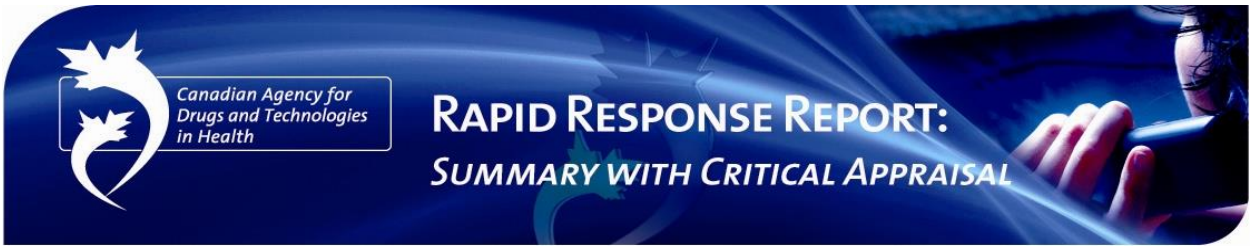

TITLE: Longevity of Removable Prosthodontics: A Review of the Clinical Evidence

DATE: 10 April 2015

CONTEXT AND POLICY ISSUES

Tooth loss is a problem that affects people during all stages of life.[1,2] It may be caused by deficiencies in tooth production or due to an existing congenital condition. Most commonly, it is caused by the development of caries resulting from microbial mediated activity, an impact causing trauma to the oral cavity, or from sustained periodontal disease.[1-3] When tooth loss occurs as a result of periodontal disease or caries development it is heavily influenced by the overall oral health care practices of the individual who is afflicted.[1,4] In addition, investigation has demonstrated that there is an association between increased edentulism and lower socioeconomic status.[1,4,5]

The location of teeth in the oral cavity plays a significant role in the likelihood of their loss.[1,6,7] For example, teeth located in the mandible typically survive longer and with less potential damage than their counterparts located in the maxilla. Furthermore teeth found in posterior regions are more prone to loss than those found anteriorly.[1,7] Current epidemiological studies have demonstrated that industrialized nations are experiencing a decrease in the amount of people afflicted with complete edentulism.[8] This suggests that the requirement for partial dental prosthesis may be on the rise.[1,8]

There are three main methods for the treatment of patients with missing teeth; a removable dental prosthesis (RDP), replacement teeth affixed to a dental bridge and abutted by natural teeth, and implants which are affixed to the jawbone permanently and either support a permanently attached prosthesis or an RDP.[3] In instances where fixed tooth-supported dentures are not advised the most common treatment option is to use a removable partial denture (RPD).[8]

Dental prostheses are a significantly expensive treatment option for many patients especially when healthcare plans do not cover the entire expenditure.[6] One advantage of RDPs is that they are both cost and time effective when compared to fixed options though research has demonstrated that they tend to require more maintenance across their lifespan.[6] As a result of this, knowledge of the longitudinal life of a prosthesis is a critical aspect of effective treatment

for dental professionals when they advise patients of appropriate options. Unfortunately powerful evidence based longitudinal studies have been lacking for these types of treatments which leaves dental specialists at a loss for sufficient information to pass on to their patients.[1,5,8-11] Furthermore, as of 2013, the majority of published literature on dental prostheses has contained a wide inconsistency in methodological design which has made it exceptionally difficult to interpret when examined as a whole.[5,7,12,13] For example, failure and success criteria tend to be unique for each study.[13] In some circumstances failures have been defined as everything from prosthesis fracture to the occurrence of the first requirement for adjustment or maintenance.[13] Moreover there is no standardization governing complications which lead to these failures.[7]

The purpose of this report is to determine the longevity of removable dental prostheses with a focus on complete dentures and partial plastic or metal dentures.

RESEARCH QUESTIONS

1. What is the clinical evidence on the longevity of complete dentures?

2. What is the clinical evidence on the longevity of plastic partial dentures?

3. What is the clinical evidence on the longevity of metal partial dentures?

KEY FINDINGS

The large degree of variability in the methodological approach and fluctuating definitions for failure criteria make comparison of publications in this review difficult. Successes ranged between 86.3% to 100% survival for all types of removable dental prostheses after a five year time point. Later time points show varied success rates ranging from 100% after seven years to 33.3% after ten years.

METHODS

Literature Search Methods

A limited literature search was conducted on key resources including PubMed, The Cochrane Library (2015, Issue 3), University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and major international health technology agencies, as well as a focused Internet search. No filters were applied to limit the retrieval by study type. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between January 1, 2005 and March 12, 2015.

Rapid Response reports are organized so that the evidence for each research question is presented separately.

Selection Criteria and Methods

One reviewer screened citations and selected studies. In the first level of screening, titles and abstracts were reviewed and potentially relevant articles were retrieved and assessed for inclusion. The final selection of full-text articles was based on the inclusion criteria presented in Table 1.

Table 1: Selection Criteria	
Population	Patients requiring removable prosthodontics.
Intervention	Q1: Complete denture Q2: Plastic (acrylic) partial denture Q3: Metal (vitallium) partial denture
Comparator	Any comparator No comparator
Outcomes	Longevity, survival rate at a particular timepoint
Study Designs	Health Technology Assessments, Systematic reviews, Meta-analyses, Randomized controlled trials, Non-randomized studies

Exclusion Criteria

Articles were excluded if they did not meet the selection criteria outlined in Table 1, they were duplicate publications, or were published prior to January 1, 2005. Finally articles were excluded if they were reviewed in a selected systematic review.

Critical Appraisal of Individual Studies

The included systematic reviews were critically appraised using Assessment of Multiple Systemic Reviews (AMSTAR) tool.[14] Randomized controlled trials and nonrandomized studies were critically appraised using the Downs and Black checklist[15] for the adequacy of allocation concealment, blinding of healthcare providers, clinicians, data collectors and outcome assessors, randomization, losses to follow-up, description of intention-to-treat, and early stopping of the trial. Summary scores were not calculated for the included studies; rather, a review of the strengths and limitations of each included study were described narratively.

SUMMARY OF EVIDENCE

Details of study characteristics, critical appraisal, and study findings are located in Appendices 2, 3, and 4, respectively.

Quantity of Research Available

A total of 283 citations were identified in the literature search. Following screening of titles and abstracts, 257 citations were excluded and 26 potentially relevant reports from the electronic search were retrieved for full-text review. One potentially relevant publication was retrieved from the grey literature search. Of these articles, 19 publications were excluded for various reasons, while 8 publications met the inclusion criteria and were included in this report. Appendix 1 describes the PRISMA flowchart of the study selection.

