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Tooth-Implant Combination Vs. Implant-Implant in Fixed Dental Prostheses; A Systematic Review & Meta-Analysis of the Long Term Complications

By

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ABSTRACT

The connection of teeth to dental implants within an FDP (fixed dental prosthesis) has broadened treatment-planning possibilities in implant dentistry worldwide. Nevertheless, concerns have arisen regarding rigidly splinting teeth to implants due to a sum of complications that have been associated with these "combination prostheses". On the other hand, many studies claim that the complications that occur with tooth-to-implant prostheses also occur with implant-to-implant prostheses, or that no complications occur at all. The aim of this systematic review is to state the long-term complications mentioned in the literature about combinations of tooth-implant FDPs, when compared with implant-implant FDPs. A comprehensive electronic search in the literature between the period of 1960 to 2015 using the following search engines: Medline, Pubmed, OvidMD Plus, was done to gather the data in the literature. The results of this study show that the incidence of complications was significantly worse for Implant-Tooth FDPs group than the Implant-Implant group in regards to "Implant loss" and "Failed FDP" type of complications. However, the conclusion is that more thorough clinical documentation must be done to be able to extract valid data in future studies on this topic, otherwise it would be impossible to attain valid quantitative data from these studies.

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1. I hereby declare that plagiarism is wrong; it is using another person's work and claiming it as one's own work.

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3. This research dissertation is my own work.

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SUMMARY OF CONTENT

SECTION A - THE RESEARCH PROTOCOL

SECTION B - THE SYSTEMATIC REVIEW & META- ANALYSIS

TABLE OF CONTENTS

SECTION A: THE RESEARCH PROTOCOL

SECTION B: THE SYTEMATIC REVIEW & META-ANALYSIS

SECTION A: THE RESEARCH PROTOCOL

LIST OF ABBREVIATIONS AND DEFINITIONS:

FDP	Fixed Dental Prosthesis; Dental Bridge
Implant-Implant FDP	Implant connected to another implant within an FDP
Implant-Tooth FDP	Implant connected to a natural tooth within an FDP
Abutment	That which is supporting the FDP (tooth or implant)
Rigid Connection	Non movable connection between abutment and FDP
Non-rigid Connection	Movable connection between abutment and FDP
Screw retained	Use of a screw to connect FDP with implant abutment
Cement retained	Use of cement to connect FDP with implant abutment
Combination Prosthesis	A prosthesis that uses both implants and teeth as abutments within the same FDP.
Freestanding Prosthesis	A prosthesis that uses only implants as abutments within the same FDP.
CAL	Periodontal clinical attachment loss

BACKGROUND

The connection of teeth to dental implants within an FDP has broadened treatment-planning possibilities in implant dentistry worldwide (1)(2)(3)(4). Nevertheless, concerns have arisen regarding rigidly splinting teeth to implants due to a sum of complications that have been associated with these "combination prostheses" (1,2,5–8). On the other hand, many studies claim that the complications that occur with tooth-to-implant prostheses also occur with implant-to-implant prostheses(9)(10)(11)(6) or that no complications occur at all (12).

The introduction of intraosseous implants into dentistry in the late 1970's by Per-Ingvar Branemark has had a tremendous impact on modern dentistry(13)(14). The use of a single implant to replace a single missing tooth has led to a somewhat predictable outcome, however with cases of partially edentulous patients, the need to connect remaining teeth with implants has become a conservative approach to treatment planning. Rather than extracting a free-end natural tooth and placing two implants as abutments - which is often the case with most practitioners, another option has simply been connecting natural teeth to implants as a means of conserving the time and finances of their patients, in addition to the anatomic limitations that might be faced when planning for correct implant placement(15). Although this seems like a practical approach for the patient, a limited number of studies have yet been conducted to summarize and compare the complications of such an approach.

Many studies state that there is no significant difference in the complications that can arise when connecting teeth to implants as opposed to connecting implants to implants (3)(12)(4)(10)(11)(6). Yet there are a number of studies that indicate specific

complications that have been correlated with fixating teeth to implants .The number of these incidences has led to suspicion and controversy on the topic (1)(5)(2)(7)(8).

It might seem quite logical that complications should happen in combining a tooth to an implant under one prosthesis; the natural tooth is supported by periodontal ligaments that give it an elastic bounce-back characteristic every time it is subjected to the natural force load of occlusion, however, an implant is technically rigidly ankylosed to the underlying alveolar bone, this difference in biomechanics could have an impact on the prosthesis placed which links these two together (16).

The complications that have been found in the various studies are first and foremost; decementation of the FDP, biomechanical failures, histological changes, intrusion of the natural tooth and radiographic marginal bone loss (at a higher rate than implant-implant prosthesis), and overall, the impact on survival rate of the prosthesis (1)(9)(5)(2)(6)(7)(8). On the other hand, in studies showing implant to implant prostheses cement wash out, marginal bone loss, histologic changes of the gingiva are also found in the long term. (1)(9)(17)(10)(11)(6).

Identifying these complications will be the prime focus of this review. Perhaps the configuration of the connectors whether rigid or non rigid plays a major role in the survival rate? (17)(2)(18), perhaps the patients' parafunctional habits have an influence on the survival of the prostheses? (5) In the majority of the studies gathered for this review, a study period of at least 5 years after placement of both types of FDP's has shown to be definitive in showing the long term effect on the attachment apparatus and on other variables (19)(5)(6)(3)(12)(4). An insufficient number of conclusive systematic reviews have been done on this topic to give clear definitive answers as to whether or not one should practice the tooth to implant approach for the long term survival of the supporting tooth, implant and prosthesis, or to practice the

implant to implant approach as a safe measure for longevity of the FDP, and how to overcome common complications that impact the survival rate of both.

AIM

To state the long-term complications mentioned in the literature about combinations of tooth-implant FDP's, when compared with implant-implant FDP's.

RESEARCH QUESTION

PICO Question: 'Are the long-term complications of tooth-implant supported FDP's comparable to that of implant-implant supported FDP's? '

OBJECTIVE

I. PRIMARY OBJECTIVE To provide the reader with more insight on what the literature has to say about using both types of FDP's; by delivering a concise systematic review of the associated long-term complications that can arise with either type of prosthesis.

II. SECONDARY OBJECTIVE To provide the solutions to these complications based on what is stated in the literature.

III. TERTIARY OBJECTIVE To collect the applicable quantitative data from this systematic review and conduct a meta-analysis to provide statistical weight to the results of study.

JUSTIFICATION OF THIS REVIEW

A few systematic reviews have been presented that are related to this topic, however this study will be an up to date review to focus only on the complications found, and to conduct a meta-analysis where applicable.

MATERIALS AND METHODS

I. STUDY DESIGN Systematic review & Meta-analysis

II. DATA EXTRACTION A comprehensive electronic search in the literature between the period of 1960 to 2015 using the following search engines: Medline, Pubmed, OvidMD Plus, by searching the keywords "implant and tooth and fixed and partial and denture" 'implant and tooth and bridge', "implant-tooth" "implant-implant" "combination and implant and tooth", "Implant-implant FDP" "Implant to implant FDP" "Implant-tooth FDP" "Implant to tooth FDP" all followed by the keyword 'complications'. Unpublished literature and grey literature included. (All unpublished data extracted will not be cited in the references however will be mentioned in the text). (This Study will follow the PRISMA statement guidelines; The PRISMA Statement consists of a 27-item checklist and a four-phase flow diagram. The aim of the PRISMA Statement is to help authors improve the reporting of systematic reviews and meta-analyses found at http://www.prisma-statement.org/)

III. INCLUSION CRITERIA All relevant study designs that have a minimum mean follow-up duration of 5 years will be included in the study; any relevant

article written in another language that appears in the searches will be included and translated.

IV. EXCLUSION CRITERIA Any study that has a mean follow-up duration that is less than 5 years, reports consisting only of abstract. Studies considered weak and are considered for exclusion: Unclear design type, no mention of presence or lack of complications, vague mentioning of dropouts from the study, no mention of cumulative survival rate or failure rate. Vague mention of complications on underlying attachment apparatus, and finally imprecise measurements of complications.

V. DATA ANALYSIS A stratified cluster sampling technique will be used to organize the articles. All studies will be divided according to type of FDP; Implant-Implant and Implant-Tooth. Within each division of FDP type, there will be a sub-categorization for each type of complication mentioned in each and every study. Each complication will be weighed qualitatively for the systematic review, - and where applicable - quantitatively for the meta-analysis.

VI. ASSESSMENT OF HETEROGENEITY There will be vast heterogeneity among the studies presented; whether randomized control trials, non-randomized controlled trials, longitudinal experimental clinical studies, longitudinal prospective studies, longitudinal retrospective studies, case control studies cross-sectional studies, other systematic reviews and other meta-analyses. In addition, heterogeneity will be seen in the quality of the studies; presentations of the methodology, presentations of the results, terms and conditions used, follow up periods, difference in terminology used to explain types of complications and measurements of the complications.

Therefore, results of this study will be based initially on qualitative measures and descriptive analysis, after sufficient data is collected, the available valid numerical values will be collected to provide a quantitative analysis of the systematic review. This descriptive and quantitative analysis will be based on the aforementioned criteria of categorization of the extracted included data in the "methods" section.

VII. ASSESSMENT OF RISK OF BIAS IN INCLUDED STUDIES: One rater will be involved; an internal study supervisor and the primary study investigator will review all data to insure eligibility of articles to be included in the study. Any disputes will be mentioned and will lead to the inclusion of a second rater. This following index was created to rate each study for eligibility of inclusion:

Rater No. _____

*****Study name**

*****Author name**

INCLUSION CRITERIA

1. Minimum follow-up duration of 5 years ☐

2. Relevance to topic ☐

EXCLUSION CRITERIA

1. **A follow up duration less than 5 years**
2. **Reports consisting only of abstract**
3. **Study considered weak and are considered for exclusion:**

a- Unclear design type
b- Non calibrated examiners
c- No mention of "presence" or "lack of" complications
d- Vague mentioning of dropouts from the study
e- No mention of cumulative survival rate or failure rate
f- Vague mention of complications on underlying attachment apparatus.

VIII. MISSING DATA All data that is missed in the studies will be mentioned, noted, and could be considered a weakness that will lead to exclusion from the meta-analysis however will still be used in the systematic review.

IX. SUB-GROUP ANALYSES A subgroup analysis will be conducted if certain variables are noted to be of significance to the study.

ETHICS

This protocol will be sent for ethical review by the ethical comity of the college and the research will commence after approval from this comity.

FUNDING

No funding is expected for this study unless certain articles will need to be purchased.

DISSEMINATION

After approval from the college research comity for validity, this study will be disseminated by peer-reviewed publications and conference presentations.

