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EVALUATING THE COST-EFFECTIVENESS OF DENTAL IMPLANT AND PROSTHESIS INTERVENTIONS: A SYSTEMATIC REVIEW[1]

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Abstract

Aim: Aim of this review is to compare cost-effectiveness in the implant and prosthesis for missing teeth, and to explore the methods used in cost-effectiveness analysis using published studies.

Methods: A systematic review was conducted on cost-effectiveness analysis in the dental implant and prosthesis for single, partial or complete replacement via PubMed, Scopus, Web of Science, EBSCO and Cochrane Library databases. Review was restricted to published articles in English language without time limit. Reporting quality assessment of dental replacement cost-effectiveness analysis used the Consensus Health Economic Criteria (CHEC) extended checklist guidelines.

Findings: Of the 526 publications identified initially, a total of 17 studies on the cost-effectiveness of dental implants and prosthesis were included in the systematic review. Of these, 8 (47.1%) were

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originated in the last four years. Most of articles (n=8, 47.1%) were on the cost-effectiveness for single-tooth replacement. The median of reporting quality of studies, assessed by the CHEC extended checklist is 74% (from 55% to 90%). Ten studies were able to define the most cost-effective among the interventions compared. Most studies were in concurrence that over the long term, dental implants represent a cost-effective treatment option. The methodology for the economic evaluation of prosthetic treatments is quite complex. Although there are concepts such as QAPY and QATY introduced into the literature, their applications have remained rather limited and not developed.

Conclusion: The majority of studies were able to provide conclusions regarding the most cost-effective intervention among the different options compared: this will assist in healthcare decision-making and resource allocation. For edentation, implant was cost-effective treatment option in comparison with dental prosthesis.

Keywords: Tooth Lost, Dental Implants, Dental Prosthesis, Cost-Effectiveness, Health Economics

Introduction

Despite the development of curative and preventive dental care and technology in the last years, edentulism continues to be a challenging problem to healthcare provider (Al-Rafee, 2020). Tooth-loss is a quite important public health problem globally because of its high prevalence and related disability (Peltzer et al., 2014; Tyrovolas et al., 2016). Globally, there were 267 million that had total tooth loss prevalence in 2017 (Bernabe et al., 2020). Prevalence's of edentulism, severe tooth loss, and lacking functional dentition in U.S were 10.8%, 16.9%, and 31.8%, respectively (Parker, Thornton-Evans, Wei, & Griffin, 2020). Dental conditions are mostly chronic and, the costs of treating dental diseases impose on families large economic burdens to and healthcare systems (Peres et al., 2019).

Dental implants started to be used more recently while dental prostheses are a technology with more a long history for treatment of tooth-lost. But, implants have been a very strong alternative treatment to dental prostheses. As time moves on patients prefer the very best in tooth replacement choices for their present and future needs (Rajput et al., 2016). Therefore, implant treatment may have been more preferred. Since especially implant technology is more expensive and the opportunities for application are extensive, questions about its effectiveness and efficiency have been asked. A lot cost-effectiveness evaluations inclusive different conclusion

has been published so far. However, there are no systematic review of CEA (Cost-Effectiveness Analysis) studies for dental implant modalities versus prosthesis modalities.

As in all areas of health, there are discussions for budget optimization in oral and dental health. Detailed descriptions of the resources used, together with estimates of the costs and outcome data of the treatments, can provide good guidance in the decisions made. Dentists always want to apply the most effective method to the patient. However, in some cases, serious differences may arise between alternatives in terms of cost and effect. Due to scarcity of the clinical trials aimed to compare the implants with prostheses, it is indefinite whether implants are more effective than the prostheses (Chun, Har, Lim, and Lim, 2016). But, implant is believed use a longer time than the prosthesis although the implant brings a higher cost. In order to explore this issue, articles using CEA have been published in recent years. These studies provided considerable information for the clinical decision-making process. This study aims to review published articles on CEA of dental implant modalities in comparison with prosthesis modalities for dental replacement, and also to explore the methods used in CEA.