Summary of Study Characteristics

There were five systematic reviews, one randomized controlled trial and two non-randomized studies found for this report. The details of their characteristics are found in Appendix 2.

Study Design

The first systematic review written by Chatzivasileiou et al.[8] in 2013 and it included the most extensive assessment of existing literature as no restriction was used for the type of publication that could be included. Authors searched both PubMed and Embase for articles with no restrictions on publication dates. When papers were found hand searches were performed on the included references. Their goal was to present existing knowledge on implant assisted RPDs and critical aspects of their use in patients with follow-up times of at least 12 months.

The second systematic review was published in 2013 by Verna et al.[5] and included 17 publications which encompassed randomized controlled trials and both prospective and retrospective cohort studies. The online databases that were examined were MEDLINE and Embase and were limited to results from January 1966 to December 2009. Their goal was to examine the survival and associated complications encountered with dental or implant retained double crown abutments and removable prostheses under functional loading for a follow-up of at least three years.

The third review was composed by Ploumaki et al.[16] in 2013. This article included four publications which were randomized controlled trials or retrospective or prospective cohort studies. These articles were found by searching PubMed for publications from 1970 to June 2012 and once they were identified for inclusion hand searches were performed on the included reference lists. The goal of this review was to examine the success rate of either single-crowns, fixed, and removable prostheses, as well as the various types of posts used for root canal treated teeth and to discover the typical causes of failure.

Tong et al.[12] completed the fourth review in 2012 and it included nine studies. The authors searched online databases such as Ovid MEDLINE, the Cochrane Library in addition to the Journal of Prosthodontics, Journal of Prosthetic Dentistry and the International Journal of Prosthodontics, limiting to studies published between 1946 and 2012. When studies were identified, hand searches of the references were conducted. The authors were attempting to determine how technical and biological complications will determine the longevity of removable dental prosthetics. The follow-up terms were from 2 to 13.5 years.

The final systematic review that was included was produced by de Frietas et al.[10] It was written in 2012 and incorporated 5 studies which included both randomized and clinical controlled trials along with retrospective and prospective cohort studies. Once this was completed the references of the included articles were hand searched for any relevant records. Publications were obtained from the Cochrane Library and PubMed databases and limited to articles from January 1981 to September 2011. The objective of this work was to investigate overall patient satisfaction, survival rates, and prosthetic complications for rehabilitation using free end RPDs associated with Kennedy class I and II cases. Publications were only included if they contained a follow-up period of at least 12 months.

The randomized controlled trial was produced by Stober et al.[11] in 2014. A total of 54 patients presenting at the University Hospital of Heidelberg were randomly assigned to either a cast double crown-retained removable denture prosthesis group or an electroplated double crown-retained removable denture prosthesis group. Their mean age was 64 and ranged from 38 to 80 with 63% of the population being males. The goal was to determine the clinical performance of RDP supported by either electroplated of cast double crowns contained on metal frameworks.

Patients were initially screened at one week after prosthesis installment and then at 6, 12, 24, 38, 46, 60 and 72 months.

The initial non-randomized study that was found was produced by Behr et al.[17] in 2012 with the goal of investigating the longevity of clasp-retained RPDs made at the Department of Prosthodontics at the Regensburg University Medical Center over a 25 year period. The study included a retrospective review of the medical records of 174 patients with 43.1% women and 56.9% men and a mean age of 62 years. These patients had been treated with clasp-retained RPD with acrylic resin dentures. If patients had prostheses installed on both arches then only the first that was installed was included in order to treat each RPD individually. The examination period for each prosthesis lasted until the first event occurred. Additionally the authors examined the occurrence of caries and periodontitis of the abutment teeth.

The final study that was included was a non-randomized retrospective cohort analysis produced by Purcell et al.[7] in 2008. This investigation included 46 patients with a mean age of 59 years of which 14 were men and 32 were women. All patients had a maxillary removable complete denture constructed of an acrylic resin base and acrylic resin teeth supported by either 5 or 6 implants. In addition to this, patients also had a mandibular metal-resin implant fixed dental prosthesis. The goal of this study was to examine the complications associated with using a fixed mandibular denture opposed by a removable maxillary complete prosthesis.

Country of Origin

Of the eight studies that were included in this report three of them were produced in Germany. These included one systematic review,[16] one randomized controlled trial,[11] and one non-randomized retrospective cohort study.[17] The remaining four systematic reviews were produced in Canada,[12] Switzerland,[5] Greece,[8] and Brazil.[10] The final investigation was a non-randomized retrospective cohort study produced in the United States of America.[7]

Interventions

A variety of removable dental prostheses were utilized in the publications included in this report. There was only one study found that contained detailed analysis of complete RDP and was produced by Purcell et al.[7] They examined patients treated with mandibulary metal-resin implant fixed complete dental prosthesis. This was made out of Steri-Oss precision margin esthetics transmucosal abutments, cast-to-copings (60% gold, 20% palladium, 19% platinum and 1% iridium) with a hexed coping screw (titanium), cast metal alloy frames, acrylic resin teeth and heat processed acrylic resin. The complete maxillary prosthesis was made out of an acrylic resin base and acrylic resin teeth which was supported by either 5 or 6 external Steri-Oss hexagonal implants.

The remaining seven studies focused on patients with partial edentulism. Tong et al.[12] conducted a review on patients treated with RDPs and no limits were placed on the style of RPD that was used, the location of missing teeth, or the materials of RPD construction. Verna et al.[5] reviewed partially edentulous patients treated with tooth or implant supported RPD. Chatzivasileiou et al.[8] examined publications focusing on partially edentulous patients who had been treated using either maxillary or mandibulary RPD in conjunction with at least one implant. The review by de Frietas et al.[10] examined patients treated with RPD in the mandible which were supported by implants. Ploumaki et al.[16] used a broader spectrum approach in their review and included studies on all prosthetic restorations of endodontically treated teeth. In the

randomized controlled trial by Stober et al.[11] the focus was on either cast or electroplated double crown-retained RDPs (C-RPD and ER-RPD). C-RDPs were made from precious metal alloy for both crowns and were conventionally cast via the lost wax technique with a conically designed 6^0 milling. ER-RDPs were constructed from a cast primary crown of precious metal alloy and a secondary crown cast using electroplating with 0^0 milling (99.9% gold) and had a composite resin-luting agent which was luted to a CoCrMo framework. Finally, the non-randomized study by Behr et al.[17] utilized clasp-retained RPD with acrylic resin dentures.