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SECTION B: THE SYSTEMATIC REVIEW AND META-ANALYSIS

LIST OF ABBREVIATIONS AND DEFINITIONS:

FDP	Fixed Dental Prosthesis; Dental Bridge
Implant-Implant FDP	Implant connected to another implant within an FDP
Implant-Tooth FDP	Implant connected to a natural tooth within an FDP
Abutment	That which is supporting the FDP (tooth or implant)
Rigid Connection	Non movable connection between abutment and FDP
Non-rigid Connection	Movable connection between abutment and FDP
Screw retained	Use of a screw to connect FDP with implant abutment
Cement retained	Use of cement to connect FDP with implant abutment
Combination Prosthesis	A prosthesis that uses both implants and teeth as abutments within the same FDP.
Freestanding Prosthesis	A prosthesis that uses only implants as abutments within the same FDP.
CAL	Periodontal clinical attachment loss

BACKGROUND

The connection of teeth to implants within the same fixed dental prosthesis (I-T) FDP has facilitated treatment modalities in implant dentistry worldwide(1). This treatment option spurs a topic that brings about great controversy, yet many clinicians resort to it due to the advantages it can offer for their patients. Briefly, The most common advantages in placing an I-T FDP are; a reduction in cost for the patient and anatomic limitations of the proposed implant placement site (whether ridge modification and sinus lifting are refused by the patient or avoidance of vital structures is required)(1)(2). These advantages of I-T FDPs serve to fulfill patients' needs - but this is occasionally a short-term fulfillment(3).

When it comes to placing FDPs supported by natural teeth we have an abundance of long-term studies to rely on in terms of survival and complication rates. When placing FDPs solely on implants we have slightly less long-term data, yet we are sure that the two abutments (implant – implant) are alike in nature, therefore not much speculation exists(4). However when it comes to I-T FDPs the available long term studies are scarce, and there is vast heterogeneity among them- in terms of study design, documentation, terminology and treatment modalities- to the level where it is very difficult to draw clear conclusions(5)(6). Many studies have been conducted which advocate the use of freestanding I-I FDPs as a first option whenever possible(5)(6)(3)(7), and other studies state that there is no difference in the long-term survival and complication rates between I-I and I-T FDPs(8)(2)(9)(10). A definitive review on the complications and risks that are associated with both I-I FDPs and I-T FDPs to help make the judgment on how best to restore patients' dentitions to avoid long-term complications is needed; A review that will focus mainly on the types of

complications one may face and ways to avoid these complications based on each authors' recommendations and conclusions stated in the studies.

The question that is the base of this study is "Are the long-term complications of tooth-implant supported FDPs comparable to that of implant-implant supported FDPs?"

Therefore, the aim of this systematic review is to shed light on the long-term complications stated in the literature about combinations of tooth-implant FDPs, and compare them with long-term implant-implant FDP complications.

MATERIALS AND METHODS

I. **SEARCH STRATEGY** A comprehensive electronic search in the literature between the period of 1960 to 2015 using the following search engines: Pubmed, OvidMD Plus, by searching the keywords "implant and tooth and fixed and partial and denture" 'implant and tooth and bridge', "implant-tooth" "implant-implant" "combination and implant and tooth", "Implant-implant FDP" "Implant to implant FDP" "Implant-tooth FDP" "Implant to tooth FDP" all followed by the keyword 'complications'. Initially all abstracts were included based on titles until full text was obtained. (This Study followed the PRISMA statement guidelines; The PRISMA Statement consists of a 27-item checklist and a four-phase flow diagram. The aim of the PRISMA Statement is to help authors improve the reporting of systematic reviews and meta-analyses found at http://www.prisma-statement.org/)

II. **INCLUSION CRITERIA** All relevant study designs on I-I FDPs and I-T FDPs that have a minimum follow-up duration of 5 years were included in the study regardless of the types of implants used in the study or the amount of remaining dentition of the

study subjects, or the material of the superstructures that were used in both types of restorations.

III. **EXCLUSION CRITERIA** Any study that had a follow up duration less than 5 years and reports consisting only of abstract were excluded. Studies considered weak and were considered for exclusion: Unclear design type, no mention of presence or lack of complications, vague mention of dropouts from the study, no mention of cumulative survival rate or failure rate. Studies based on surveys and questionnaires were excluded due to unspecified follow up durations but could be mentioned in the discussion.

IV. **STUDY SELECTION** Titles and abstracts were all screened and gathered by the primary investigator. Full text articles were then obtained and reviewed by one rater; one internal supervisor. The raters created an index according to the inclusion and exclusion criteria and rated each article. Any dispute over inclusion was discussed among the rater and primary investigator and finally agreement was made over each article to be included. The following flowchart from PRISMA was used to document the included and excluded studies (Figure 1).

PRISMA 2009 Flow Diagram

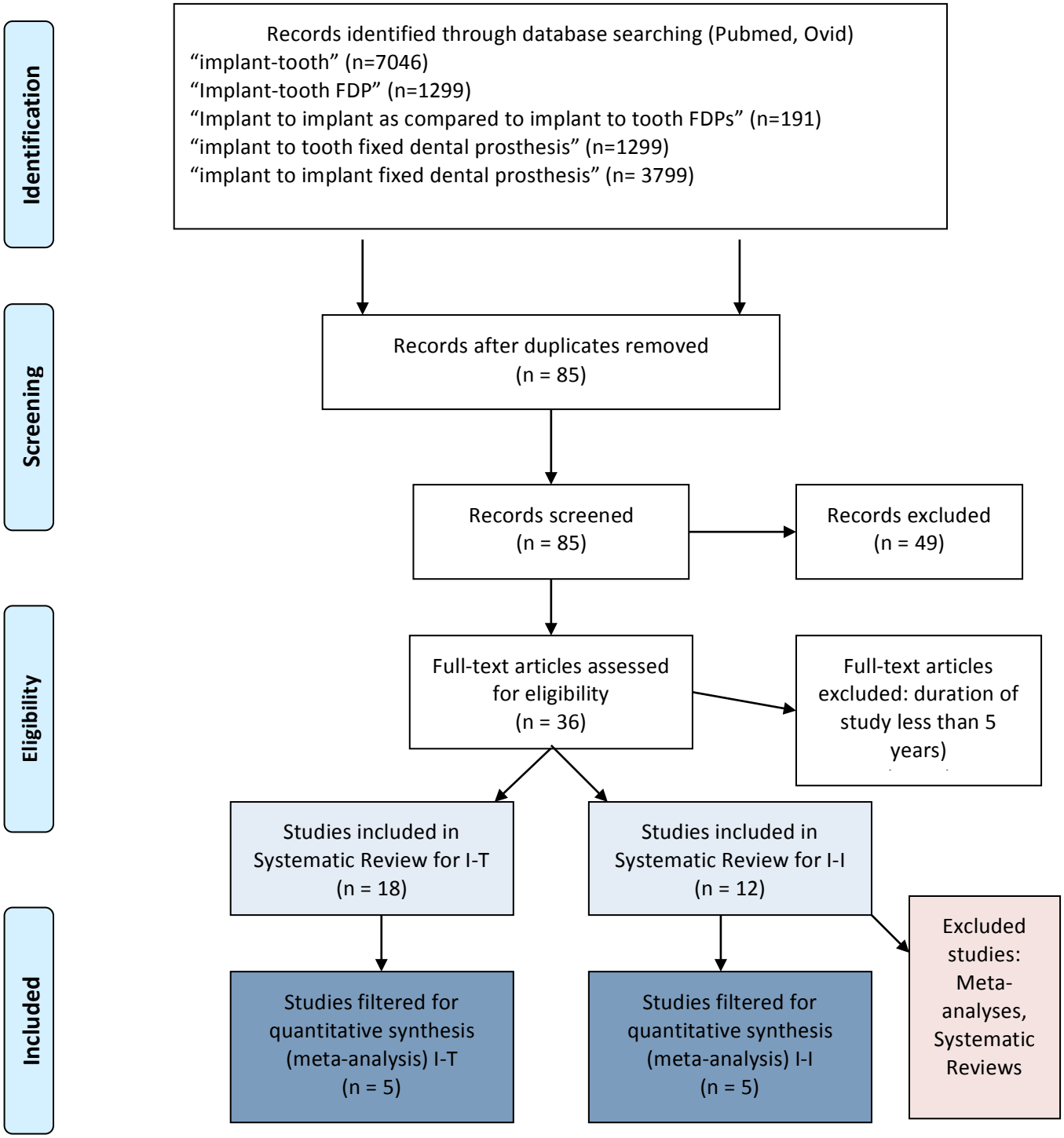


Figure (1)

V. DATA EXTRACTION All studies that were included in the systematic review were divided into two tables for extraction of relevant data; one table with 12 studies on I-I FDPS, and one table with 18 studies on I-T FDPs. All data that was relevant to this study was extracted from each article (Author, study name, year of publication, journal of publication, follow up period, study design, and type of connection that was used between the I-I abutments within the FDP, and the type of connection that was used between I-T abutments within the FDP). The next set of data extraction also involved documenting every type of terminology that was used in every study to describe each complication and categorizing them into two other tables of "Types of Complications" which documents the rate of the complications and sample size that was used in each study only based on what the authors stated. (Table1)(Table2): tables of included I-T studies (Table3)(Table4): tables of included I-I studies. (Table 5) I-I, (Table 6) I-T: List all the types of complications that have been mentioned in the studies word for word using their own terminology and their rates of occurrences in relation to each sample size that was measured from within that study. None of the complications that were stated in the studies were changed to another name, and no assumptions were made for what they "might be". For example: "soft tissue inflammation around implants" was not substituted for "periimplantitis" however "biological complication around implants with probing depth > 5mm" was grouped with "periimplantitis" as mentioned in one study(11). Also, "Screw loosening" was not substituted for "retention loss", however "Ceramic fracture" was considered as "veneer fracture". "Vitality loss" and "periapical radioluency" were not merged under one complication. "Periodontal disease"

and “Mobility” were however, merged under one category. In (tables 5&6): Only the retrospective and prospective studies in both I-I and I-T groups we categorized for complication rates to quantitative measures since the systematic reviews and meta-analysis studies will be used only for qualitative assessment. **Studies shown in (Tables 1,2,3,4) in red are the studies that will be included in the final meta-analysis.