1. Background

The replacement of missing teeth used removable dental prosthesis, fixed dental prosthesis and implants. Removable Dental Prostheses are artificial appliances that can be inserted and removed from the mouth. Removable dental prosthesis is commonly referred to as ‘‘dentures’’ or ‘‘false teeth’’ (Schütte and Walter, 2010). Removable dental prostheses are relatively economical to make and maintain. However, the compliance of this type of prostheses is inferior to that of the dental implants and fixed prosthesis. Also, it does not preserve dental bone the same way dental implants do. The patients preferred more a fixed prosthesis in opposition to the removable. (Resnik, 2020: Aslam et al., 2017).

Fixed prosthodontic treatment involves replacement of lost natural teeth using fixed artificial substitutes with an aim to restore function, esthetics and comfort (Shah et al., 2014). The abutmenting of healthy teeth makes them less favorite (Prasanna et al., 2012).3, But fixed dental prostheses (FDPs) are still preferred because of their esthetics, lack of any surgical preparation and especially less cost (Riaz, Aslam and Aziz, 2018). In general, fixed dental prostheses (FDPs), supported by teeth, have proven to yield good medium- and long- term

results. In the past decades, dental implants have become widely used and implants too seem to provide a reliable support for dental restorations (Pjetursson et al., 2015; Pjetursson et al., 2014).

Dental implants have become a vital part of prosthodontics for especially partially and completely edentulous patients. The implant is similar as self-natural of teeth and often offer a more predictable treatment course than removable and fixed prosthesis. Dental implant restorations have the highest survival rate compared with any other type of prosthesis to replace missing teeth. They do not decay, no require endodontic treatment, also less prone to fracture and resist periodontal disease better than a natural tooth. But is the treatment plan and the treatment of complications (such as screw loosening, crystal bone loss, prosthesis fracture, or implant failure) are most often unique to implant dentistry. In addition, patients should pay more attention to oral and dental hygiene (Misch, 2015; Resnik, 2020).

There is gradually growing for the need to perform economic evaluations of missing tooth replacement. Economic evaluations analyze comparing the cost and outcome of alternative treatment/healthcare interventions. Cost-effectiveness and cost-utility analysis are the most widely used. (Drummond, 2015). Health outcome are usually measured as quality-adjusted life-years (QALYs), accounting also for the quality-of-life outcomes. In dentistry, special concepts such as QAPY and QATY have been developed. In the cost-effectiveness analysis (CEA) are used is often referred to as with its parameters of interest being called incremental cost-effectiveness ratio (ICER), whereas an analysis in which QALYs are used is often called cost-utility analysis (CUA). QALY takes a value between 0 (death) and 1 (perfect health). In QAPY and QATY it can have values between "0" (missing tooth) and "1" (a tooth that remains in perfect condition). ICER calculated by the difference in costs between two health care interventions/programs divided by the difference in outcomes between the interventions/programs (Fox, 2005; Oscarson, 2006; Fyffe and Kay, 1992).

2. Research Methodology

Literature searches were conducted by using the PubMed, Web of Science, Cochrane and EBSCO databases from their inception to 2019, and were limited to articles written in English. The search term combinations used to search the knowledge included dental implant, dental prosthesis, cost-effectiveness AND dental implant, cost-effectiveness AND dental prosthesis,

cost-utility AND dental implant, cost-utility AND dental prosthesis. In this study excluded studies that are not original and research article.

Studies that met the following criteria were considered eligible for this systematic review: (1) designed about tooth replacement (single, partially or completely); (2) comparison prosthesis versus dental implant or, comparison within themselves either implant strategies or prosthetic strategies ; and (3) the studies reporting data about the costs (initial costs of treatment, total costs, or long-term maintenance costs etc.), outcomes and cost-effectiveness of missing tooth treatment, (4) published in English language.