Outcomes

In three of the included systematic reviews a wide range of failure criteria were found, and each publication had its own definition of what constituted a failure, success, or complication.[5,10,16] The review by Chatzivasileiou et al.,[8] did not specify any limitations or description for outcomes. Verna et al.,[5] defined success as any prosthesis that was found in situ at follow-up visits no matter of the condition that it was found in. Technical complications for implant-supported prostheses were screw or abutment tooth fractures, loss of retention, and fracture or deformation of framework or veneers. In the review by Ploumaki et al.,[16] success was given to any restoration that did not require any sort of modification/intervention of any kind during the observation period. Failures occurred when any sort of restoration was completed, if the teeth in question were removed, and if post intervention occurred (recementation of debonded post or replacement of post). Finally in the review by de Frietas et al.,[10] complications were classified as relining, pitting of the healing abutment, replacement of any resilient component of the attachment, damage in framework, screw loosening, and damage in the acrylic denture base.

The included RCT[11] contained five definitions for what constituted failure which were: requirement for renewal of RPD, extraction of abutment teeth, loss or fracture of facing and need of repair, loss of cementation of primary crowns, and the need for post-prosthetic endodontic treatment. In the non-randomized study by Behr et al.[17] events (failures) were defined as: renewal of entire denture, reline, fracture of clasp, fracture of major/minor connector, acrylic resin denture base fracture, and loss of artificial teeth. The final non-randomized study[7] defined complications as: implant failure or fracture, abutment screw loosening or fracture, retaining screw loosening or fracture, stripped screws, abutment fracture, framework fracture, metal-resin implant fixed complete dental prosthesis (MRIFCDP) fracture of teeth, MRIFCDP replacement of teeth, MRIFCDP acrylic fracture, lab processed hard reline, complete removable denture prosthesis (CRDP) tooth replacement, new CRDP requirement, CRDP fracture of teeth, and temporomandibular joint symptoms.

Summary of Critical Appraisal

Details of the critical appraisal for individual studies are found in Appendix 3.

The systematic reviews included for this report are of limited quality. All of them contained clearly defined goals and had well documented criteria for publication inclusion or exclusion. They also contained descriptions of the limitations put on searches for finding literature in the databases that were examined. In addition three of them[10,12,16] used flow charts for the depiction of paper selection. One of the reviews included a statement regarding excluding papers due to duplication,[10] and four of them give detail on how data was extracted,[5,10,12,16]

The review conducted by Tong et al.[12] contained a variety of papers that had inconsistent inclusion criteria for aspects such as prosthesis type, subject age, location of arch placement

and Kennedy classification therefore restricting the ability of the authors to make conclusions on any of these aspects. In addition there is insufficient discussion of the included paper results in the text of the review. This limitation also occurred in the review by Chatzivasileiou et al.[8] where the information regarding longevity is only briefly discussed even though this is one of the key factors they are attempting to define. The included investigations also contained a limited patient population which will make it difficult to accept their conclusions in a broad spectrum of applications. The authors provide the most inclusive analysis of the existing literature, in terms of the quantity of literature reviewed, but did not provide a detailed analysis of the identified studies. Finally there was no statement made concerning potential of conflicts of interest.

In the reviews by de Frietas et al.[10] and Ploumaki et al.[16] there is also a limited discussion of the results of the included papers. The Ploumaki et al. review has an insufficient review of RDP data as extremely few numbers are included other than percentages for general success rates. The review by de Frietas et al. gave well-described inclusion and exclusion criteria and in these criteria it was stated that papers must contain details of failure of the implant and prosthesis. However, it appears as if this was not explicitly followed as one included investigation did not have any data on these aspects and no explanation is given as to why it was included. In addition the criteria stated that information on the characteristics of implants must be given and another paper does not provide this and was included without justification.

The randomized controlled trial conducted by Stober et al.[11] was a well-conducted study. One of the strong points was that only dental laboratories with personnel who were highly experienced in the protocols used were enrolled to fabricate the required prostheses. They were also calibrated to the techniques before the study began in order to maintain the standard. All of the evaluations were completed by the authors who were familiar to the processes and calibrated to ensure result consistency. Unfortunately there was missing information as the process for randomizing the patients into the two test groups was not provided nor was any detail given on blinding of participants or assessors. However, given the nature of the interventions, blinding was likely not feasible. A dropout rate totaling 26% of the patients which resulted in a 30% loss of the included prostheses was encountered. The authors briefly mention that this was accounted for in statistical calculations but do not discuss the reasons that it occurred or give specific analyses of what impact it may have caused. Another condition which may potentially bias the results is that multiple dentists were used for the installation of the prostheses. These dentists all came from various backgrounds therefore their expertise in specific areas will vary and they were not calibrated before enrollment, unlike the fabrication or evaluation teams.

The two non-randomized studies had similar strengths and limitations. They both included appropriate, standardized statistical calculations which were all well documented. Their conclusions are all logical and fit with the information that was gathered. The study by Behr et al.[17] utilized a fabrication protocol that is well documented and will allow all patients to be standardized and therefore easily comparable. Unfortunately both articles contained low numbers of included patients which therefore makes it difficult to apply the conclusions that they make to a broad spectrum of situations. In addition both of these papers are retrospective cohort analyses meaning that their conclusions are based on the use of dated medical records. This may impart bias as the investigators are limited to the information that was included in the records as opposed to compiling the information from direct study. The study by Behr et al. utilized clinicians who did not have the same levels of education or opinions regarding the treatments of specific situations. This may impart bias as people well versed in a technique may be more prone to favorable evaluation towards it than a technique they are not as familiar with.

Summary of Findings

Details for the summary of findings may be found in Appendix 4.

What is the clinical evidence on the longevity of complete dentures?

The investigation by Purcell et al.[7] resulted in a 100% success rate for all of the prostheses included in the study and the average recall time was 7.9 years and ranged from 5.9 to 9.7. One implant failed and this event occurred after 6 years of functional loading. The complication that occurred the most frequently was mandibular tooth replacement and it occurred in 47.8% of patients during the >5 year category. In the <2 year category the most significant complication found was fractured teeth in the mandible and this occurred in 15.2% of cases. During the 2 to 5 year category the complication most commonly found was hard relines of maxillary complete dentures which occurred in 32.6% of cases. When logistic regression was used to examine the effect of time period, age and gender for tooth fractures it was found that none of these had any significant contribution. The only statistically significant complication that was reported was for complete denture relines which were considerably higher during the 2 to 5 year time point when compared to the <2 year time point. Additionally the odds of requiring both a reline and a tooth replacement rose as each year of age increases. The three most common complications encountered in this investigation were: replacement of acrylic resin posterior teeth due to wear, a requirement for maxillary complete denture laboratory heat-processed hard reline, and fractures of acrylic resin anterior teeth. All of these results demonstrated that a patient using complete maxillary acrylic resin dentures opposed by fixed complete dental metal-resin prostheses are 1.06 times more likely to need heat-processed hard relines with each increasing year of age. Furthermore relines are 3.7 times more likely to be required in the 2 to 5 year period and 8.5 times more likely after five or more years. Finally patients are 52.5 times more likely to require replacement of the posterior teeth after five years of use than in two or less years.