	Study Name	Author	Journal	Year	Follow-up	Study Design	Connection type
1	A Case report of a TPS dental implant rigidly connected to a natural tooth: 19-year-follow-up	Quaranta A 2013	Annali di Stomatologia. 4(3-4):263-8, 2013 Jul-Dec.	2013	19 years	case report	Rigid cemented
2	A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. II. Combined tooth--implant-	Lang NP 2004	Clinical Oral Implants Research. 15(6):643-53, 2004 Dec.	2004	5 years - 10 years	Systematic Review	Rigid, non rigid
3	Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function	Bragger 2001	Clinical Oral Implants Research February 2001;12(1):26-34	2001	4-5 years	Prospective cohort Study	Screw retained 24.8% , cement retained 75.2%
4	Bridges supported by free-standing implants versus bridges supported by tooth and implant. A five-year prospective study.	Olsson 1995	Clinical Oral Implants Research. 6(2):114-21, 1995 Jun.	1995	5 years	Prospective cohort	Rigid screw retained
5	Tooth-implant and implant supported fixed partial dentures: a 10-year report.	Gunne 1999	International Journal of Prosthodontics. 12(3):216-21, 1999 May-Jun.	1999	10 years	Prospective cohort	Precision attachment (McCollum T-Attachment, Cendres et Métaux).,rigid
6	Risks and Benefits of Connecting an Implant and Natural Tooth. [Article]	Davis S. 2014	Implant Dentistry June 2014;23(3):253-257	2014	5-10 years	Review	Rigid, non rigid
7	Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients: Part I An up to 15-years clinical evaluation	Naert 2001	Clin. Oral Impl. Res. 12, 2001; 237–244	2001	15 years mean 6.5yrs	Prospective cohort	Rigid, non rigid , temporary and permanent cement on abutment teethNeyA-slot, C&MA screw, I.M.Z.-TA block, Combi-snapA,Screw-retained base mantle coping, Cementedwith without base mantle coping
8	Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients: Part II: An up to 15-years radiographic evaluation	Naert 2001	Clinical Oral Implants Research June 2001;12(3):245-251	2001	15 years mean 6.5yrs	Prospective cohort	Rigid, non rigid , temporary and permanent cement on abutment teethNeyA-slot, C&MA screw, I.M.Z.-TA block, Combi-snapA,Screw-retained base mantle coping, Cementedwith without base mantle coping

(Table 1)

9	Retrospective evaluation of complete-arch fixed partial dentures connecting teeth and implant abutments in patients with normal and reduced periodontal support.	Cordaro L. 2005	Journal of Prosthetic Dentistry. 94(4):313-20, 2005 Oct.	2005	7 years	retrospective	Scew retained and cement , rigid and non rigid
10	Splinting osseointegrated implants and natural teeth in partially edentulous patients: a systematic review of the literature. [Review]	Mamalis 2012	Journal of Oral Implantology. 38(4):424-34, 2012 Aug.	2012	5 years	Systematic review	Rigid , non rigid
11	Survival and Complication Rates of Combined Tooth-Implant–Supported Fixed and Removable Partial Dentures	Nickenig HJ. 2008	Int J Prosthodont 2008;21:131–137	2008	median 6.7 yrs	Retrospective study	Screw retained(61.3%), cement (14.9%), or a telescopic system (23.1%) , 18.8% non rigid
12	Survival and complication rates of fixed partial dentures supported by a combination of teeth and implants	Weber 2012	Evidence Based Dent Pract. 2012 Sep;12(3 Suppl):215-6	2012	5-10 years	Meta analysis	Rigid, non rigid
13	Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study.	Bragger 2005	Clinical Oral Implants Research. 16(3):326-34, 2005 Jun.	2005	10 years	Prospective cohort Study	Rigid , non rigid
14	Tooth- and implant-supported prostheses: a retrospective clinical follow-up up to 8 years.	Kindberg 2001	International Journal of Prosthodontics. 14(6):575-81, 2001 Nov-Dec.	2001	8 years	Retrospective	All rigid except one patient, copings
15	Tooth-Implant Connection: A Review. [Review]	Hoffmann 2012	Journal of Oral Implantology April 2012;38(2):194-200	2012	not mentioned	Review	Rigid, non rigid
16	Connecting Teeth to Implants: A Critical Review of the Literature and Presentation of Practical Guidelines	Greenstein 2009	Compend Contin Educ Dent. 2009 Sep;30(7):440-53.	2009	not mentioned	literature review	Rigid, non rigid
17	Implant/Tooth–Connected Restorations Utilizing Screw-Fixed Attachments: A Survey of 3,096 Sites in Function for 3 to 14 Years	Fugazzotto 1999	Int J Oral Maxillofac Implants 1999;14:819–823	1999	3-14 years	retrospective	intramobile connectors (screw fixed attachments) vertical and horizontal , Rigid/non rigid. Of these attachments, 2,206 utilized vertical fixation screws and 890 employed horizontal fixation screws
18	Survival and complication rates of combined tooth–implant-supported fixed partial dentures	Nickenig Hj.2006	Clin. Oral Impl. Res. 17, 2006; 506–511	2006	2.2-8.3 years median 4.73 yrs	retrospective	1/3 non rigid, the rest rigid

(Table 2)

	Study Name	Authors	Journal	Year	Follow up Period	Study Design	Connection type
1	A systematic review of the survival and complication rates of implantsupported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years	Pjetursson B.E 2012	Clin. Oral Implants Res. 23(Suppl. 6), 2012, 22–38	Jum. I-05	5 - 10 yrs	Systematic review	81% of the FDPs being screw retained and 19% being cemented
2	Complication and Failure Rates with Implant-Supported Fixed Dental Prostheses and Single Crowns: A 10-Year Retrospective Study	Wittenben J 2014	Clinical Implant Dentistry and Related Research, Volume 16, Number 3, 2014	2014	10 yrs	Retrospective	Cemented and screw retained
3	A Meta-Analysis of Prosthodontic Complication Rates of Implant-Supported Fixed Dental Prostheses in Edentulous Patients After an Observation Period of at Least 5 Years	Bozini T 2011	Int J Oral Maxillofac Implants 2011;26:304–318	2011	5 yrs	Meta-analysis	All screw retained
4	A Systematic Review of Biologic and Technical Complications with Fixed Implant Rehabilitations for Edentulous Patients	Papaspyridakos P 2012	Int J Oral Maxillofac Implants 2012;27:102–110	2012	5 yrs	Systematic review	All screw retained
5	Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function	Bragger 2001	Clinical Oral Implants Research February 2001;12(1):26-34	2001	4-5 years	Prospective cohort study	24.8% screw retained,75.2% cement
6	Bridges supported by free-standing implants versus bridges supported by tooth and implant. A five-year prospective study.	Olsson M 1995	Clinical Oral Implants Research. 6(2):114-21, 1995 Jun.	1995	5 years	Prospective cohort study	Precision attachment (McCollum T-Attachment,Cendres et Métaux)Rigid
7	Tooth-implant and implant supported fixed partial dentures: a 10-year report.	Gunne J 1999	International Journal of Prosthodontics. 12(3):216-21, 1999 May-Jun.	1999	10 years	Prospective cohort study	Precision attachment (McCollum T-Attachment,Cendres et Métaux) Rigid

(Table 3)

8	Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients: Part I An up to 15-years clinical evaluation	Naert 2001	Clin. Oral Impl. Res. 12, 2001; 237–244	2001	15 years mean 6.5yrs	Prospective cohort study	Rigid, non rigid , temporary and permanent cement on abutment teethNeyA-slot, C&MA screw, I.M.Z.-TA block, Combi-snapA,Screw-retained base mantle coping, Cemented with and without base mantle coping
9	Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients: Part II: An up to 15-years radiographic evaluation	Naert 2001	Clinical Oral Implants Research June 2001;12(3):245-251	2001	15 years mean 6.5yrs	Prospective cohort study	Rigid, non rigid , temporary and permanent cement on abutment teethNeyA-slot, C&MA screw, I.M.Z.-TA block, Combi-snapA,Screw-retained base mantle coping, Cemented with and without base mantle coping
10	Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study.	Bragger 2005	Clinical Oral Implants Research. 16(3):326-34, 2005 Jun.	2005	10 years	Prospective cohort Study	Rigid , non rigid
11	Technical complications of implantsupported fixed partial dentures in partially edentulous cases after an average observation period of 5 years	Kreissl 2007	Clin. Oral Impl. Res., 18, 2007; 720–726	2007	5 years	Prospective	Rigid
12	Clinical and Radiographic Evaluation of Patients Receiving Both Tooth- and Implant-Supported Prosthodontic Treatment After 5 Years of Function	Wolleb 2012	Int J Prosthodont 2012;25:252–259.	2012	5 years	Retrospective	Mostly screw retained, some cemented

(Table 4)

	Study	Sample Size			Veneer fracture	Screw Loosening	Decementation	Periimplantitis	Retention Loss	Abutment screw fracture	Implant Fracture	Biological Complications	Implant Loss	Failed FDP
		FDPS	Implants	Patients										
1	Wittneben 2014	127			28.35%		0.00%						0.79%	3.94%
2	Bragger 2001	40	84	33			0.00%				2.50%	15.00%	2.50%	2.50%
3	Olsson 1995	23	46	23			0.00%						13.04%	17.39%
4	Gunne 1999	23	46	23		8.70%	0.00%						0.00%	0.00%
5	Naert Pt 1 2001	123	329	123			0.00%			0.61%	0.30%		0.30%	0.30%
6	Bragger 2005	33	69	29		30.30%	0.00%	11.59%	30.30%		0.00%	1.45%	1.45%	6.06%
7	Kreissl 2007	7	17		0.00%	0.00%	0.00%	0.00%		0.00%			0.00%	0.00%
8	Wolleb 2012	15	39		6.67%		0.00%			0.00%	0.00%		0.00%	0.00%

(Table 5)

	Study	Sample Size				Veneer fracture	Screw Loosening	Decementation	Intrusion	Caries	Vitality Loss	Periapical RL	Periodontal diseaese CAL	Periimplantitis	Retention Loss	Abutment Fracture	Implant Fracature	Tooth Extraction	Biological Complications	Implant Loss	Failed FDP
		FDPS	Teeth	Implants	Patients																
1	Bragger 2001	18		19	15									5.26%			5.56%		16.67%	5.26%	5.56%
2	Olsson 1995	23	23	23	23															8.70%	8.70%
3	Gunne 1999	20	20	20	20		15.00%			5.00%	5.00%		5.00%					5.00%		0.00%	0.00%
4	Naert 2001	140	313	339	123			9%	6.07%	0.96%	0.96%	3.51%	0.96%	1.77%		0.88%	1.18%	1.60%		2.95%	2.14%
5	Cordaro 2005	19	72	90	19				5.56%	0%	0%				47.37%					1.11%	
6	Nickenig HJ 2008	178		343		2.81%	2.62%	8.96%	8.99%	6.18%	6.18%		10.11%	4.96%	5.06%	1.69%		5.62%	4.96%	1.69%	10.67%
7	Bragger 2005	22	24	22	21		18.18%		0%	16.67%				13.64%	18.18%		4.55%	16.67%	22.73%	22.73%	31.82%
8	Kindberg 2001	41	85	115	36	9.76%	9.76%		7.32%		5.88%	5.88%	3.53%		7.32%	5.88%		5.88%		7.83%	4.88%
9	Fugazzotto 1999	1206		3096 atchms	843		2.14%		0.29%						0.58%	0.17%					
10	Nickenig HJ 2006	84	132	142	83	5.95%	10.71%	11.43%		2.27%	0.76%	0.76%	5.30%	0.70%	1.19%	0%		3.03%	1.41%	0.00%	4.76%