For study selection primarily the search results from all databases were merged, and duplicates removed. It started with reviewing the abstracts of these articles published to find out which of the studies met our inclusion criteria, and then reviewed dental health-economics full text articles. 15 CEA articles were included. Also additional to it included cost-utility and Health Technology Assessment (HTA) studies that fulfilled all the selection criteria. These 17 articles reviewed in detail. LT and NM assessed the risk of bias and the quality for each included study using the CHEC (Consensus Health Economic Criteria) extended checklist. CHEC is an internationally accepted criteria list for quality assessment of economic evaluations that could be used in systematic reviews (Evers, Goossens, de Vet, van Tulder, & Ament, 2005; Sagili et al., 2018). The 20-items in checklist scored as having met the criteria in full (“1”) and not at all (“0”). The total score for each item converted to a percentage (<50; low, 51–75; moderate, 76–95; good and >95; excellent) with the range of scores ranging from zero to 100. Selected 17 articles were analyzed and, gathered that information such as study country, perspective, intervention area, time horizon, discount rate, report of ICER (Incremental Cost-Effectiveness Ratio) state, alternative treatments. Article selection process in accordance with the PRISMA Guidelines was given in Figure 1.

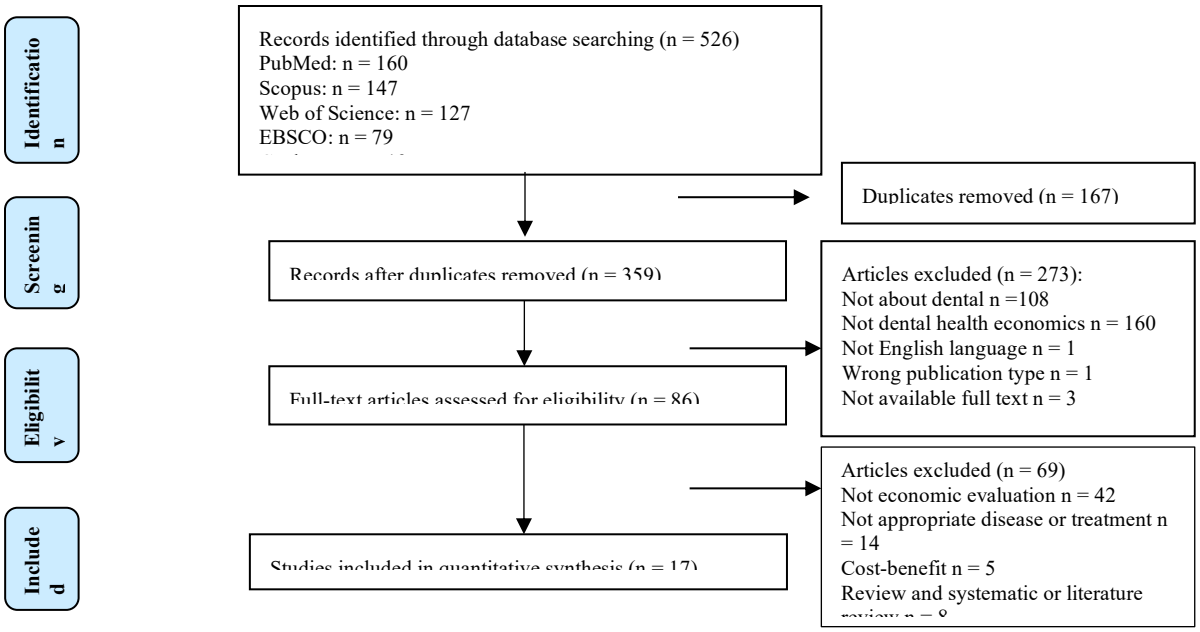

Figure 1. PRISMA diagram depicting the systematic review strategy

3. Analysis

Initially 526 studies were found with keywords. A total of 86 studies were read in full, 17 articles were included in the systematic review (Figure 1). CHEC scores of 17 studies included in the review, quality of nine studies were moderate, quality of eight studies were good, showing lower risk of bias. When looking at common negativities, it is remarkable that there are only two studies discussing ethical and distributional issues (Della Vecchia et al., 2018; Y. Kim et al., 2014). Nine studies did not clearly structural of the model. Eight studies did not mention discount.

