvantage of overdentures is the long-term maintenance requirement. Special attention is required in order to minimize maintenance appointments by following manufacturer instructions and replacing attachment components in a timely fashion.

Limitations

Thirty-one published reports met the inclusion and exclusion criteria, which limited the sample size and possibly biased our conclusions. Additionally, since this evaluation sought to evaluate and assess the combined findings of published literature, there are inherent problems in combining study outcome measures due to differing study designs and definitions of outcomes.

CONCLUSION

The aim of this committee assessment was to summarize and recommend several implant-supported rehabilitation options for the edentulous mandible, while examining the effect of the number and type of implants and the type of restoration (fixed/removable) on the success of rehabilitation treatment. Studies reporting different types of attachments were also examined. The high survival and success rates reported in the reviewed studies confirm the predictability and efficacy of multiple implant and tilted implant treatment (all-on-four concept) for rehabilitation of completely edentulous mandibles. Minimal marginal bone loss was also reported, along with increased patient satisfaction. Regardless of differences in efficacy and the various long-term maintenance/complications, the different available attachment systems have been successfully used with removable implant overdentures restoration and assist in preventing vertical movement of the denture, leading to increased patient satisfaction. Evidence-based guidelines were provided which considered patient age and level of suitable bone when planning for restoration.

Table 1: Results from Data Extraction: Fixed Implants-Retained Denture (Multiple or Tilted Implants)

Author	Study Type	Follow up Period	No. of Patients	Implant Survival, %	Bone Resorption	Complications
Fixed Protheses Studies						
Agliardi, et al, 2010 ¹⁵	Prospective	30.1 months	24	100	Tilted implant = 0.8 mm Axial implant = 0.9 mm	None
Capelli M et al, 2007 ³⁶	Multicenter	4 years	24	100	Upright implants: 0.82 ± 0.64 mm tilted implants: 0.75 ± 0.55 mm.	Not reported
Aalam, et al, 2005 ²⁴	Prospective	3 years	16	96.6	1.2 ± 0.1 mm	Not reported
Ekelund JA et al, 2003 ²⁵	Prospective	20-23 years	30	98.9	Mean Bone Level: 1.6 mm below the reference point after 20 years. Mean bone loss: 0.2 mm between the 15-and 20-year follow-ups	Loose gold screws needed to be retightened in 2 patients, 1 patient lost fillings in the screw holes.
Malo. P et al, 2011 ²⁶	Retrospective	10 years	245	94.8	Low Bone resorption	Two patients lost 4 implants
Grandi T et al, 2012 ²⁷	Prospective	18 months	47	100	At 0, 6, 12 and 18 months were -0.02 ± 0.12 mm, 0.31 ± 0.12 mm, 0.58 ± 0.11 mm and 0.7 ± 0.11 mm, respectively	The resin portion of 3 (6.3%) of the provisional fixed dental prostheses fractured in 3 patients.
Gallucci GO et al, 2009 ²⁸	Prospective multicenter Study	5 years	45	100	3 implants with mild bone loss	Reversible numbness of mental nerve (n=4) Inflammation around an implant