(Table 6)

VI. STATISTICAL ANALYSIS

All complication rates shown in (Table 5) and (Table 6) are corresponding to what is stated in each study. Every type of complication was measured using a different sample size within the same study depending on how the author measured the event rate. For example: "Implant loss" rate in one study(7) was measured as 1/69 implants; 69 is the sample size for this complication, however within the same study 10 cases of "screw loosening" were mentioned but the percentage yielded was from an FDP sample size - not implants therefore; 10/33 FDPS would yield a different weight. This was documented within each study to assure accurate event rates and occurrences for each complication type. First a "Qualitative" description will be given regarding each complication and what is exactly mentioned in the results and conclusions for each study. Secondly, a "Quantitative" measurement will be given using forest plots for each complication in each group of I-I and I-T. This is done to measure the standard error for each complication to obtain the 95% confidence interval (CI) of the summary estimates of the event rates; the measurements in the forest plot will be submitted using the normal scale 0 as the null value. Finally a miniscule meta-analysis will be done for the 5 studies which are highlighted in red in the tables (Table 1,2,3,4); these 5 studies are the only studies in which they used control groups and study groups and compared I-I and I-T within the same study which will give a better estimate of the event rates of these complications. All statistical data was measured using the program *Comprehensive Meta-analysis Software CMA*.

RESULTS

A total of 12 studies for the I-I group, and 18 studies for the I-T group were included for the systematic review. (Table 1)(Table 2) represent the studies chosen for the I-T group; 6 prospective cohort studies *(Bragger,2001)(10) (Olsson,1995)(9) (Gunne,1999)(8)(Naert,2001 pt. I,II)(12)(13)(Bragger,2005) (7)*, 5 reviews/systematic reviews *(Lang,2004)(14) (Davis,2014)(1) (Mamalis,2012)(15) (Hoffmann,2012)(16) (Greenstein,2009)(2)*, 5 retrospective studies *(Cordaro,2005)(17) (Nickenig,2008)(11) (Kindberg,2001)(18) (Fugazzotto,1999)(19) (Nickenig,2006)(20),* 1 meta-analysis *(Weber 2012)* (4) and 1 case report *(Quaranta,2013)(21)*. For the I-I studies shown in (Table3)(Table4); 7 prospective cohort studies *(Bragger,2001) (Olsson,1995)/(Gunne,1999) (Naert,2001 pt.I,II) (Bragger,2005) (Kreissl 2007)(22)* , 2 systematic reviews *(Pjetursson,2012)(23) (Papaspyridakos,2012)(24)* , 2 retrospective studies *(Wittneben,2014)(25) (Wolleb,2012)(26)* and 1 meta-analysis *(Bozini,2012)(27).* The mean minimum follow-up duration for all the studies is 5 years as shown in (Table 1)(Table 2) (Table3) (Table 4). The type of connections within the FDPs that were described in the I-T (Tables 1&2): *(Lang,2004) (Davis,2014) (Naert,2001 pt.I,II) (Cordaro,2005) (Mamalis,2012) (Nickenig,2008) (Weber,2012) (Bragger,2005) (Kindberg,2001) (Hoffmann,2012) (Greenstein,2009) (Fugazzotto,1999) (Nickenig,2006)*: All used "Rigid and Non Rigid" Connectors. Only *(Quaranta,2013) (Olsson,1995)/(Gunne,1999) (Bragger,2001)* used only "Rigid" connectors. From the I-I group all connections were "Rigid" either Screw retained or cement retained. When "0%" is used as a figure in the tables, this signifies that the author stated that there were no complications. However when the cell is blank, this signifies that there was no mention of that complication in the study itself. 16 complications were stated in the I-T group of prospective and retrospective studies

which are: 1.Veneer fracture 2.Screw loosening 3.Decementation 4.Intrusion 5.Caries 6.Vitality loss 7.Periapical radiolucency 8.Periodontal disease 9.Periimplantitis 10.Retention loss 11.Abutment fracture 12.Implant fracture 13.Tooth loss 14.Biological complications 15.Implant loss 16.Failed FDP. The results of the complications in the systematic reviews and meta-analysis of the I-T FDPs are presented after the prospective and retrospective studies. Finally for I-T section, a summary of results regarding the "rigid" or "non-rigid" attachments that were mentioned in all of the studies is stated. For the I-I group, 9 complications were mentioned in the prospective and retrospective studies; 1.Veneer fracture 2.Screw loosening 3.Periimplantits 4.Retention Loss 5.Abutment screw fracture 6.Implant fracture 7.Biological complications 8.Implant loss 9. Failed FDP, I-I group did not have any reports on "decementation" as the I-T group did. The complication "marginal bone loss" was eliminated from this study due to missing data on standard deviations and inconsistency of measurements between the studies. The results of the systematic reviews and meta-analysis of the I-I FDP studies are presented afterwards. Furthermore, a section of comparison of the results of both (I-T) and (I-I) groups will be presented qualitatively, and finally a meta-analysis of the 5 studies *(Bragger,2001) (Olsson,1995) (Gunne,1999)(Naert,2001)* and *(Bragger,2005)* will be presented as the final portion of the results of this study.

COMPLICATIONS:

(I-T)

A. RESULTS OF COMPLICATIONS STATED IN THE PROSPECTIVE AND RETROSEPCTIVE STUDIES:

1. Veneer Fracture:

In reference to (Table 5)(Table 6); Of the 10 prospective and retrospective studies; only 3 studies mentioned "veneer fracture" or "ceramic fracture" or "Acrylic veneer fracture": *(Nickenig,2008)* had 5/178 FDPs (2.81%) , *(Kindberg,2001)* had 4/41 FDPs (9.76%) and *(Nickenig,2006)* had 5/84 FDPs (5.95%) with veneer fracture. The summary estimate for this complication is (5.2%) (95% CI: 3.1%-8.6%). (Figure 2)

2. Screw Loosening:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 6 studies mentioned screw loosening; *(Gunne,1999)* had 3/20 implants (15%), *(Nickenig,2008)* had 9/343 implants (2.62%), *(Bragger,2005)* had 4/22 implants (18.18%), *(Kindberg,2001)* had 4/41 FDPs (9.76%), *(Fugazzotto,1999)*had 18/843 patients (2.14%), *(Nickenig,2006)* had 9/84 FDPs (10.71%) cases with screw loosening. The summary estimate for this complication is (4%) (95% CI: 3%-5.4%). (Figure 3)

3. Decementation:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), only 3 studies mentioned "decementation"; *(Naert, 2001)* had 12/140 FDPs (9%), *(Nickenig,2008)* had 6/67 cemented FDPs (8.96%), and *(Nickenig,2006)* had 4/35 cemented FDPs (11.43%) with decementation. The summary estimate for this complication is (17.5%) with a (95% CI: 11.7%-25.3%). (Figure 4)

4. Intrusion:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 6 studies mentioned "intrusion" of the natural tooth abutment; *(Naert,2001)* had 9/313 teeth (6.07%), *(Cordaro,2005)* had 4/72 teeth (5.56%), *(Nickenig,2008)* had 16/178 FDPs (8.99%), *(Bragger,2005)* had 0/24 teeth (0%), *(Kindberg,2001)* had 3/41 FDPs (7.32%), and *(Fugazzotto,1999)* had 9/3096 attachments (0.29%) with intrusion of the natural tooth abutment. The summary estimate for this complication is (3.90%) with (95% CI: 3%-5.2%). (Figure 5)

5. Caries:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 6 studies mentioned "caries" incidence with the natural tooth abutment; *(Gunne,1999)* had 1/20 teeth (5%), *(Naert,2001)* had 3/313 teeth (0.96%), *(Cordaro,2005)* had 0/72 teeth (0%), *(Nickenig,2008)* had 11/178 FDPs (6.18%), *(Bragger,2005)* had 4/24 teeth (16.67%), and finally *(Nickenig,2006)* had 3/132 teeth (2.27%). The summary estimate for this complication is (4.6%) with (95% CI: 3.1%-6.9%). (Figure 6)

6. Vitality Loss:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 6 studies mentioned "vitality loss" of the natural tooth abutment. *(Gunne,1999)* had 1/20 teeth (5%), *(Naert,2001)* had 3/313 teeth (0.96%), *(Cordaro,2005)* had 0/72 teeth (0%), *(Nickenig,2008)* had 11/178 FDPs (6.18%), *(Kindberg,2001)* had 5/85 teeth (5.88%) and finally *(Nickenig,2006)* 1/132 teeth (0.76%) had abutment teeth which lost its vitality. The summary estimate for this complication is (4.3%) with (95% CI: 2.8%-6.4%). (Figure 7)

7. Periapical Radiolucency:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 3 studies mentioned "periapical radiolucency" of the natural tooth abutment. *(Naert,2001)* had 11/313 teeth (3.51%), *(Kindberg,2001)* had 5/85 teeth (5.88%) and *(Nickenig,2006)* had 1/132 teeth (0.76%) with periapical radiolucency. The summary estimate for this complication is (3.7%) with (95% CI: 2.3%-5.9%). (Figure 8)

8. Development of periodontal disease and Mobility:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 5 studies mentioned "periodontal disease" and "mobility" of the natural tooth abutment. *(Gunne,1999)* had 1/20 teeth (0.96%) with mobility, *(Naert,2001)* had 3/313 teeth (0.96%), *(Nickenig,2008)* had 18/178 FDPs (10.11%), *(Kindberg,2001)* had 3/85 teeth (3.53%) and finally *(Nickenig,2006)* had 7/132 (5.30%) indcidences of periodontal disease. The summary estimate for this complication is (7.4%) with (95%CI: 5.3%-10.2%). (Figure 9)

9. Periimplantitis:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 5 studies mentioned "periimplantitis"; *(Bragger,2001)* had 1/19 implants (5.26%), *(Naert,2001)* had 6/339 implants (1.77%), *(Nickenig,2008)* had 17/343 implants (4.96%), *(Bragger,2005)* had 3/22 implants (13.64%), and finally *(Nickenig,2006)* had 1/142 implants (0.70%) with incidence of periimplantitis. The summary estimate for this complication is (4.1%) with (95% CI: 2.8%-5.9%) (Figure 10)