3.1.Characteristics of included studies

Among the seventeen articles, fifteen of them were cost-effectiveness studies, one cost-utility study and one HTA report were included in the review. Descriptions of the included articles are provided in Table 1. The number of CEAs articles of dental implant and prosthesis treatment has increased from three articles (17.6%) from 2005 to 2010, to eight CEAs (47.1%) from 2016 to 2019. The majority of studies were conducted in the European; (n = 7; 41.2%) and American Countries (n = 6; 35.3%). The studies reported from the Asian region were four (23.5%). The studies reported from the European region were conducted in Germany (n = 1), Switzerland (n =

3), France (n = 1), Holland (n = 1) and İreland (n = 1). The studies reported from the America region were conducted in U.S. (n = 3), Canada (n = 1) and Brazil (n = 2). The studies reported from the Asian region were conducted in Japan (n = 2) and Korea (n = 2). Most of articles were on single missing tooth treatment; (n = 8; 47.1%). 17 studies' perspectives included provider, health services or treatment, public health, patient, societal, and health insurances, and whereas two studies did not explicitly state the perspective used in their analysis.

Five of the studies used ten years' time horizon. Three of the studies used twenty years' time horizon and two studies thirty years' time horizon, and two studies not explicitly stated time horizon. Most of the studies (n = 8) did not report the discount rate. Five studies used 3% to discount both costs and outcome. Few studies have not reported an ICER (n = 6) and sensitivity analysis (n = 4). Two studies provided values for the cost-effectiveness rate. The health outcome included in the analyses showed marked differences in their scope and categorization. The health outcomes had significantly difference such as survival rate, success rate, QAPY (Quality-Adjusted Prosthesis Years), QATY (Quality-Adjusted Tooth Years), QALY (Quality-Adjusted Life Year), TTO (Time Trade-off), WTP (Willingness-to-Pay), MID (Minimally Important Clinical Difference), OHIP-EDENT (Oral Health Impact Profile for Edentulous) and OHIP-20. Ten studies have able to identify the most cost-effective intervention among the compared replacements.

Table 1: Characteristics of the cost-effectiveness analysis articles in dental implant and prosthesis interventions

Characteristic			Characteristic		
Year of publication	**N**	**%**	**Study country**	**N**	**%**
2005-2010	3	17.6	European Countries	7	41.2
2011-2015	6	35.3	American Countries	6	35.3
2016-2019	8	47.1	Asian Countries	4	23.5
Intervention			**Discount rate****		
Mandibular edentulism	4	23.5	%2	2	11.1
Single missing tooth	8	47.1	%3	5	27.8
Partially dentate	4	23.5	%5	3	16.7
Maxillary edentulism	1	5.9	Not discounting	8	44.4
Study perspective*			**Time Horizon**		
Public health	3	15.8	10 years	5	29.4
Patient	3	15.8	20 years	3	17.6
Societal	3	15.8	30 years	2	11.8
Provider	4	21.1	Other	5	29.4
Treatment	3	15.8	Not explicitly stated	2	11.8
Health insurances	1	5.3			
Sensitivity analysis			**Reporting of cost-effectiveness ratio**		
Used	13	76.5	ICER reported	11	64.7
Not used	4	23.5	Not reported	4	23.5
			Cost-effectiveness rate reported	2	11.8

* Two studies used more than one perspective ** One studies used more than one discounting

Since the identified studies are heterogenic, it was divided into those assessing the CEA in single-tooth replacement, mandibular, maxillary and partial edentulism. Also it should be considered that in the present systematic review, limited the scope for synthesizing the data due to the heterogeneity in terms of the patient populations under investigation, the study designs, outcome measures and alternative treatment, therefore were not carry out meta-analysis.

A total of eight studies focusing on the CEA for single-tooth replacement was identified (Table 1). These studies compared different treatment modalities; four studies are of implants versus fixed dental prostheses (Chun et al., 2016; Kim et al., 2014; Korenori et al., 2018; Teranishi, Arai and Baba, 2019), two studies are of implant-support crown versus fixed dental prostheses (G. Antonarakis, Prevezanos, Gavric, & Christou, 2014; Bouchard et al., 2009), one study is fixed partial denture versus three different modalities including implant-support restoration (Kim and Solomon, 2011), one study is implant versus bridge strategy (Bouchard et al., 2009).

