Economic Evaluation of Implant-Supported Overdentures in Edentulous Patients: A Systematic Review

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Purpose: Edentulous patients benefit significantly from implant-supported overdenture prostheses. The purpose of this systematic review was to evaluate the cost-effectiveness of implant-supported overdentures (IODs) for edentulous patients. Materials and Methods: The search was limited to studies written in English and included an electronic and manual search through MEDLINE (Ovid, 1946 to November 2015), Embase (Ovid, 1966 to November 2015), Cochrane Central Register of Controlled Trials (CENTRAL) (to November 2015), and PubMed (to November 2015). Two investigators extracted the data and assessed the studies independently. No meta-analysis was conducted due to the high heterogeneity within the literature. Results: Of the initial 583 selected articles, 10 studies involving 802 participants were included. Of these, 6 studies had a high risk of bias and the rest had an unclear risk of bias. Implant-supported prostheses were more cost-effective when compared to conventional dentures and fixed implant-supported prostheses. Overdentures supported by two implants and magnet attachment were reported as cost-effective. Conclusion: Implant-supported overdentures are a cost-effective treatment for edentulous patients. More clinical studies with appropriate scientific vigor are required to further assess the cost-effectiveness of implant-supported overdentures. Int J Prosthodont 2017;30:321–326. doi: 10.11607/ijp.5023

The successful management of edentulous patients depends on biomechanical support from the alveolar ridges. However, due to the ongoing and cumulative bone resorption observed in edentulous patients, the alveolus will not provide adequate long-term support.1 Conventional removable dentures (CDs), originally the only treatment available for edentulous patients, exhibit psychosocial and functional limitations.2 Dental implants readily rectify the observed clinical limitations by improving chewing ability and biomechanical shortcomings in the edentulous mandible.3–5 Such treatment provides a high level of oral health-related quality of life (OHRQoL), which is particularly relevant in aging populations.5 It was reported that mandibular overdentures supported by two implants provide significantly better mastication and greater satisfaction than CDs in edentulous patients.6–8 However, the treatment costs substantially increase with the number of implants placed in the mandible.9 Economic data on the initial treatment and long-term maintenance provide important information to health authorities and to patients with regard to treatment protocols and decisions.

There is growing evidence for the need to perform economic evaluations of implant-supported overdentures (IODs). Economic evaluations analyze the cost and efficiency of alternative healthcare interventions.10 Cost-effectiveness analysis (CEA) is a recognized method of measuring efficiency in health care.11 In CEA, the incremental effectiveness relative to the incremental costs of an intervention is measured in terms of a clinical outcome or an index of health-related quality of life. Studies have recently been published that emphasize the cost-effectiveness of CDs versus IODs. These studies evaluated the initial treatment and maintenance stages up to a year.12,13 In addition, numerous studies discuss various treatment

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strategies (such as the number of implants and attachment systems) from an economic viewpoint to reduce treatment costs while preserving function. However, proper assessment of the cost-effectiveness of IODs is limited. The purpose of this systematic review was to evaluate, on the basis of currently available evidence, the economic implications of IODs for edentulous patients.

Materials and Methods

This systematic review was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Guidelines.16

Inclusion Criteria

Literature that met the following criteria were considered eligible for this systematic review: (1) the studies were designed as controlled clinical trials (CCTs) or randomized controlled trials (RCTs); (2) participants were diagnosed as edentulous; (3) the comparison for included studies was IOD versus CD or IOD versus implant-supported prostheses; and (4) the studies reported data related to the direct cost (such as initial costs of treatment, total costs, or long-term maintenance costs) or cost-effectiveness of IODs in edentulous patients.

Studies that met the following criteria were excluded from the review: case reports, letters, literature reviews, surveys, and willingness-to-pay studies.

Search Strategy

A thorough literature search was undertaken in the databases of MEDLINE (through Ovid, 1946 to November 2015), Embase (through Ovid, 1966 to November 2015), CENTRAL (to November 2015), and PubMed (to November 2015). The search strategy was established based on a combination of Medical Subject Headings (MeSH). The following MeSH terms were used to retrieve the database: “Dental Implants,” “Dental Implantation, Endosseous,” “Dental Prosthesis, Implant supported,” “Denture, Overlay,” “Mouth, Edentulous,” “Jaw, Edentulous,” and “Costs and Cost Analysis.” In addition, potential useful publications were checked from reference list of eligible studies and relevant articles.

Two reviewers (Q.Z. and X.J.) selected the studies independently by first identifying studies through titles and associated abstracts. For those studies identified as potentially eligible for inclusion, full-text documents were obtained for further assessment. In case of disagreement, a third investigator (X.L.) was consulted.