What is the clinical evidence on the longevity of plastic partial dentures?

There were six studies found to address this question and all of them varied in their manner of determining failure criteria. When viewed from a broad spectrum the survival percentages for the included studies ranged between 86.3% to 100% for follow-up of five years or less. The lowest survival score after 5 years was found as a result of Meier probability scoring for the removable parallel telescopic crowns investigated in the review by Verna et al.[5] The main issues resulting in tooth loss from the investigations included in this review was the progression of periodontal disease, secondary caries development, and tooth fracturing. After a time period of between six to ten years this range grew to between 33.3% and 100% success. The lowest survival rate was again found in one of the studies included in the Verna et al. review. This result was found in RDPs using conical retention of telescopic crowns and resulted from a loss of the retention ability which accounted for 25% of the total failures.

The definitions of complications found in these studies varied from study to study. After 5 years, complications such as caries, periodontal problems, pitting of surface healing around abutments, or mandibular denture case framework fracture occur at rates of 15.6% up to 58.4%. The most common complication that was encountered was the development of caries. This result was found in the investigation by Behr et al.[17] and was not specific to the five year time point but occurred all throughout the follow-up period. Longer time periods did not appear to

alter the type of complications that were encountered though detailed examination of this is not possible due to the variability on study design.

What is the clinical evidence on the longevity of metal partial dentures?

The randomized controlled trial conducted by Stober et al.[11] had an overall success rate of 87% for both prosthesis types after 72 months (77% in ER-RDP and 97% in C-RDP). Using Chi-square testing they demonstrated that two characteristics were significantly different for their two testing groups; complications in the position of abutment teeth and maximum probing depth. Teeth positioned more towards the anterior and premolar regions in the ER-RDP group contained more complications than those in C-RDP group. The mean probing depths were also deeper in the ER-RDP group than the C-RDP group, 3.7 mm versus 3.1 mm respectively. Failures were found in 23% of the ER-RDP group after 72 months and were a result of a loss of retention and facings in one individual and the loss of abutment teeth due to caries and periodontal disease in the remaining ones. The C-RDP group experienced a 3% failure rate as a result of one patient who experienced caries development. The difference in survival rates between the two groups was not found to be statistically significant though authors do indicate that the C-RDP group may demonstrate a slightly increased survival potential. Characteristics such as age, gender, number/arch position/mobility of abutments were all not found to have any significant impact on prosthesis survival. The main complication found in this investigation was the requirement for 29% of facings to be re-veneered and it occurred equally across both study groups. Interestingly, it was found that the number of abutment teeth in the RDP increased the likelihood of veneer failure. As a result of these findings the authors concluded that the clinical performance of ER-RDP and C-RDP were acceptable for the time period of examination. They do state that longer periods of examination will be required in order to determine if any significant difference develops for these treatment styles.

Limitations

This report was limited in the analysis of clinical longevity for both complete dentures and metal partial dentures as one study meeting the inclusion criteria for each question was identified. The study for the examination of complete dentures enrolled 46 patients, therefore caution is warranted when attempting to apply their findings to the general population. In addition it was a retrospective investigation meaning that patient records were reviewed in order to gather data. This is problematic as there is the potential for bias since all of the data will rely on the information included in the reports and not direct observation. The randomized controlled trial included for metal partial dentures is lacking on key information about randomization techniques and also contains high dropout rates both of which limit its reliability.

Information for the examination of plastic partial dentures is also limited. While six papers were included, the majority of them contained small numbers of included patients. For example, in the review composed by de Frietas et al. they analyzed five papers enrolling a total of only 49 participants. In all of the studies that were found there is a wide degree of variation for how failure and success are classified. Furthermore what may be seen as a failure in one study is considered only an inconvenient complication in another. This therefore makes comparison of one study to another challenging. Additionally there is a lack of information on RDP longevity. In the review by Ploumaki et al.,[16] four studies were included but only one of them had any information on the success rates of RDP restorations which was one of the main goals for the composition of the paper. Furthermore, in three quarters of the papers that were included the authors state that there is a need for future studies to have standardized definitions for failure

and complication criteria as well as a requirement for longer term survival investigations with larger patient populations.

CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING

The investigations included in this report for complete and partial plastic removable dental prostheses demonstrate a wide range of survival at various time points. After 5 years survival times ranged from 83.6% for plastic RPDs to 100% for complete dentures. This suggests that the overall endurance of these prostheses at this time point may be acceptable. In many situations the complications that were encountered were easily repaired though the variability in these results makes analysis of this difficult.

The randomized controlled trial examining the use of metal removable dental prostheses demonstrated that after six years survival rates were 97% for the cast double crown-retained removable dental prosthesis group while prosthesis survival in the group using electroplating was 77%. This suggests a potentially acceptable clinical performance for both of these approaches. Caution must be taken here as there was a relatively small patient population included and a high dropout rate which limits the application of these results to the general population and suggests the need for further study.

Survival at later time points demonstrates a wide variation in success rate which is partially a result of the variation in study methodology. After seven years one reviewer found that there was 100% survival with only minor complications at all time points for implant supported RPDs. The lowest survival rate was found in a study investigating RDPs with conical retention for telescopic crowns where only 33.3% survived after ten years. Unfortunately, the majority of these investigations were completed on small numbers of patients which means caution must be taken in their interpretation. There appears to be distinct need for long-term, large scale investigation with standardized definitions of failure, success, and all complications.