In the studies comparing implants and fixed prostheses is a common point that the implant is a more effective method. A total of two studies focusing on the CEA of fixed prosthesis versus ISC (Implant-Supported Crowns) for single-missing teeth replacement were identified (Antonarakis et al., 2014; Zitzmann, Krastl, Weiger, Kühl and Sendi, 2013). These studies reported inconsistent findings. In the study conducted by Antonarakis et al (2014) the five different treatment modalities were ranked according to their cost-effectiveness ratio: The most cost-effective treatment modality was auto-transplantation, while the least cost-effective was full-coverage FPDs (Fixed Partial Denture), and as for ISC is in fourth place. As for in the study conducted by Zitzmann et al., ISC is the dominant strategy (Zitzmann et al., 2013). Bouchard et al., reported that the dental implant is the dominant strategy as less costly and more efficient over time than bridge therapy (Bouchard et al., 2009). In the study conducted by Kim & Solomon et al., endodontic microsurgery was the most cost-effective approach, and a single implant-supported restoration, despite its high survival rate, was shown to be the least cost-effective treatment option (Kim and Solomon, 2011).

When studies investigating treatments in mandibular edentulism were examined, it was found that implant strategies in general were more cost-effective (Heydecke et al., 2005; Probst et al., 2019; Zitzmann, Marinello and Sendi, 2006). When comparing standard implants and mini-

implants, mini-implants were found to be more cost-effective (Della Vecchia et al., 2018). One studies focusing on the cost-effectiveness for maxillary edentulism treatment was identified (Listl, Fischer and Giannakopoulos, 2014). The results of relevant study demonstrate that bar-retained maxillary overdentures based on six implants compared four implant provide better patient satisfaction but are a lot more expensive.

There are four studies on cost effectiveness that are identified in the literature review partial edentulism treatment alternatives (Jensen et al., 2017; McKenna et al., 2014; Ramamoorthi & Esfandiari, 2016; Ravidà et al., 2019). In the study conducted by Ravidà et al. (2019) survival rates in rehabilitating a 3-unit edentulous area were 100% in the ISB (Implant-Supported Bridge), 92.5% in the NSC (Non-Splinted crowns), and 88.5% in the SC. Besides has been found out that the total cost of the ISB group is lower. Jensen et al. (2017) have performed a CEA comparing RPD and ISRPD (Implant-Supported Removable Partial Dentures) in patients with a bilateral free-ending situation (Kennedy class I). Their results demonstrate that the ISRPD came at substantial additional costs though incremental benefits. In another a study has been conducted a CEA of RDP (Removable Dental Prostheses) and SDA (Shortened Dental Arch) in partially dentate older patients. SDA is remarkable lower than the total cost for the RDP group, also in terms of impact on oral health-related quality of life, SDA is more cost-effective than RDP treatment (McKenna et al., 2014).

4. Conclusions and Recommendations

Previous studies have not focused on implant and fixed prosthetic interventions. In general, they only compared implant options (Mainkar, 2017; Zhang et al., 2017; Vogel, Smith-Palmer and Valentine, 2013). This study, unlike the others, dealt with tooth deficiencies as a whole. It included studies that analyzed the cost-effectiveness of implant and fixed prosthesis intervention, which are different technologies. Whereas among reviewed 17 studies are reported inconsistent findings, there are findings of that support each other also. These studies are pretty complicated by heterogeneity in terms of outcome parameters, perspective, included costs, patient population, discount rate and time horizon. In addition, findings are incomparable in terms of toward the replacement modalities of missing teeth, affordability of dental treatment, pricing policy, insurance state, level of reimbursement. In the literature review conducted by Vogel, Smith-

Palmer, and Valentine (2013) have been determined similarly findings. Additional, the details of treatment strategies are not expressed in most of the studies we have reviewed.