Quality Assessment

The methodologic quality of the studies was independently assessed by two reviewers (Q.Z. and X.J.) using the Cochrane Collaboration tool. The following aspects were assessed as criteria: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors, incomplete outcome data, and selective reporting. A study was considered to have a high risk of bias if any of the items was assessed as high risk. If any item was considered as unclear risk, the study would be assessed as unclear risk of bias. Only if all the items were evaluated as low risk would the study be considered to have a low risk of bias. A consensus discussion was conducted in case of disagreement. A third reviewer (X.L.) was consulted if necessary.

Data Extraction

The outcome measures were extracted by the same two reviewers and independently recorded in data extraction forms. The same methodology discussed previously was performed in case of disagreement. The following information was extracted: author names, publication year, study design, follow-up period in months, participant numbers, study description, and outcome.

Results

Results of Search

A total of 583 studies were identified from the search. After preliminary assessment of the titles and abstracts, 559 studies were excluded, leaving 24 for further evaluation. Of these, 14 studies were excluded because 2 were systematic reviews, 2 were review articles, 3 were survey articles, and the other 7 did not involve any economic evaluation. Figure 1 presents the flow chart of study inclusion through different phases in accordance with the PRISMA Guidelines.16

Characteristics of Included Studies

The ten included studies consisted of four CCTs and six RCTs. In total, 802 participants were involved. Five studies12,15,20,21,23 compared the treatment costs and cost-effectiveness of CDs with those of IODs in edentulous patients. One study19 reported the clinical and time costs of implant-supported fixed prostheses compared with IODs. Two studies13,22 discussed the cost analysis of implant numbers for IODs. One study18 investigated the cost analysis of loading protocol for IODs. One study14 compared different types of attachment systems for IODs (Table 1).
Due to the heterogeneity of the studies with respect to study design, definition of economic variables, clinical outcome variables, and reported follow-ups, the present authors decided to present the results of this systematic review in a descriptive way.

Quality of Included Studies

All the included studies had good applicability. Risk of bias assessment (Table 2) showed that no study had a low risk of bias, six studies \(^{13-15,18-20}\) had a high risk of bias, and the rest \(^{12,21-23}\) obtained an unclear risk of bias.

Economic Evaluation of Included Studies

CDs vs IODs

Five studies compared the cost and cost-effectiveness of IODs with CDs in edentulous patients \(^{12,15,20,21,23}\).

Heydecke et al \(^{21}\) conducted a RCT involving 60 participants to compare the cost and cost-effectiveness of CDs with overdentures supported by two implants.

Table 1: Characteristics of Included Studies

<table>
<thead>
<tr>
<th>Study design</th>
<th>Follow-up (mo)</th>
<th>Participants (n)</th>
<th>Study description</th>
<th>Outcome reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attard et al (^{19}) (Canada)</td>
<td>CCT</td>
<td>≥ 120</td>
<td>90</td>
<td>Evaluation of long-term costs of implant-supported fixed prostheses vs IOD and treatment years in patients with an edentulous mandible</td>
</tr>
<tr>
<td>Attard et al (^{18}) (Canada)</td>
<td>CCT</td>
<td>12</td>
<td>77</td>
<td>Evaluation of the patient-based outcomes and associated clinical costs of an immediate loading protocol for mandibular overdentures compared with conventional protocol in edentulous patients</td>
</tr>
<tr>
<td>Cristache et al (^{14}) (Romania)</td>
<td>RCT</td>
<td>60</td>
<td>69</td>
<td>Three groups compared different attachment systems for IOD: Group B (balls), Group M (magnets), and Group L (locators)</td>
</tr>
<tr>
<td>Heydecke et al (^{21}) (Canada)</td>
<td>RCT</td>
<td>60</td>
<td>60</td>
<td>Cost-effectiveness analysis of mandibular CDs vs two-implant overdentures</td>
</tr>
<tr>
<td>Stoker et al (^{22}) (Netherlands)</td>
<td>RCT</td>
<td>96</td>
<td>110</td>
<td>Analysis of initial treatment costs and long-term maintenance costs in patients with three different types of IOD (bar on four implants, bar on two implants, or ball attachments on two implants)</td>
</tr>
<tr>
<td>Takanashi et al (^{12}) (Canada)</td>
<td>RCT</td>
<td>12</td>
<td>60</td>
<td>Cost comparison of mandibular two-implant overdenture treatment vs conventional dentures</td>
</tr>
<tr>
<td>Van der Wijk et al (^{23}) (Netherlands)</td>
<td>RCT</td>
<td>12</td>
<td>240</td>
<td>Comparison of the costs of different treatment strategies with CDs: treatment with a mandibular overdenture on permucosal dental implants, an overdenture on a transmandibular implant, new dentures after preprosthetic surgery, and new dentures only</td>
</tr>
<tr>
<td>Walton et al (^{13}) (Canada)</td>
<td>RCT</td>
<td>12</td>
<td>86</td>
<td>Comparison of patient satisfaction, component costs and treatment/maintenance time in patients with mandibular overdenture</td>
</tr>
<tr>
<td>Zitzmann et al (^{20}) (Switzerland)</td>
<td>CCT</td>
<td>6</td>
<td>60</td>
<td>Economic evaluation compared the cost-effectiveness of implant-retained overdentures (2 implants), implant-supported overdentures (4 implants), and CDs</td>
</tr>
<tr>
<td>Zitzmann et al (^{15}) (Switzerland)</td>
<td>CCT</td>
<td>36</td>
<td>60</td>
<td>Cost-effectiveness analysis of implant-retained overdentures, IODs, and CDs</td>
</tr>
</tbody>
</table>