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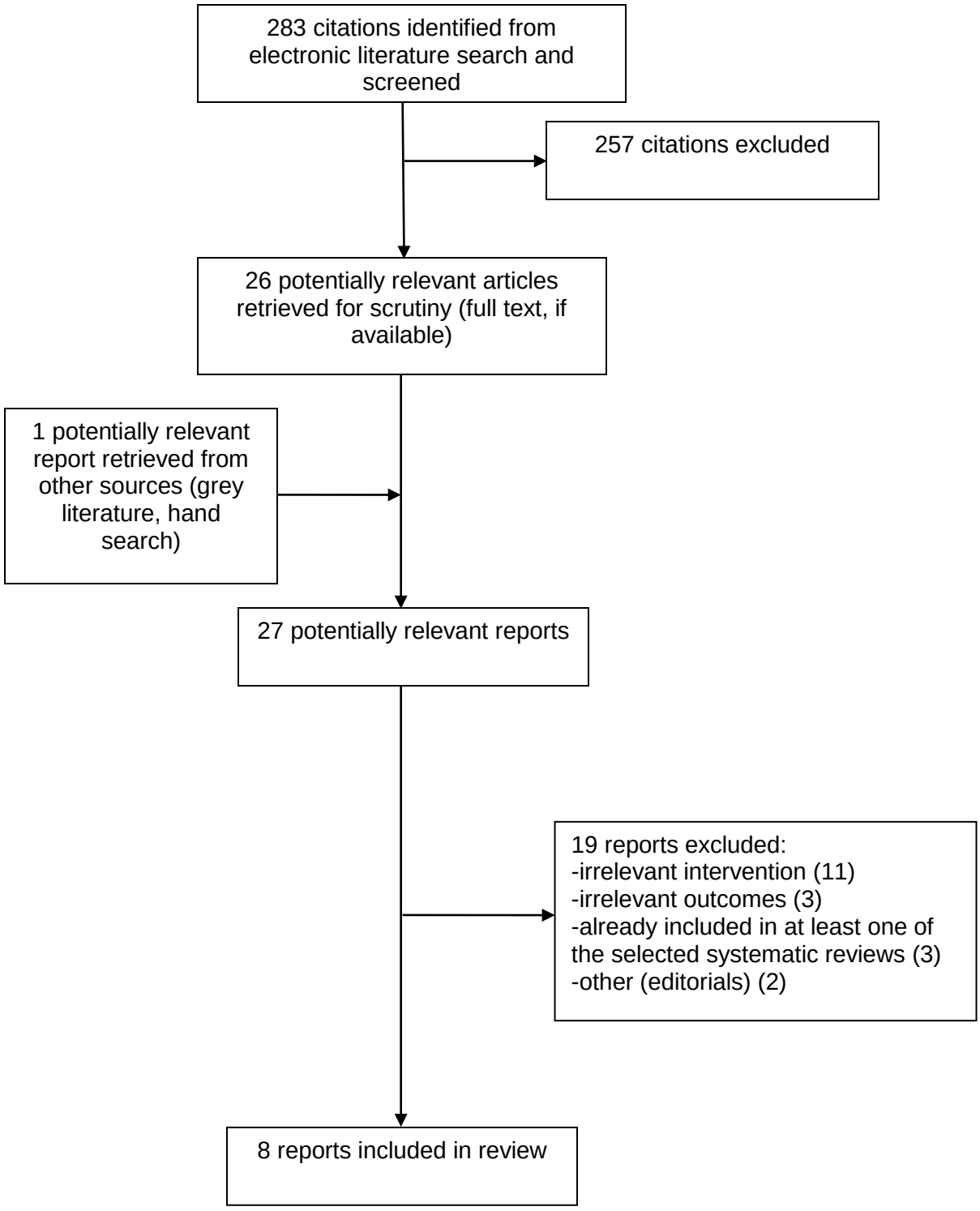
APPENDIX 1: Selection of Included Studies



APPENDIX 2: Characteristics of Included Publications

Table A1: Study Characteristics of Systematic Reviews

First Author, Publication Year, Country	Types and numbers of primary studies included	Databases searched/Goal of review	Intervention	Length of Follow-Up
Chatzivasileiou et al.,[8] 2013, Greece	-37 papers included in review - No restrictions for study type were used	- PubMed and Embase were searched with no limits placed on date of publication, included hand search of selected included papers - To review the current literature concerning implant assisted RPDs and present existing knowledge about critical aspects of this treatment	- Examine rehabilitation of partially edentulous maxilla or mandible with RPD in conjunction with at least 1 dental implant	- No restriction was used for follow-up length
Verna et al.,[5] 2013, Switzerland	-17 papers were included in the review and included RCTs and both prospective and retrospective cohort studies	-MEDLINE and Embase searched for literature published between January 1966 to December 2009 -Goal was to screen published peer-reviewed literature for information regarding survival and associated complications encountered with dental or implant retained double crown abutments and removable prostheses under functional loading for a minimum of 3 years -	-Partial edentulous patients -Studies with at least 10 patients included who were treated with tooth or implant supported RPD -The technique used for implant insertion was not specified	-Length of follow-up must be at least 3 years
Ploumaki et al.,[16] 2013, Germany	-4 studies included in review - RCTs, prospective and retrospective investigations included	-PubMed searched -Articles included if published from 1970 to June 2012 -Hand search of included publications completed - To review success rates of either single-crowns, fixed and removable dental prostheses, as well as the various types of posts utilized for root canal treated teeth and to discover the typical causes of failure	-Prosthetic restorations of endodontically treated teeth	- Follow-up was at least 6 years
Tong et al.,[12] 2012, Canada	- 9 studies included in review (4 RCTs, 4 retrospective cohort studies, and 1 cohort study)	- Ovid MEDLINE (1946 to January 2012), Embase (1980 to January 2012), The Cochrane Library databases (Issue 2, 2012), Journal of Prosthodontics, Journal of Prosthetic Dentistry and the International Journal of Prosthodontics - Hand search of references for included reviews	-partially edentulous patients whom had been treated using RPDs	- Length of follow-up was from 2 to 13.5 years

Table A1: Study Characteristics of Systematic Reviews

First Author, Publication Year, Country	Types and numbers of primary studies included	Databases searched/Goal of review	Intervention	Length of Follow-Up
		completed - To examine how both technical and biological failure or complication will determine the longevity of removable dental prosthetics		
de Frietas et al.,[10] 2012, Brazil	-5 studies included in review -Included randomized and controlled clinical trials, retrospective and prospective cohort studies	-PubMed and the Cochrane Library databases searched -Included publications in Spanish, English and Portuguese -Hand search of references in included studies completed -Limited to studies published between January 1981 to September 2011 -To conduct a systematic review about patient satisfaction, survival rates and prosthetic complications for rehabilitation with RPDs associated with implants in mandibular Kennedy class I and II cases	-Examined rehabilitations completed on patients with mandibular free end RPD prosthesis supported by implants	-Length of follow-up was 12 months minimum

RCT = randomized controlled trial
RPD = removable partial denture

Table A2: Study Characteristics of Randomized Controlled Trials and Non-randomized Studies