10. Retention Loss:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 6 studies mentioned "retention loss" of the FDP. *(Cordaro,2005)* had 9/19 FDPs (47.37%), *(Nickenig,2008)* had 9/178 FDPs (5.06%), *(Bragger,2005)* had 4/22 FDPs (18.18%), *(Kindberg,2001)* had 3/41 FDPs (7.32%), *(Fugazzotto,1999)* had 7/1206 FDPs (0.58%), and finally *(Nickenig,2006)* had 1/84 FDPs (1.19%) with loss of retention. The summary estimate for this complication is (5.5%) with (95% CI: 3.8%-7.8%). (Figure 11)

11. Abutment Fracture:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 5 studies mentioned "Abutment Fracture" of the FDP, some were tooth abutments and some implant abutments; *(Naert,2001)* had 3/339 implants (0.88%), *(Nickenig,2008)* had 3/178 FDPs (1.69%), *(Kindberg,2001)* had 5/85 teeth (5.88%), *(Fugazzotto,1999)* had (0.17%) and finally *(Nickenig,2006)* had 0/84

(0%) fractures of the abutment. The summary estimate for this complication is (1.6%) with (95% CI: 0.9%-2.6%). (Figure 12)

12. Implant Fracture:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), only 3 studies mentioned "Implant Fracture"; *(Bragger,2001)* had 1/18 implants (5.56%), *(Naert,2001)* had 4/339 implants (1.18%), and finally *(Bragger,2005)* had 1/22 implants (4.55%) that fractured. A summary estimate for this complication is (1.9%) with (95% CI: 0.9%-4.2%). (Figure 13)

13. Tooth Extraction/Loss:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 6 studies mentioned "tooth loss" or "tooth extraction" as an FDP abutment; *(Gunne,1999)* had 1/20 teeth (5%), *(Naert,2001)* had 5/313 teeth (1.6%), *(Nickenig,2008)* had 10/178 FDPs (5.62%), *(Bragger,2005)* had 4/24 teeth (16.67%), *(Kindberg,2001)* had 5/85 teeth (5.88%), and finally *(Nickenig,2006)* had 4/132 teeth (3.03%) extracted or teeth that were lost as a result of the I-T FDP. The summary estimate for this complication is (4.8%) with (95% CI: 3.3%-6.8%). (Figure 14)

14. Biological Complications:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 4 studies mentioned "Biological Complications", biological complications was mentioned as a general term referring to a group of problems (soft tissue, endodontic, periapical) instead of mentioning them separately. *(Bragger,2001)*

had 3/18 FDPs (16.67%), *(Nickenig,2008)* had 17/343 implants (4.96%), *(Bragger,2005)* had 5/22 implants (22.73%), and finally *(Nickenig,2006)* had 2/142 implants (1.41%) incidences of biological complications. The summary estimate of this complication is (6.6%) with (95% CI: 4.5%-9.5%). (Figure 15)

15. Implant Loss:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 9 studies mentioned "Implant Loss", *(Bragger,2001)* had 1/19 implants, (5.26%), *(Olsson,1995)* had 2/23 implants (5yrs) (8.70%), *(Gunne,1999)* had 0/20 implants (0%) (10yrs), *(Naert,2001)* had 10/339 implants (2.95%), *(Cordaro,2005)* had 1/90 implants (1.11%), *(Nickenig,2008)* had 3/178 FDPs (1.69%), *(Bragger,2005)* had 5/22 implants (22.73%), *(Kindberg,2001)* had 9/115 implants (7.83%), and finally *(Nickenig,2006)* had 0/142 implants (0%) of implants that were lost. The summary estimate for this complication is (5%) with (95% CI: 3.6%-7.1%). (Figure 16)

16. Failed FDP/Loss:

Of the 10 prospective and retrospective studies (Table 5) (Table 6), 8 studies mentioned "Failed FDP" as a broad term to describe that the FDP did not survive and had to be remade completely; *(Bragger,2001)* had 1/18 FDPs (5.56%), *(Olsson,1995)* had 2/23 FDPs (8.70%) (5yrs), *(Gunne,1999)* had 0/20 FDPs (10 yrs), *(Naert,2001)* had 3/140 FDPs (2.14%), *(Nickenig,2008)* had 19/178 FDPs (10.67%), *(Bragger,2005)* had 7/22 FDPs (31.82%), *(Kindberg,2001)* had 2/41 FDPs (4.88%), *(Nickenig,2006)* had 4/84 FDPs

(4.76%) that failed. The summary estimate for this complication is (10%) with (95% CI: 7.5%-13.3%). (Figure 17)

B. RESULTS OF COMPLICATIONS STATED IN THE SYSTEMATIC REVIEWS AND ONE META-ANALYSIS:

Of the 5 (I-T) FDP systematic reviews and 1 meta-analysis; *(Lang,2004)* estimated the cumulative rate of biological complications in his 5-year study which was (11.7%) with (95% CI: 9.7%-14.7%). The incidence of technical complications ranged from (0.7%) to (9.8%), the most common technical complication was "fracture of the veneer" with an incidence of (9.8%) followed by "loss of retention" (6.2%) and "abutment screw loosening" at (3.6%), "abutment and screw fracture" was only (0.7)% and "implant fracture" only (0.9%). However, after an observation period of 10 years, "loss of retention" was detected in (24.9%) of FDPs and "abutment screw loosening" was up to (26.4%). Within 5 years, "intrusion" of the natural tooth was observed in (5.2%) of the cases. In another systematic review *(Davis,2014)* also mentioned the occurrence of many biological complications for I-T abutments including-but not limited to- caries in the natural tooth, loss of vitality of the natural tooth abutment, periapical pathology, periodontal disease or periimplantitis related to the implant abutment of the I-T FDP. *(Mamalis,2012)* gave a 5-year summary estimate for survival rate of the I-T FDP which was (94.73%) (95% CI: 89.27%-97.45%), the 10-year summary estimate for survival was, however, (77.77%) with (95% CI: 64.85%-86.42%). "Intrusion" of the natural tooth was reported in 6 of his studies and the rate of intrusion ranged from (0%) – (3.36%) with a summary estimate of 1.07% (95%

CI: 0.40%-2.87%). *(Greenstein,2009)* gave a summary of the technical and biological problems from his review, the technical problems were: Implant fracture, tooth intrusion, (also intrusion of teeth within telescopic crowns), decementation, fracture of the abutment tooth, loosening of the abutment screw, fracture of the veneer facing of the FDP, and fracture of the prosthesis itself. The biological complications that he summarized in his review were: Peri-implantitis, endodontic pathologies, abutment tooth loss, implant loss, caries of the natural tooth abutment, and root fracture of the natural tooth abutment. Finally, *(Hoffman,2012)* gave an overall summary in his review stating that the complications as a whole in the I-T FDP suprastructure was observed in (5-90%) of all cases, intrusion of the natural tooth abutment presented in (0-66%) of all cases, and more often in cases with non-rigid connection within the I-T FDP and (0%-44%) incidence of intrusion in cases with a rigid connection. For the results on the meta-analysis conducted by *(Weber,2010),* the study combined results on the biological complications of (I-T) FDP this cumulative rate was (11.7%) in a follow up period of 5 years.

C. RESULTS OF STUDIES REPORTING ON THE USE OF RIGID AND NON-RIGID CONNECTIONS IN I-T FDPs; (*In Relation To The Rate Of Complications And Specifically The Intrusion Phenomena)*:

I. *(Cordaro,2005)* reported that intrusion of the natural tooth abutment was associated with a) Non-rigid connectors b) Non-periodontally susceptible (healthy) patients. No cases of intrusion in this study occurred with patients who had periodontal disease.

II. *(Davis,2014)* stated in their review, that non-rigid connectors could cause "orthodontic-like" forces resulting in intrusion of the natural tooth abutment, but on the other hand rigid connectors require a passive fit which could lead to fracture or loosening of the implant components.

III. *(Fugazzotto,1999)* used the IMZ protocol in their study; which is an intra-mobile connection between the implant and prosthesis, and a screw fixed rigid attachment between the natural tooth and prosthesis which is cemented to the natural tooth. They stated that this design can prevent the intrusion of the natural tooth in the I-T prosthesis. Only 9 cases of intrusion out of 3096 attachments and this was purely due to the loss of the screw or fracture of the screw that was used in the connector; which caused the FDP to become mobile; and therefore lead to the intrusion of the natural tooth abutment.

IV. *(Greenstein,2009)* summarizes his review indicating that rigid connections must be used between teeth and implants to eliminate the incidence of intrusion; and when rigid connections are used, this reduces the overall mechanical complications in I-T FDPs which will almost be comparable to complications in I-I FDPs.

V. *(Hoffman,2012)* stated that the incidence of intrusion was seen more in cases with a non-rigid connection (0%-66%) as apposed to cases with rigid connections (0%-44%). Despite the fact that non-rigid connections have a more favorable force distribution, rigid connections achieve better outcomes with regard to less complications, more long term stability, however more marginal bone loss is seen when using this rigid connection.

VI. *(Kindberg,2001)* reported that the intrusion cases in their study were among the three patients in which non-rigid connections were used as seen within the first

year of examination. They concluded from their study that rigid connections provided better, if not, “excellent” long-term follow up results.

VII. *(Lang,2004)* concluded in their review, that after a 5 year observation period, intrusion was detected in (5.2%) of the abutment teeth. These incidences were associated with fractures or loosening of the connections. This was an indication that intrusion in I-T is almost exclusively seen in non-rigid connections.

VIII. *(Mamalis,2012)* stated in their systematic review to conclude the information gathered from their studies ; in cases where a connection between teeth and implants in inevitable , “a rigid connection should be established by the two different abutments”.

IX. *(Naert,2001)* reported in their Part I, 15-year prospective cohort study, that if there were to be an FDP connecting teeth with implants, then a rigid connector is favored, as they were seeing more intrusion complications with the non rigid connectors. However, from their Part II radiographical study, (which was the same cohort however a purely radiographic analysis was done on these patients) more bone loss was seen around rigid connections between teeth and implants.

X. *(Nickenig,2006)* concluded in their retrospective study; in the cases of a non-rigid connection between teeth and implants, the complication rates that have been seen were significantly higher than the cases where a rigid connection was used. This was again confirmed in their second study two years later *(Nickenig,2008)* confirming the same statement to these complications; when a non-rigid connection between teeth and implants is used, the complication rates in the FDP are significantly higher.