CCT = controlled clinical trial; RCT = randomized controlled trial.

Fig 1: Flowchart of study inclusion.
Cost was recorded in Canadian dollars (CAD). The data indicated that for the first year, the total mean Oral Health Impact Profile 20 (OHIP-20) score after treatment was 33% better in the IOD group than in the CD group, at an additional expense of CAD 1,583. Taking an average 17.9 years for the life expectancy into account, the additional cost of the IOD group was CAD 226 per year. There was a difference of 15.7 OHIP-20 points compared with CD treatment.

Zitzmann et al15,20 compared the cost-effectiveness of CDs and overdentures supported by four or two implants. Groups of 20 patients each were followed up for 3 years. Cost was recorded in Swiss Francs (CHF). Incremental cost-effectiveness ratios were CHF 228 (complete dentures), CHF 581 (two implants), and CHF 2,258 (four implants) per percentage increase in chewing ability. Over 3 years, the incremental cost of quality-adjusted prosthesis per year was CHF 9,100 (two implants) and CHF 19,800 (four implants) for implant treatment, as compared to the CD treatment. Over a 10-year period, this incremental cost of quality-adjusted prosthesis per year was reduced to CHF 3,800 (two implants) and CHF 7,100 (four implants), as compared to the CD group.

A cost comparison of IODs with two implants to CD treatment12 indicated that the direct cost of IOD treatment was 2.4 times higher than that of CD. The total cost ratio of IOD to CD decreased to 1.8 when indirect costs were included. Another RCT23 confirmed that direct costs for IODs were seven times those for CDs. However, for patients requiring preprosthetic surgery, the cost for new dentures was almost the same as for treatment with IOD.

The available evidence suggested that IODs in edentulous patients were associated with high initial treatment costs but were cost-effective over the long term when compared to CDs.

**IODs vs Fixed Implant-Supported Prostheses**

Attard et al19 compared the costs of IODs with those of fixed implant-supported prostheses. This study included 90 participants. Clinical time costs associated with various stages were measured and valued according to patients’ salary rated by age, occupation, and sex. A sensitivity analysis was performed to test the robustness of the cost outcomes. The initial treatment and maintenance costs during the follow-up period were significantly higher for the fixed implant-supported prostheses compared to IODs. There was a significant improvement in the maintenance costs for the fixed prostheses group over the follow-up period. Long-term results over the 15 years of observation indicated that the costs of fixed implant-supported prostheses were significantly higher than those for IODs. The sensitivity analysis at a balanced salary rate demonstrated the same trend. This study showed that the IOD was a less expensive treatment compared to the fixed implant prosthesis.

**Comparison of Implant Numbers for Implant-Supported Overdentures**

Stoker et al22 and Walton et al13 investigated the minimum number of implants for IODs. According to the 8-year follow-up RCT by Stoker et al22 an overdenture supported by two implants might be the most cost-effective protocol over the long term. There were no significant differences in direct maintenance costs between groups with two and four implants ($P = .94$). According to the study, initial costs constituted 75% of total costs. The initial costs in the group with four implants were significantly higher ($P = .018$). In a 1-year follow-up RCT, Walton et al13 indicated that a mandibular overdenture retained by a single midline implant might be an alternative to the customary two-implant overdenture. Over the...
1-year observation, improvement in satisfaction and prosthodontic maintenance time was similar in the two-implant and single-implant groups. However, the single-implant group had significantly lower component costs \( (P < .001) \), shorter surgery times \( (P = .002) \), and less postsurgical denture maintenance \( (P = .021) \) and denture relines \( (P < .001) \).

Comparison of Loading Time for IODs
In a prospective study on 77 participants, Attard et al\(^{18}\) compared different loading protocols for IODs. It was concluded that immediate loading was related to higher maintenance costs and higher total costs. No significant differences were observed in the time costs between immediate and conventional loading protocols. Within-group analysis of costs at various stages of the immediate protocol suggested that IOD treatment was more cost-effective than the conventional protocol.