First Author, Publication Year, Country	Study Design	Patient Characteristics, Sample size	Intervention(s)	Outcomes	Goal
Randomized Controlled Trials					
Stober et al.,[11] 2014, Germany	-RCT -Patients randomly assigned to either C-RDP or ER-RDP group -Baseline clinical diagnosis of prosthesis and abutments preformed 1 week after incorporation of RPD and then at 6, 12, 24, 38, 46, 60 and 72 months -Used *T, U* and Chi square tests to determine any differences between testing groups -Survival differences were investigated using log-rank tests and Cox proportional regressions	- 54 patients who attended the University Hospital of Heidelberg -Age range 38 to 80 with 63% males (mean age 64 SD=9)	-C-RDP made from precious metal alloy for both crowns, conventionally casing lost wax technique with conical design 6”milling -ER-RDP primary crown made by casting using precious metal alloy and secondary crown cast using electroplating with 0^0 milling (99.9% gold) and had a composite resin-luting agent which was luted to a CoCrMo framework	-Contained 5 criteria : ○ Failure is renewal versus survival of RDP ○ Failure is extraction or survival of abutment teeth ○ Loss or fracture of facing with need of repair ○ Loss of cementation of primary crowns ○ Need for post-prosthetic endodontic treatment	-To investigate the clinical performance of RDP supported by either electroplated or cast double crowns
Non-Randomized Studies					
Behr et al.,[17] 2012, Germany	-Non-randomized retrospective cohort study -If patient had a prosthesis on both arches only the first installed was included in the study in order to treat each unit individually -Examination period of each prosthesis lasted until the first event occurred -Used standard Kaplan-Meier analysis for estimation of survival -Univariate Cox regression analysis was used to examine the effect of age on loss of abutment teeth -Also examine the occurrence of caries and periodontitis of abutment teeth	-174 patients from the Regensburg University Medical Center -75 women (43.1%) and 99 men (56.9%) with a mean age of 62 ±12 years -Patient records excluded if incomplete or follow-up occurred for less than 6 months	-Clasp-retained RPD with acrylic resin dentures	-Events defined as: ○ Renewal of entire denture ○ Reline ○ Fracture of clasp ○ Fracture of major/minor connector ○ Acrylic resin denture base fracture ○ Loss of artificial teeth	-To investigate the longevity of clasp-retained removable partial dentures made in the Department of Prosthodontics at the Regensburg University Medical Center over a 25 year period
Purcell et al.,[7] 2008, United States of America	-Retrospective cohort analysis -Patients obtained	- 46 patients included (14 men and 32 women)	--All patients had a maxillary removable	-Events defined as: ○ Implant	-To examine complications associated with a

Table A2: Study Characteristics of Randomized Controlled Trials and Non-randomized Studies

First Author, Publication Year, Country	Study Design	Patient Characteristics, Sample size	Intervention(s)	Outcomes	Goal
	as a subset of an ongoing investigation focused on analyzing the impact of implants on soft tissues -Percentage of population exhibiting each complication and the 95% confidence interval were calculated -Recall periods were divided into: <2 years, 2-5 years and >5 years -Logistic regression used to calculate the effect of recall period, age, and gender on: tooth fracture, complete denture reline, screw complications and tooth replacement	-Mean age at start of study was 59 years old	complete denture constructed of an acrylic resin base with acrylic resin denture teeth supported by 5 or 6 external hexagon Steri-Oss implants in the anterior mandible - patients also received a mandibular metal-resin implant fixed complete dental prosthesis made of Steri-Oss PME transmucosal abutments, cast-to copings (60% gold, 20% palladium, 19% platinum and 1% iridium) with a hexed coping screw (titanium), cast metal alloy frames, acrylic resin teeth and heat processed acrylic resin	failure or fracture ○ Abutment screw loosening ○ Abutment screw fracture ○ Retaining screw loosening ○ Retaining screw fracture ○ Stripped screws ○ Abutment fracture ○ Framework fracture ○ MRIFCDP fracture teeth ○ MRIFCDP replace teeth ○ MRIFCDP fractured acrylic ○ Lab-processed hard reline ○ CRDP replace teeth ○ New CRDP ○ CRDP fracture teeth ○ TMJ symptoms	fixed mandibular prosthesis opposed by a maxillary complete RDP in relation to recall time, age and gender

C-RDP = cast double crown-retained removable denture prosthesis; CRDP = complete removable denture prosthesis; ER-RDP = electroplated double crown-retained removable denture prosthesis; MRIFCDP = metal-resin implant fixed complete dental prosthesis; RCT = randomized controlled trial; RDP = removable denture prosthesis; RPD = removable denture prosthesis; TMJ = temporomandibular joint

APPENDIX 3: Critical Appraisal of Included Publications

Table A3: Strengths and Limitations of Systematic Reviews based on AMSTAR[14]

Strengths	Limitations
Chatzivasileiou et al [8]	
• Provided the most extensive review of the existing literature contained in this report • All search criteria were clearly defined and the study was written in a logical and easy to follow manner	• There is an extremely low patient population in all of the included studies which may make it difficult to accept the conclusions in a broad spectrum sense • The included investigations were only discussed in a limited manner where only minimal information regarding longevity is described • How data was extracted is not described in any manner • The discussion section gives an excellent comparison to existing literature not included in this review but does not examine or analyze the included papers to a sufficient degree as results are only briefly discussed • No statement regarding a lack of conflict of interest is provided
Verna et al.[5]	
• All criteria for aspects such as database selection, article screening and inclusion/exclusion are clearly stated • Gives clear description of the method of data extraction • Provides a figure defining the search design and strategy used to eliminate publications from the final included grouping	• There is a defined lack of information on abutment and denture exposure times • The included studies do not have a standardized definition of either complications or failures, these are defined by each author and vary significantly from one investigation to the next
Ploumaki et al.[16]	
• Excellent discussion of inclusion/exclusion criteria • Included a PRISMA flow chart for ease of included study understanding • A description of the method of data extraction from the papers is included	• Due to variability in included study design, definitions of failures and successes it was not possible to fully compare the results • An insufficient review of RDP data is included as extremely few numbers are included other than a general success rate
Tong et al.[12]	
• All goals and questions under examination were clearly stated • Selection criteria and selection methodology are detailed in depth and includes a PRISMA chart for clarification	• The included studies lacked the use of effective control populations • There is a wide degree of variation in the classification of failures in the included studies, each study author invents their own classification regimen and interprets it in different manners • All studies included had variable inclusion criteria for aspects such as prosthesis type,

Table A3: Strengths and Limitations of Systematic Reviews based on AMSTAR[14]	
Strengths	**Limitations**
	subject age, location of arch placement, Kennedy classification therefore making analysis of these aspects impossible • There is insufficient discussion of the results of the included papers in the text of the review
de Frietas et al.[10]	
• Paper inclusion/exclusion well documented and a flow chart for graphical representation was included. • The method of data extraction is provided	• A very limited discussion of the results is provided and included figures lacked data that was discussed • Papers were included that appeared to be contraindicated by the selection criteria • Insufficient discussion of the length of follow-up for each study therefore is unclear when each failure/complication occurred