XI. *(Quaranta,2013)* presented a case report on just one I-T connection that was observed for a period of 19 years with no intrusion and had a rigid connection between teeth and implants, they stated that no prosthetic complications were observed.

(I-I)

A. RESULTS OF COMPLICATIONS STATED IN THE PROSPECTIVE AND RETROSEPCTIVE STUDIES

1. Veneer fracture:

Of the 8 prospective and retrospective studies, Only 3 studies reported on "veneer fracture"; *(Wittneben,2014)* had 36/127 FDPs (28.35%), *(Kreissl,2007)* had 0/7 FDPs (0%) , and *(Wolleb,2012)* had 1/15 FDPs (6.67%) with veneer fracture. The summary estimate for this complication is (26.6%) with (95% CI: 19.9%-34.5%). However, there is insufficient power to draw conclusions from this estimate (Figure 18)

2. Screw loosening:

Of the 8 prospective and retrospective studies, 3 studies reported on "screw loosening"; *(Gunne,1999)* had 2/23 FDPs (8.70%), *(Bragger,2005)* had 10/33 FDPs (30.30%), *(Kreissl,2007)* reported having 0/7 FDPs (0%) with screw loosening. The overall summary estimate for this complication is (22.7%) with (95% CI: 13.3%-35.8%). However, there is insufficient power to draw conclusions from this estimate (Figure 19)

3. Periimplantits:

Of the 8 prospective and retrospective studies, only two studies mentioned the word "periimplantitis"; *(Bragger,2005)* had 8/69 implants (11.59%) and *(Kreissl,2007)* had 0/17 cases (0%) with periimplantitis. The summary estimate for this complication is (8.7%) with (95% CI: 4.6%-16%). However, there is insufficient power to draw conclusions from this estimate (Figure 20)

4. Retention Loss:

Of the 8 prospective and retrospective studies, only one study mentioned "loss of retention"; *(Bragger,2005)* 10/33 FDPs (30.30%) which yielded a summary estimate of (30.30%) and (95% CI: 17.1%-47.7%). However, there is insufficient power to draw conclusions from this estimate (Figure 21)

5. Abutment screw fracture:

Of the 8 prospective and retrospective studies, only 3 studies mentioned "abutment screw fracture"; *(Naert,2001)* had 2/329 implants (0.61%) incidences of abutment screw fracture and *(Kreissl,2007)* and *(Wolleb,2012)* reported to have none (0/7 and 0/15) FDPs respectively. The summary estimate for this complication is (1.2%) with a (95% CI: 0.4%-3.6%). However, there is insufficient power to draw conclusions from this estimate (Figure 22)

6. Implant Fracture:

Of the 8 prospective and retrospective studies, only 4 studies mentioned "implant fracture"; *(Bragger,2001)* had 1/40 FDPs (2.5%), *(Naert,2001)* had 1/329 implants (0.30%) , *(Bragger,2005)* had 0/69 implants (0%) , *(Wolleb,2012)* had 0/39 implants (0%) with fractured implants. The summary estimate for this complication is (0.9%) with (95% CI: 0.3%-3.2%). However, there is insufficient power to draw conclusions from this estimate (Figure 23)

7. Biological Complications:

Of the 8 prospective and retrospective studies, only 2 studies reported on "biological complications"; *(Bragger,2001)* had 6/40 FDPs (15%) and in their later study *(Bragger,2005)* had 1/69 implants (1.45%) as incidences of biological complications. The summary estimate for this complication is (10.6%) with a (95% CI: 5.1%-20.7%). However, there is insufficient power to draw conclusions from this estimate (Figure 24)

8. Implant Loss:

Of the 8 prospective and retrospective studies, all 8 studies reported on "implant loss"; *(Wittneben,2014)* lost 1/127 FDPs (0.79%), *(Bragger,2001)* lost 1/40 FDPs (2.5%), *(Olsson,1995)* at 5 years lost 6/46 implants (13.04%), *(Gunne,1999)* at 10 years had 0/46 implant losses (0%), *(Naert,2001)* lost 1/329 implants (0.3%), *(Bragger,2005)* lost 1/69 implants (1.45%), *(Kreissl,2007)* had 0/17 implant losses (0%) and *(Wolleb,2012)* also had 0/39 implant losses (0%). The summary estimate for this type of complication is (3.8%) with a (95% CI: 2.1%-6.8%). (Figure 25)

9. Failed FDP/FDP Loss:

Of the 8 prospective and retrospective studies, all 8 studies reported on "Failed FDP" or "FDP Loss"; *(Wittneben,2014)* lost 5/127 FDPs (3.94%), *(Bragger,2001)* lost 1/40 FDPs (2.50%), *(Olsson,1995)* lost 4/23 FDPs (17.39%), *(Gunne,1999)* lost 0/23 FDPs(0%), *(Naert,2001)* lost 1/329 implants (0.30%), *(Bragger,2005)* lost 2/33 FDPs (6.06%), *(Kreissl,2007)* lost 0/7 FDPs(0%) and finally *(Wolleb,2012)* lost also 0/15 FDPs (0%). The summary estimate for this complication is (6.3%) with a (95% CI: 3.7%-10.6%). (Figure 26)

B. RESULTS OF COMPLICATIONS STATED IN THE SYSTEMATIC REVIEWS AND ONE META-ANALYSIS:

The systematic review of *(Papaspyridakos,2012)* reported on the complications face with metal-resin (I-T) FDPs , and the most frequent "biological implant-related complication" was excessive peri-implant bone loss >2mms. The summary estimated annual complication rate was (4%) with (95% CI: 3%-5.1%), the 5 year complication rate is (20.1%) with a (95%CI:17.7%-22.6%) and for the 10 year complication rate it was (40.3%) with a (95% CI: 36.9%-43.7%). The second most common "implant-related biological complication" stated in this study was "periimplant mucositis" with a (2.1%) (95% CI: 7.6%-13.4%), the 5 year complication rate was (10.5%) (95% CI: 7.6% to 13.4%) and (21.1%) at 10 years (95%CI: 16.9%-25.2%). The most frequent "biological prosthesis-related complication" was hypertrophy or

hyperplasia of the soft tissue. The estimated annual rate of this complication is (2.6%) (95% CI: 1.5%-3.7%), the 5-year complication rate was (13%) (95% CI: 10.6%-15.4%) and the 10-year complication rate is (26%) (95% CI: 22.6%-29.3%). The most frequent " technical implant-related complication" reported was abutment screw loosening. The second most common technical complications with implants was screw fracture at an annual incidence rate of (1.9%) (95% CI: 1.3%-2.4%) The 5-year estimated complication rate is (9.3%) (95% CI: 7.9%-10.6%) and the 10-year estimate is (18.5%) (95% CI: 16.6%-20.4%). Finally, the most frequent prosthesis-related technical complication reported with metal-resin (I-I) FDPs was veneer fracture, the annual complication rate is (6.7%) (95% CI: 5.7%-7.6%). The meta-analysis of this whole study indicated a (33.3%) incidence of overall complication rates (95% CI: 31.1% to 35.5%) at 5 years, and (66.6%) (95% CI: 63.5% to 69.7%) at 10 years. *(Pjetursson,2012)* reported in their systematic review that the estimated cumulative rate of "biological complications" at 5 years was (8.5%) (95% CI: 5.5%-13.2%). The estimated cumulative rate of bone loss at 5 years was (2.6%) (95% CI: 5.5%-13.2%) >2mm. When the technical complications were analyzed, I-I FDPs with ceramic facing, at 5 years, had a complication of (7.8%) (95% CI: 4.7%-12.7%) and a (20.2%) complication rate at 5 years for the acrylic veneered FDPs (95% CI: 14.8%-27.3%). The second most common technical complication was the actual loss of the access screw hole, this occurred at (5.4%)(95% CI: 2.9%-10.7%) at 5 years. The third most common technical complication is abutment or screw loosening. The cumulative complication rate at 5 years is (5.3%) (95% CI: 3.6%-7.7%). However fracture of the abutments or the abutment screws had an incidence of only (1.3%) (95%

CI: 0.7%-2.3%) at 5 years. Implant fracture and FDP framework fracture had the least incidence at (0.5%) (95% CI: 0.2%-1.1%). According to the meta-analysis *(Bozini,2011)* on metal-acrylic facings of I-I FDPs, the most frequent prosthodontics complications were "veneer fracture", they were reported in 14 of 19 studies, the estimated cumulative incidence rates were (30.6%) at 5 years, (51.9%) at 10 years and (66.6%) at 15 years. The estimated cumulative rates of abutment and prosthetic screw loosening at 15 years was (13.4%) and (15%), the estimated rate of abutment fracture at 15 years was (6.3%), and prosthetic screw fracture at 15 years was (11.7%). The estimated rates for framework fracture was (8.8%), material wear (43.5%) and finally esthetic deficiencies was (9%) at 15 years.

COMPARISON BETWEEN THE INCIDENCE OF COMPLICATIONS FOUND BETWEEN (I-T) AND (I-I) STUDIES:

A. The Qualitative Results Of The Prospective And Retrospective Studies Only:

Due to the first (I-I) 7 complications having insufficient statistical power to yield a valid estimate of the overall incidence rates, only the last two complications will be used for qualitative measurement of comparison:

1) Implant loss:	(I-T)	(5%), (95% CI: 3.6%-7.1%)
	(I-I)	(3.8%), (95% CI: 2.1%-6.8%)
2) Failed FDP:	(I-T)	(10%), (95% CI: 7.5%-13.3%)
	(I-I)	(6.3%), (95% CI: 3.7%-10.6%)

B. The Qualitative Results Of The Systematic Reviews And Meta-Analysis Studies on comparison between I-I and I-T complications:

I. *(Bragger,2001)* stated that I-T FDPs did not show higher risk for technical or biological complications thank I-I.

II. *(Bragger,2005)* stated that significantly fewer biological and technical complications occurred with I-I FDPs when compared to I-T, (*p*-value 0.022).

III. *(Davis,2014)* stated that I-T FDPs can have similar success rates like I-I FDPs.

IV. *(Greenstein,2009)* stated that similar survival rates of I-I FDPs within the first 5 years, however at 10 years I-I FDPs have higher survival rates.

V. *(Gunne,1999)* reported that after 10 years of function, no differences could be seen between I-I FDPs and I-T FDPs regarding failure rates or marginal bone level changes. No negative influences on the abutment tooth were seen.

VI. *(Hoffman,2012)* reported that long-term success rates for I-T FDPs were lower than I-I with regards to the teeth, implants and supra-structure.

VII. *(Lang,2004)* compared the 5 year cumulative failure rates of I-I and I-T there is no statistical difference, however at 10 years I-T has a statistically higher failure rate than I-I.