Comparison of Attachment Systems for IODs
Cristache et al\(^{14}\) evaluated three different types of attachment systems for mandibular IODs. In this 5-year RCT, 69 edentulous patients were treated with two screw-type Straumann implants. Three types of attachment systems (balls, magnets, and locators) were placed according to the early loading protocol. The results indicated that the highest number of maintenance events was observed in the ball group (195) compared with 31 in the locator group and 15 in the magnet group. In addition, the magnet group had the highest prosthetic success rate (82.6%) in 5 years. However, the magnet group had higher costs compared with the other two groups \( (P < .05) \). Analysis of different attachment systems for IODs showed that, despite the relatively higher initial costs, magnets were associated with a high success rate and low maintenance requirements.

Discussion
A discussion on implant success should include all treatment outcomes.\(^{24}\) This systematic review was conducted to present an economic evaluation of IODs for edentulous patients.

It was observed that although IODs led to greater improvement in functional outcomes in edentulous patients, it required substantially higher initial costs compared to complete dentures. These costs were almost three times higher for two implants and six times higher for four implants compared to conventional treatment with complete dentures.\(^{15,20}\) However, Takanashi et al\(^{12}\) pointed out that the total initial treatment time and the following 6 months was similar for CDs and IODs. In another long-term study,\(^{15}\) IODs were reported to have higher incremental cost-effectiveness ratios after 10 years compared to CDs. This indicated that IOD treatment was more cost-effective in the long term, as observed in the present review.

Although initial IOD treatment costs were higher than those for CDs, improvements in OHRIQoL and patient satisfaction were also typically higher in edentulous patients treated with dental implants.\(^{20}\) Many researchers used OHIP-20 scores to analyze the cost-effectiveness of IOD. Heydecke et al\(^{21}\) reported that the total mean post-treatment OHIP score was approximately 33% higher in the IOD group than in the CD group. Meanwhile, there was an additional expense of $1,593 in the IOD group compared to the CD group. To further calculate the costs and lifetime benefits, cost per quality-of-life unit was used. In a study\(^{8}\) on OHIP-20 scale assessment in IOD patients, an improvement of 33% in total OHIP score was observed, while the improvement for the functional limitations and physical disability subscales was 32% and 40%, respectively, indicating that cost per quality-of-life unit improvements in function were similar to those of overall improvements.

A sensitivity analysis of economic evaluation for IODs revealed that cost-effectiveness thresholds depended on the distribution of patient denture satisfaction relating to number of implants.\(^{26}\) In a meta-analysis,\(^{27}\) the IOD implant survival rate (SR) in the cases of six implants was 98.2%, while the IOD SR in the cases of four and two implants were 96.3% and 95.2%, respectively. This review indicated that overdenture supported by six implants was the most successful treatment in terms of survival of implants and overdentures. However, the most cost-effective IOD plan was overdenture supported by two implants. Though overdentures supported by one implant were reported to be cost-effective, the long-term results are still debatable. The results indicated that the initial cost would increase with the number of implants used. Few researchers discussed the cost and cost-effectiveness over the long term for edentulous patients.\(^{21,22}\) Most studies restricted cost-effectiveness estimates of IODs to the follow-up period, usually 1 year, of clinical trials.\(^{12,28}\) However, it took much longer to identify improved outcomes in function and maintenance.\(^{29}\) In short-term studies, dental implants were reported to be more expensive. These studies did not capture the cost of complications or failures that could manifest after several years. The time-horizon analysis, which presented the life expectancy of dental implant treatments, was needed to avoid such bias against the cost-effectiveness of interventions. Moreover, the long-term data played an important role in the sensitivity analysis in cost-effectiveness studies. The overall methodology of studies on IODs for edentulous patients had high heterogeneity. It was difficult to unify the methodologies due to the different definitions in terms of effectiveness endpoints, costs, population, and time frame.
Comparison between studies was also difficult due to differences between settings in terms of attitudes toward the replacement of lost teeth, the availability and affordability of dental care, pricing policies and level of reimbursement of dental implants, and the discount rate applied to cost-effectiveness analyses. Thus, heterogeneity among studies was unavoidable.

The present study was based on the current available evidence on clinical outcomes of IODs. This review suggested that IODs with conventional protocol were more cost-effective when compared to CDs and fixed implant-supported prostheses. Overdentures supported by two implants and magnet attachments also were reported to be cost-effective. Due to the dearth of studies and high heterogeneity within the reported literature, a meta-analysis could not be conducted. More studies concerning long-term economic evaluation of IODs for edentulous patients are expected.

Conclusions

IODs improved OHRQoL for edentulous patients compared to CD. This study suggests that IODs for edentulous patients represent a cost-effective treatment. To better assess the cost and cost-effectiveness of IODs in edentulous patients, more cost analysis studies with well-established methodologies are needed.

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