Author	Study Type	Follow up Period	No. of Patients	Implant Survival, %	Bone Resorption	Complications
						(n=3). Hypertrophy or hyperplasia of tissue (n=3) Fracture of acrylic tooth or denture base (n=20). Fracture upper denture (n=12)
All-On-Four Implant Studies						
Alzoubi et al 2017 ¹²	Retrospective	10+ years	34	Overall CSR 98.2 Axial implant CSR 98.0 Tilted implant CSR 96.9	Not reported	Not reported
Krennmaier et al, 2016 ³⁴	prospective	3 years	41	100	At 1 year 1.11 ± 0.4 mm At 2 yrs 1.26 ± 0.42 mm At 3 yrs 1.40 ± 0.41 mm	Mucositis Gingival hyperplasia Fistula Recessions
Malo et al, 2015 ³⁵	Retrospective	7 years	324	CSR at 7 yrs 95.4	Marginal bone level 1.81mm	Not reported
Balshi et al, 2014 ¹¹	Retrospective	5+ years	152	CSR after 5 yrs 97.8	Not reported	Not reported
Galindo and Butura 2012 ¹	Retrospective	1+ year	183	CSR 99.86	< 1mm	Not reported
Malo et al, 2012 ⁹	Prospective cohort	1-107 months Mean-26 months	142	CSR at 2 years 94.8 Implant-related	At 1 year 1.4±0.3mm At 5 years 1.7±0.6mm	Peri-implant pathology 0.02% Pockets and clinical attachment loss 100%
Crespi et al, 2012 ¹⁴	Prospective	3+ years	20	CSR 97.5	Upright implants 1.06±0.41 mm Tilted implants 1.12±0.35 mm	Not reported
Malo et al, 2011 ²⁶	Longitudinal	10+ years	245	CSR at 5 yrs 98.1 CSR at 10 yrs 94.8 Implant-related	Low rate	Peri-implant pathology Peri implant pockets of 6mm Bone resorption
Agliardi et al, 2010 ⁶³	Prospective	5+ years	93	CSR at 1 year 99.73%	At 1 year 1.2±0.9 mm	No complications were recorded

Author	Study Type	Follow up Period	No. of Patients	Implant Survival, %	Bone Resorption	Complications
Capelli et al, 2007 ³⁶	Multicentral clinical study	4 years	24	CSR 100	Upright implants 0.82±0.64 mm Tilted implants 0.75±0.55 mm	Not reported
Malo et al, 2003 ³⁷	Retrospective	3 years	44	CSR 96.7	Development group 1.2±1.2 mm Routine group 0.6±0.6 mm	Implant mobility Periapical implant pathology
Multiple Implants Studies						
Schwarz et al 2014 ³²	Prospective	Mean – 7.2 yrs	37	89.7	1.1±1.2 mm	Not reported
Schwarz et al 2010 ³³	Prospective	Mean – 4.5 yrs	37	89.2	Not reported	Not reported
Gallucci et al 2009 ²⁸	Prospective	5+ years	45	100	Not reported	Healing screw Final screw loosening Final screw fracture
Branemark et al 1995 ²⁹	Retrospective	10 years	156	93.2	Not reported	Not reported
Friberg et al 2005 ³⁰	Retrospective	1 year	152	97.5	0.4 mm	Not reported
Friberg and Jemt 2008 ³¹	Retrospective	1 year	90	100	0.49 mm	Not reported

CSR=Cumulative Survival Rate

Table 2: Results from Data Extraction: Removable Implant Overdentures using Various Attachment Types

Author	Study Type	Follow up Period	No. of Patients	Implant Survival, %	Bone Resorption	Complications
Removable Implants Studies						
Bilhan H et al, 2011 ¹⁹	Retrospective	12 months	59	Not reported	Not reported	Ulceration, Dislodged attachment clip, Loss of retention, Fracture of denture Base, Screw loosening
Krennmair G et al, 2007 ⁴⁵	Prospective	5 years	25	100	1.5 ± 0.4 mm	Matrix activated; Overdenture relined/rebased
Elsyad MA et-al, 2014 ⁶⁴	Crossover	12 months	12	Not reported	Not reported	Not reported
Krennmair G et al, 2012 ⁶⁰	Prospective	3 years	51	100	1.4 ± 0.5 mm	Prosthesis teeth fracture/renewed, Overdenture Fracture, Overdenture rebased
Krennmair G et al, 2008 ⁶¹	Prospective	5 years	51	100	Not reported	Gingival hyperplasia, bar fracture, prosthesis fracture
Cakarar S et al, 2011 ²¹	Prospective	41.17 months	36	97.18	Not reported	Overdenture fracture, implant failure, attachment fracture
Krennmair G et al, 2012 ⁶²	Crossover Clinical Study	1 year	19	100	1.6 mm for ball attachment, 1.5 mm for locator attachment	Attachment (Ball/Locator) worn/fracture, Overdenture prosthesis fracture, Overdenture rebased, Denture renewed or rebased

CSR=Cumulative Survival Rate

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