VIII. *(Naert,2001)* indicted that more implants failed in the I-T FDPs than in the I-I FDP group however not reaching a statistical significance. (cumulative success rate of I-I was (98.4%) and (I-T) was (94.9%) however this did not reach the 95% statistical level)

IX. *(Nickenig,2008)* stated that the survival data for I-T FDPs were comparable to I-I prostheses.

X. *(Olsson,1995)* reported that at a 5-year follow up , differences seen at bone level could not be detected between I-I and I-T FDPs. Furthermore, at 5 years, no higher risk of prosthetic or implant complications could be seen between I-I or I-T FDPs.

XI. *(Weber,2010)* reported that the survival rate for I-T FDPs were lower than I-I FDPs at 10 years based on data gather only from 60 FDPs.

C. The Quantitative Results Of The 5 Studies Included In The Meta-Analysis:

5 studies were included in the meta-analysis; these 5 studies were the only studies that measured both I-I and I-T FDPs within the same studies. Thus the study subjects and control groups were all within the same setting, using the same examiners and yielding valid comparisons between I-I and I-T measures.

The following 8 complications were compared in a meta-analysis between the two groups: (In all figures, A is the control I-I, B is the intervention I-T)

I. Screw loosening: The Odds ratio of the 2 studies that reported on I-I and I-T screw loosening *(Gunne,1999)* and *(Bragger,2005)* is (0.7), which is <1, this signifies that the I-I complications were more frequent than the I-T. The measure of heterogeneity I-squared is (16.27%), which is low. The *p*-value is (0.644) which signifies that this is not a significant difference (Figure 27-A,B).

II. Periimplantitis: The odds ratio of the 3 studies that reported on I-I and I-T periimplantitis *(Bragger,2001)* *(Naert,2001)* *(Bragger,2005)* is

(2.4) which is >1 , this signifies that I-T had more incidences of periimplantitis than I-I. The measure of heterogeneity I-squared of the studies is (39.6%), which is low. The *p*-value is (0.131) which is not significant. (Figure 28 A,B)

III. Retention Loss: The odds ratio of 1 study reporting on loss of retention *(Bragger,2005)* is (0.5) <1 , this means that the I-I group had more cases of retention loss than I-T. The heterogeneity percentage of I-squared was of course was (0%), which indicates that it is homogenous. The *p*-value is (0.317) which indicates no significant difference between the two groups. (Figure 29 A,B)

IV. Implant Loss: The odds ratio of 4 studies reporting on implant loss *(Bragger,2001) (Olsson,1995) (Naert,2001)* and *(Bragger,2005)* is (3.5) this is >1 which indicates that there were more incidences of I-T implant loss than I-I. The heterogeneity I-squared among the studies had an I-squared percentage of 55.14%, which is moderate heterogeneity. The *p*-value (0.018) indicates that the higher incidence of I-T implant loss when compared to I-I is significant. (Figure 30 A,B)

V. Implant Fracture: The odds ratio of the 3 studies reporting on implant fracture *(Bragger,2001) (Naert,2001)* and *(Bragger,2005)* is (4.1) which is >1 ; indicating that the incidences of I-T implant fracture are higher than I-I. The heterogeneity I-squared among the studies is (0%), which indicates homogeneity. The *p*-value is (0.07) which is not a significant difference. (Figure 31 A,B)

VI. Failed FDP/Loss: The odds ratio of the 4 studies reporting on loss or failure of FDP *(Bragger,2001) (Olsson,1995) (Naert,2001)*

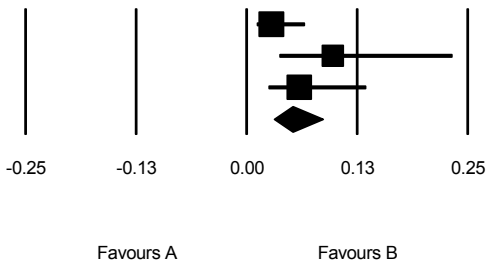
(Bragger,2005) is (2.7) which is >1, this indicates that incidences in I-T FDP loss are higher than I-I, the heterogeneity I-squared of the studies is (41.6%) which is low. The *p*-value for this complication is (0.05) which is statistically significant. (Figure 32 A,B)

VII. Biological complications: The odds ratio for the 2 studies reporting on biological complications *(Bragger,2001) and (Bragger,2005)* is (2.8) which is >1 , this indicates that biological complications that were found in I-T FDPs were more than I-I, the heterogeneity of the studies using the I-squared percentage is (77.3%) which is a considerably high level of heterogeneity. This difference however is not significant with a *p*-value of (0.103). (Figure 33 A,B)

VIII. Abutment fracture: The odds ratio for the only study reporting on abutment fracture is (1.4) which is > 1, this indicates more abutment fractures in the I-T group than the I-I group. The heterogeneity of course, is 0% which means it is homogenous, being one study. The higher incidence of abutment fracture in I-T group is not significant with a *p*-value of (0.88). (Figure 34 A,B)

Veneer Fracture I-T

Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Nickenig HJ 2008	0.028	0.012	0.066	-7.812	0.000	36.89		-1.78		
Kindberg 2001	0.098	0.037	0.233	-4.227	0.000	27.41		1.51		
Nickenig HJ 2006	0.060	0.025	0.135	-5.985	0.000	35.70		0.39		
	0.052	0.031	0.086	-10.534	0.000					

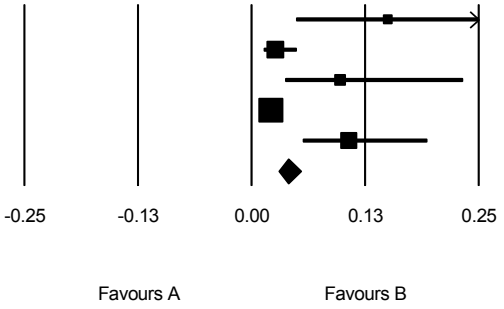


(Figure 2)

Screw Loosening I-T

Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	0.150	0.049	0.376	-2.770	0.006	6.28		2.36		
Nickenig HJ 2008	0.026	0.014	0.050	-10.699	0.000	21.60		-1.49		
Kindberg 2001	0.098	0.037	0.233	-4.227	0.000	8.90		1.88		
Fugazzotto 1999	0.021	0.013	0.034	-16.054	0.000	43.42		-3.67		
Nickenig HJ 2006	0.107	0.057	0.193	-6.010	0.000	19.80		3.32		
	0.040	0.030	0.054	-20.180	0.000					

Event rate and 95% CI

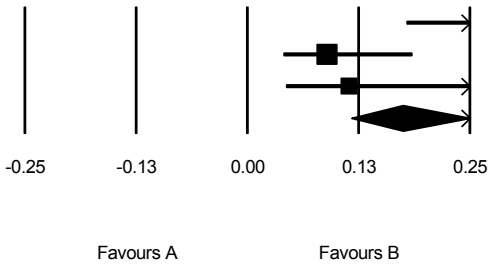


(Figure 3)

Decementation I-T

Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Naert Pt 1 2001	0.300	0.179	0.457	-2.456	0.014	48.26		2.85		
Nickenig HJ 2008	0.090	0.041	0.185	-5.420	0.000	31.38		-2.16		
Nickenig HJ 2006	0.114	0.044	0.268	-3.854	0.000	20.35		-1.04		
	0.175	0.117	0.253	-6.481	0.000					

Event rate and 95% CI

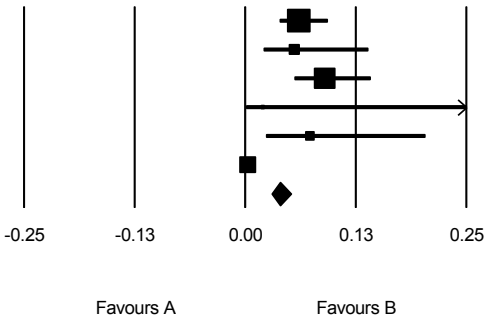


(Figure 4)

Intrusion I-T

Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Naert Pt 1 2001	0.061	0.039	0.093	-11.572	0.000	36.85		2.41		
Cordaro 2005	0.056	0.021	0.139	-5.507	0.000	7.80		0.73		
Nickenig HJ 2008	0.090	0.056	0.142	-8.834	0.000	30.07		4.01		
Bragger 2005	0.020	0.001	0.251	-2.724	0.006	1.01		-0.49		
Kindberg 2001	0.073	0.024	0.204	-4.234	0.000	5.74		1.12		
Fugazzotto 1999	0.003	0.002	0.006	-17.488	0.000	18.53		-8.78		
	0.039	0.030	0.052	-22.223	0.000					

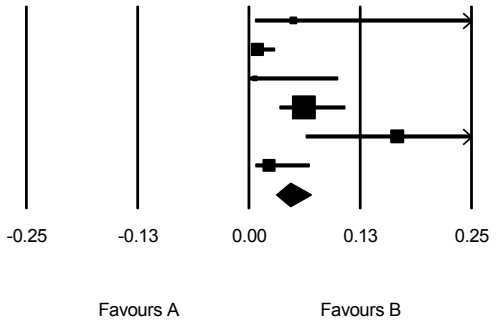
Event rate and 95% CI



(Figure 5)

Caries I-T

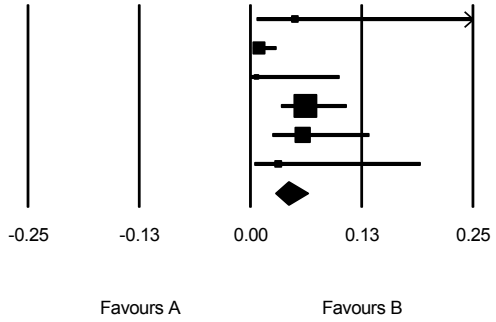
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	0.050	0.007	0.282	-2.870	0.004	4.52		0.08		
Naert Pt 1 2001	0.010	0.003	0.029	-7.995	0.000	14.15		-3.00		
Cordaro 2005	0.007	0.000	0.100	-3.507	0.000	2.36		-1.39		
Nickenig HJ 2008	0.062	0.035	0.108	-8.738	0.000	49.14		1.37		
Bragger 2005	0.167	0.064	0.369	-2.938	0.003	15.87		2.82		
Nickenig HJ 2006	0.023	0.007	0.068	-6.440	0.000	13.96		-1.36		
	0.046	0.031	0.069	-13.859	0.000					



(Figure 6)