RDP = removable denture prosthesis\

Table A4: Strengths and Limitations of Randomized Controlled Trials and Non-randomized Studies[15]

Strengths	Limitations
Randomized Controlled Trials	
Stober et al.[11]	
• Only dental laboratories with highly experienced personnel with accredited and calibrated technicians and dentists were used for fabrication of prostheses • All evaluations were completed by the authors who were all calibrated to ensure consistency of results	• The techniques utilized for randomization of patients are not described • A high dropout rate for both patients (26%) and their prostheses (30%) was encountered which may bias results • The potential for bias exists as multiple dentists were used for treatment procedures and their backgrounds were variable therefore expertise in specific areas may not be equal
Non-randomized Studies	
Behr et al.[17]	
• Statistical calculations utilized are well described and appropriate for the investigations being undertaken • All CR-RPDs were fabricated according to the standards provided in Spiekerman and Gruendler's book published in 1977 therefore making comparison highly reliable • Conclusions fit with the data that was presented	• Results are all obtained through examination of medical records not direct observation therefore quality of the information is subject to the reliability of the record itself • Patients are all advised to visit the clinic for follow-up appointments at 1 year time points without any obligation resulting in high dropout rates • The clinicians included did not have the same levels of education or opinions regarding treatments of specific patient situations which may impart bias • Study contained a low number of patients therefore using the results for large scale interpretation may not be valid
Purcell et al.[7]	
• Used appropriate standardized statistical calculations for data interpretation • Investigation is well broken down into easy to follow sections • Discussion provides excellent analysis of the data generated and that of existing literature • The conclusions are logical and directly related to the information examined	• Study contained a low number of patients therefore using the results for large scale interpretation may not be valid • Study is retrospective in nature therefore the results are based upon the data provided in medical records not actual observation which may impart bias

CR-RPD = clasp-retained removable partial denture

APPENDIX 4: Main Study Findings and Author's Conclusions

Table A5: Summary of Findings of Included Studies

Main Study Findings	Author's Conclusions
Chatzivasileiou et al., 2013[8]	
• In a 2 to 7 year study of 15 patients using RPDs had 100% success and only minor complications • Another study followed 10 patients with 16 implants in total and RPDs and found 100% survival after 1 to 4 years. Complications encountered were; pitting of surface healing around abutments, mandibular denture case framework fracture, inflammation of hyperplastic tissue requiring surgery • Another study of 21 patients found 100% survival after 5 years • Complications for RPD use tend to occur at a higher frequency during the first year after installation though they are typically easily solved problems • Current amount of investigation into the use of implant supported RPD is very limited though the authors agree that the existing literature is encouraging	• Implant assisted RPDs represent a money saving modality for patients and are simple to modify to a patients specific needs • Use of this type of prosthesis must be approached cautiously as a limited amount of literature exists • Future studies need to include much larger patient populations and longer follow-up periods
Verna et al., 2013[5]	
• Removable parallel telescopic crowns o After 7.4 years 37% required tooth re-cementation and 25% had corrosion and degradation of the acrylic around the metal bracing o Kaplan-Meier probability scoring demonstrated that survival rates during functional loading after 1, 5 and 10 years was 97.8%, 86.3% and 72.4% respectively • Telescopic removable partial dentures o failure rates of 4.7% and 3.8% of abutment teeth required removal o survival probabilities after 5.3 years were 95.1% for RPDs and 95.3% for abutment teeth o if an RPD had only 1 abutment tooth survival probability was 70.9%, with 2 abutments was 90.4%, 3 abutments was 95.8%	• Removable tooth supported double crown prostheses had higher survival rates than removable tooth supported double crown abutments • Loss of abutment teeth and denture fractures were major failure causes • Main technical complications encountered were incidence of denture relining and rebasing • RPDs with 3+ tooth supports had much lower rates of failure than those with only 1 or 2 • RPDs with implants supporting telescopic prostheses have higher survival rates compared to tooth-retained double crown RDP though the number of studies on this topic is limited • Removable implant supported mandibular overdentures survive longer compared to reconstructions on teeth • No matter the type of dental prosthesis being examined extensive maintenance protocols are needed • Additional study is required that utilizes

Table A5: Summary of Findings of Included Studies	
Main Study Findings	**Author's Conclusions**
and 4 abutments was 97.9% • Removable prostheses with conical retention of telescopic crowns had the highest failure percentage, 66.7% after 10 years • Removable conical crown retained dentures had a failure rate of 33.3% after 10 years • Removable clasp-retained dentures had a failure rate of 44.8% after 10 years	appropriate investigation of long-term survivability with standardized definitions for survival, failure and complications • All included studies demonstrated a wide range of survival for double crown tooth abutments and the main reasons for tooth loss were advancing periodontitis, secondary caries and fractures of abutment teeth
Ploumaki et al., 2013[16]	
• Only one included paper found that reported on RDP used on root-canal treated teeth and they found a survival rating of 66% after 6 years when RDPs were retained using posts • Authors indicated that when root canal treated teeth are used for abutments of RDPs they should be reinforced using posts	• The success rate of RDP on root canal treated teeth with cast post-and-cores and a follow-up of 6 years was 66% • The most common failure of root canal treated teeth is post or crown dislodgement. Secondly is root fracture and periapical inflammation. • Other complications such as periodontal problems, secondary carie development, partial crown fractures and crown replacement occurred at low levels
Tong et al., 2012[12]	
• Technical failures increased as time passed, 1.4% after 5 years and 33% after 10 years • Technical complications increased more dramatically, ranged from 20% after 5 years to 60% after 10 years • Biological failures were not related to time and ranged from 1% after 4.2 years to 26% after 13.5 years • Many studies have their own definitions for failure criteria (no standardization exists)	• Technical and biological complications are more likely to occur than failure for either category • Technical failures and complications along with biological complications increased as time passed • Biological failures occurred independent of time • Optimal longevity for a partially edentulous patient must incorporate oral hygiene program, correct RPD design and proper abutment selection
de Frietas et al., 2012[10]	
• There were five studies included in this review and their total patient populations were; 10, 6, 12, 15 and 6 and follow up ranged between 12 to 96 months • The implants demonstrated 100% survival in the first four studies and 95% in the fifth one • The study by Mitrani et al reported on one case where the framework required refabrication and the study by Mijiritsky had one case of rest rupture • Prosthesis survival was 100% in two studies, one after 8 years and the other after 7.5	• There is a high success rate for implants and prostheses in Kennedy classes I and II • Complications and the requirement for repairs are common • Is a lack of studies for long term success of implant supported RPDs in Kennedy class I and II cases and further analysis is required