CEA of dental implant and prosthesis interventions started to be carried out after 2005 and has increased gradually. Most of the studies reviewed, it demonstrates that CEA is used in missing tooth interventions in developed countries. Though implant overdentures are now recommended as the standard of care for patients with edentulous, it was increased CEA studies particularly after 2000. CEA can be performed from different perspectives such as those of a healthcare provider, a health system, patients, insurance institution or society (Drummond, Sculpher, Claxton, Stoddart and Torrance, 2015). Reviewed studies included very different perspectives and whereas only two studies did not explicitly state the perspective used in their analysis. The perspective chosen affects the types of costs included in the analysis.

The provide an effective intervention may offer some immediately health benefits but, in many conditions, the health benefits will occur in future periods. Similarly, intervention will impose costs or offer cost savings in future periods as well. During economic evaluation like CEA, in order to compare costs and outcomes in different time periods, discounting is used (Drummond et al., 2015; Kobelt, 2013). It is noteworthy that almost half of the studies reviewed did not discounted. There are guidelines in CHEC extended checklist for the reporting of the CEA studies. In the present review, scanning was carried out without time limitation, it revealed high-quality reporting associated with CEAs for dental implant and prosthesis interventions published during the years 2005-2019. The reporting quality of studies appraised by the CHEC are varied from 55% to 90% (median 74%).

A CEA that perform in a recent in Japan for treatment for a single-tooth missing was reported that implant-to-insurance fixed dental prostheses ICER was €2,454.37 (Teranishi et al., 2019). Another study in Japan was reported ICER on the implant versus insurance FDP (Fixed Dental Prosthesis) for treatment for a single-tooth missing was €1423.00 (Korenori et al., 2018). A study in Korea for treatment for a single-tooth missing was stated implants cost more than three-unit FPDs, and implant survival rates were 10.4% higher, therefore the ICER was reported that was $2,514 in a clinic and $3,290 a hospital.(Kim et al., 2014) Another study in Korea for treatment for a single-tooth missing was reported that the tendency of being more-effective changed from conventional FDP to implant in the course of time (Chun et al., 2016).

In a recent study in Brazil to perform for mandibular edentulism was reported that compared to conventional total prosthesis, implant-supported total prosthesis is more cost-effective (ICER of BRL 464.22 per QAPY) (Probst et al., 2019). In a study conducted Canadian were OHIP mean score was approximately 33% better in the two-implant overdentures group than compared complete dentures (cost $14.41 per OHIP-20) (Heydecke et al., 2005). Another study in Brazil for mandibular edentulism was reported that mini-implants are more cost-effective compared to those retained by 2 standard implants (Della Vecchia et al., 2018). In the past a study that in edentulous patients comparing implant-supported overdenture (4 implants), implant-retained overdentures (2 implants), and complete dentures, was reported that implant-retained overdentures are the most cost-effective, in the time horizon 10 years (Zitzmann et al., 2006). In a systematic review conducted by Zhang et al., (2017) have been showed that implant-supported overdentures are a cost-effective treatment.

The majority of reviewed 17 CEA articles were of moderate quality as assessed by the CHEC extended checklist. Mostly are focused on the economic evaluation of tooth loss in developed countries (Switzerland, Germany, France, Holland, İreland, Canada, Brazil, Japan, Korea). Because in almost all the studies used different variables to estimate the effectiveness, it should be improving of the methodologic related to reporting of CEA studies. An evaluation form with a special scale for missing-tooth effect related aspects needs to be developed. Health outcome measures as QAPY and QATY should use integrating in economics evaluation of tooth loss.

Dental care costs are considerably great. Given resource scarcity, results from such a review are highly relevant not only to patients but also to health care decision makers who need to decide how resources are best spent in order to increase population wellbeing. This study suggests that implant strategies are generally a more effective but costlier method for edentulous patients. However, there is much evidence that implant strategies are more cost-effective. On the other hand, to better economic evaluation should be more deal ethical, equality of opportunity and distributional issues.

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