Table A5: Summary of Findings of Included Studies	
Main Study Findings	**Author's Conclusions**
years • The RCT included found 58.3% success rate in their control group and 41.7% success in their testing group. Complications were matrix activation/deactivation, wrought wire clasp adjustment and one case of denture base acrylic fracture.	
Stober et al., 2014[11]	
• Overall found 87% survival for both RDP types • Using Chi-square testing was found that two characteristics differed significantly between the two groups; position of abutment teeth and mean value for maximum probing depth: • Position of abutment teeth found to be located more towards the anterior and premolar area in ER-RDP group than in C-RDP group ER-RDP C-RDP Anterior 66.7% 58% Premolar 27.6% 25.9% Molar 5.7% 16.1% • Maximum probing depth in C-RDP were deeper than in ER-RDP, 3.7mm and 3.1mm respectively • Lost 11 participants on follow-up (4 died and 8 RDPs failed) • In ER-RDP group 7 of the 30 failed (23%) o 1 due to loss of retention and facings o Others due to loss of abutment teeth as a result of caries or periodontal issues • In C-RDP group only 1 failure found (3%) and resulted from carie development • Survival rate for ER_RDP group was 77% and for C-RDP group was 97% though this difference was not statistically significant (p=0.06, HR=7.27, 95% CI=0.89-59) • Age, gender, number/arch position/mobility of abutments all had no statistically significant impact of the survival of the prosthesis • Had a total of 63 loses or fractures of facings which required repair (33 in ER-RDP and 30 in C-RDP, not statistically significant p=0.45 OR=1.25 95% CI=0.70-2.25) • The number of abutment teeth in the RDP dramatically increased the risk of veneer	• Clinical performance for both groups is acceptable • RDP retained by electroplated double crowns tend to have lower survival rates • Longer time frames for observation are required for the determination of differences in double crown systems

Table A5: Summary of Findings of Included Studies	
Main Study Findings	**Author's Conclusions**
failure (p=<0.001, OR=1.63, 95% CI=1.24-2.13) • A total of 10 failures in cementation occurred for primary crowns and no statistical difference was found between the groups (p=0.88, OR=1.07, 95% CI=0.43-2.69)	
Behr et al., 2012[17]	
• Survival rate after 5 years was 96.4% and at 10 years was 89.8% and no difference was detected in RPD placement in mandible or maxilla • Overall the 5 year event free rate for pressure area patient complaints was 84.4% in the maxilla and 56.8% in the mandible. At 10 years were 84.4% in maxilla and 50.1% in mandible • 18.3% of patients required reline of base and no statistically significant was found between maxilla or mandible (p=0.235). This complication was found at all time-points with no significant increase or decrease at any time-point • Fractures occur most frequently in clasps (16.1%) followed by major connectors (5.1%) and minor connectors (3.4%) • The 5 year event free rate for clasp fractures was 80.4% and was 76.9% after 10 years • Annual hazard rate for first year clasp fracture was 0.084, second year 0.064 third year 0.036, and fourth year 0.016. It then raised in the fifth and sixth years, 0.019 and 0.043 respectively • Acrylic resin teeth lost in 4.6% of cases and 3.4% contained substantial wear • Abutment tooth caries were found in 31.6% of patients and 35.6% had periodontal disease • No significant difference was found in males or females, age groups or Eichner Index groups for biological complications • Caries occurred at all stages of investigation and at 5 and 10 years were 58.4% and 39.6% respectively • A common issue was the loss of abutment teeth which occurred in 8.6% of the population. 5 and 10 year event free results were 88% and 80.7% respectively and this was slightly age dependent (using Cox	• 10 year survival time for all CR-RPDs was ~90% but 1/3 of these patients had caries or periodontal lesions • Loss of abutment teeth increased with age • Technical complications such as clasp failure occurred in 16.1% of cases • Other complications such as fracture of connectors/bases or loss of acrylic teeth were very rare

Table A5: Summary of Findings of Included Studies	
Main Study Findings	**Author's Conclusions**
regression p=0.047 with a negligible hazard ratio of 0.987 95% CI=0.073-1.000)	
Purcell et al., 2008[7]	

• Only 1 implant failed and it occurred at the 6 year time point
• Was 100% success for all prostheses
• Average recall was 7.9 years (range 5.9-9.7)
• For complication development in <2 year time frame the low was 0% for most categories and the high was 15.2% (95% CI=6.3-28.9) and occurred in fractured teeth in the mandible
• In the 2-5 year time frame the low was 0% for most categories and the high was 32.6% (95% CI=19.5-48) for hard relines of maxillary complete dentures
• For >5 year time frame low was 0% for most categories and the high was 47.8% (95% CI=32.9-63.1) for mandibular tooth replacement
• Complete denture relines significant factor at all time points; <2 year required in 13%, 2-5 year required in 32.6%, and in >5 year required in 34.8%
• Logistic regression of time period, age, gender for tooth fracture did not show any increase for any of these categories
• The only statistically significant complication reported here was for complete denture reline which was significantly higher in the 2-5 year versus the <2 year group (odds ratio 3.71, 95% CI=1.44-9.54, p=0.0066), when compare >5 year to <2 year groups is a significant increase (OR=8.49, 95% CI=2.79-25.78, p=0.0002)
• For each year of increased age the odds of requiring a reline increased (OR=1.06, 95% CI=1.0-1.12, p=0.0386)
• The odds of requiring a tooth replacement were significantly increased with increased time, compare >5 year group to <2 year group OR=52.5, 95% CI=6.7-411.3, p=0.001
	• There were no framework or abutment fractures at any time point
	• The three most common complications were:
	  ○ Replacement of acrylic resin prosthetic posterior teeth due to wear
	  ○ The need for maxillary complete denture laboratory heat-processed hard relines
	  ○ Fracture of acrylic resin in anterior prosthetic teeth
	• Patients are 1.06x more likely to need heat-processed hard reline with each increasing year of age
	• Patients are 3.7x more likely to need a hard reline during the 2-5 year recall period and 8.5x more likely in the >5 year recall period than in the first 2 years of use
	• Patients are 52.5x more likely to need posterior tooth replacement after 5 years of use than in the first 2 years

CI = confidence interval; C-RDP = cast double crown-retained removable denture prosthesis; CR-RPD = clasp-retained removable partial denture; ER-RDP = electroplated double crown-retained removable denture prosthesis; HR = hazard ratio; RCT = randomized controlled trial; RDP = removable denture prosthesis; RPD = removable partial denture;