Vitality Loss I-T

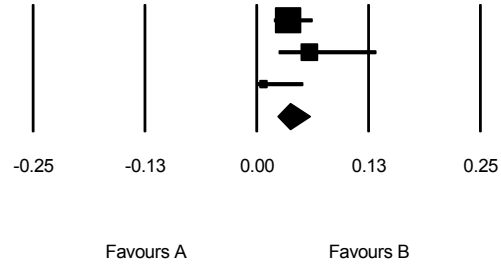
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	0.050	0.007	0.282	-2.870	0.004	4.65		0.17		
Naert Pt 1 2001	0.010	0.003	0.029	-7.995	0.000	14.56		-2.85		
Cordaro 2005	0.007	0.000	0.100	-3.507	0.000	2.43		-1.33		
Nickenig HJ 2008	0.062	0.035	0.108	-8.738	0.000	50.56		1.78		
Kindberg 2001	0.059	0.025	0.134	-6.015	0.000	23.05		0.84		
Nickenig HJ 2006	0.031	0.004	0.191	-3.380	0.001	4.75		-0.33		
	0.043	0.028	0.064	-14.054	0.000					



(Figure 7)

Periapical RL I-T

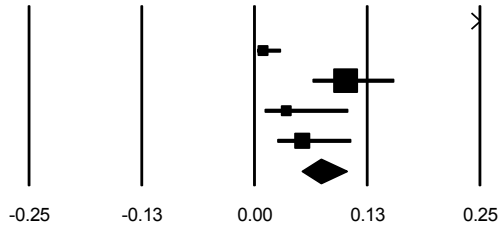
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Naert Pt 1 2001	0.035	0.020	0.062	-10.792	0.000	65.07		-0.33		
Kindberg 2001	0.059	0.025	0.134	-6.015	0.000	28.85		1.23		
Nickenig HJ 2006	0.008	0.001	0.052	-4.857	0.000	6.08		-1.67		
	0.037	0.023	0.059	-13.133	0.000					



(Figure 8)

Periodontitis/ CAL I-T

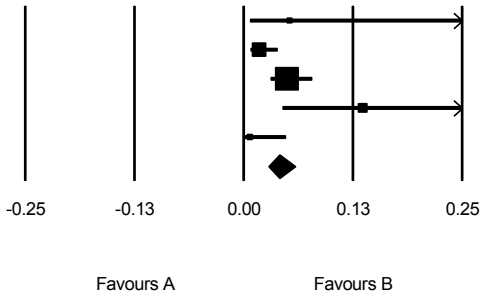
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	0.950	0.718	0.993	2.870	0.004	3.21		5.43		
Naert Pt 1 2001	0.010	0.003	0.029	-7.995	0.000	10.03		-3.83		
Nickenig HJ 2008	0.101	0.065	0.155	-8.788	0.000	54.62		2.07		
Kindberg 2001	0.035	0.011	0.104	-5.628	0.000	9.77		-1.39		
Nickenig HJ 2006	0.053	0.025	0.107	-7.421	0.000	22.38		-1.02		
	0.074	0.053	0.102	-13.782	0.000					



(Figure 9)

Periimplantitis I-T

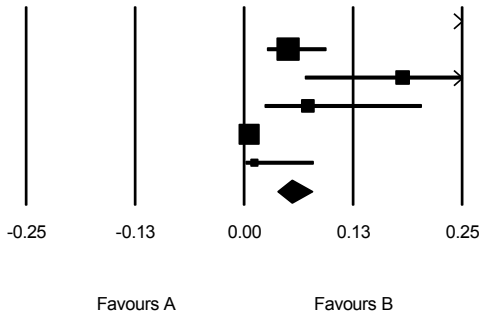
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.053	0.007	0.294	-2.813	0.005	3.56		0.26		
Naert Pt 1 2001	0.018	0.008	0.039	-9.751	0.000	22.17		-2.37		
Nickenig HJ 2008	0.050	0.031	0.078	-11.873	0.000	60.78		1.28		
Bragger 2005	0.136	0.045	0.348	-2.971	0.003	9.75		2.22		
Nickenig HJ 2006	0.007	0.001	0.048	-4.931	0.000	3.74		-1.82		
	0.041	0.028	0.059	-16.259	0.000					



(Figure 10)

Retention Loss I-T

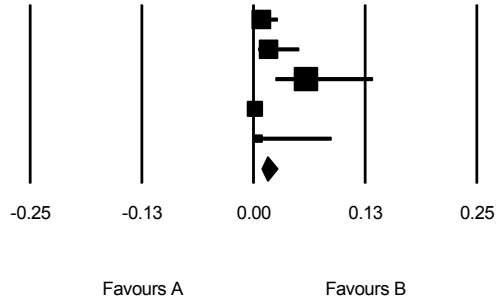
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Cordaro 2005	0.474	0.268	0.689	-0.229	0.819	17.36		6.57		
Nickenig HJ 2008	0.051	0.027	0.094	-8.573	0.000	31.32		-0.30		
Bragger 2005	0.182	0.070	0.396	-2.721	0.007	12.00		2.59		
Kindberg 2001	0.073	0.024	0.204	-4.234	0.000	10.19		0.54		
Fugazzotto 1999	0.006	0.003	0.012	-13.568	0.000	25.51		-7.02		
Nickenig HJ 2006	0.012	0.002	0.080	-4.392	0.000	3.62		-1.59		
	0.055	0.038	0.078	-14.876	0.000					



(Figure 11)

Abutment Fracture I-T

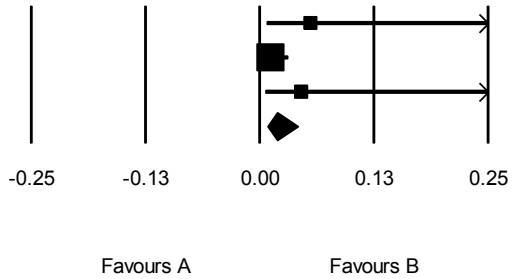
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Naert Pt 1 2001	0.009	0.003	0.027	-8.136	0.000	22.66		-1.12		
Nickenig HJ 2008	0.017	0.005	0.051	-6.983	0.000	22.48		0.15		
Kindberg 2001	0.059	0.025	0.134	-6.015	0.000	35.86		3.72		
Fugazzotto 1999	0.002	0.000	0.007	-9.044	0.000	15.22		-3.46		
Nickenig HJ 2006	0.006	0.000	0.087	-3.617	0.000	3.79		-0.71		
	0.016	0.009	0.026	-15.017	0.000					



(Figure 12)

Implant Fracture I-T

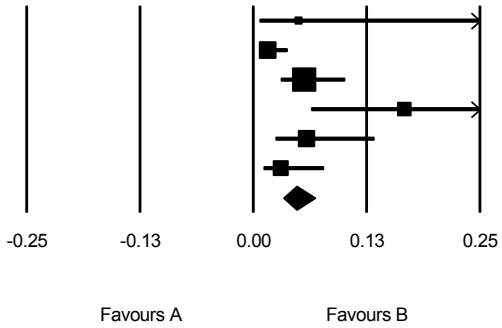
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.056	0.008	0.307	-2.753	0.006	16.14		1.18		
Naert Pt 1 2001	0.012	0.004	0.031	-8.803	0.000	67.55		-1.69		
Bragger 2005	0.045	0.006	0.261	-2.975	0.003	16.31		0.96		
	0.019	0.009	0.042	-9.543	0.000					



(Figure 13)

Tooth Loss I-T

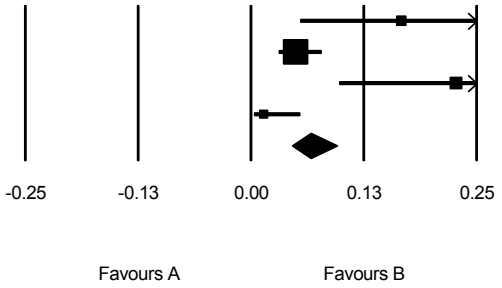
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	0.050	0.007	0.282	-2.870	0.004	3.49		0.05		
Naert Pt 1 2001	0.016	0.007	0.038	-9.140	0.000	18.07		-2.76		
Nickenig HJ 2008	0.056	0.030	0.101	-8.668	0.000	34.67		0.66		
Bragger 2005	0.167	0.064	0.369	-2.938	0.003	12.24		2.70		
Kindberg 2001	0.059	0.025	0.134	-6.015	0.000	17.28		0.53		
Nickenig HJ 2006	0.030	0.011	0.078	-6.826	0.000	14.25		-1.00		
	0.048	0.033	0.068	-15.630	0.000					



(Figure 14)

Biological Complications I-T

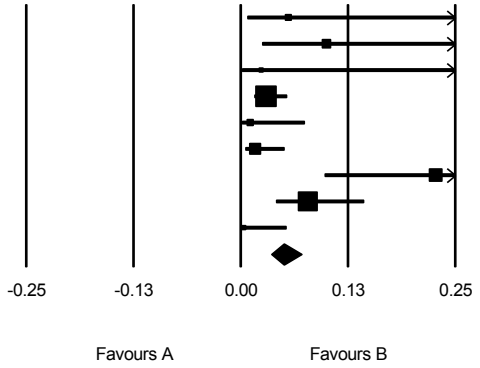
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.167	0.055	0.409	-2.545	0.011	10.21		1.73		
Nickenig HJ 2008	0.050	0.031	0.078	-11.873	0.000	65.97		-2.11		
Bragger 2005	0.227	0.098	0.444	-2.405	0.016	15.77		3.05		
Nickenig HJ 2006	0.014	0.004	0.055	-5.966	0.000	8.05		-2.34		
	0.066	0.045	0.095	-13.104	0.000					



(Figure 15)

Implant Loss I-T

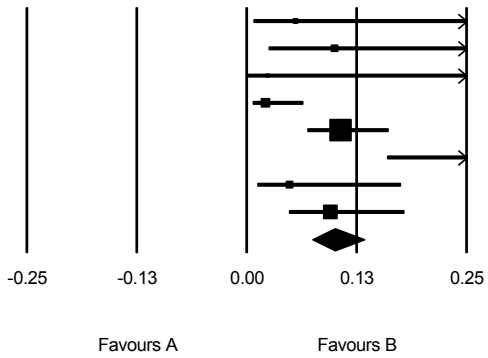
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.056	0.008	0.307	-2.753	0.006	3.20		0.10		
Olsson 1995	0.100	0.025	0.324	-2.948	0.003	6.09		1.03		
Gunne 1999	0.024	0.001	0.287	-2.594	0.009	1.65		-0.55		
Naert Pt 1 2001	0.029	0.016	0.054	-10.883	0.000	32.86		-2.11		
Cordaro 2005	0.011	0.002	0.075	-4.464	0.000	3.35		-1.57		
Nickenig HJ 2008	0.017	0.005	0.051	-6.983	0.000	9.99		-2.04		
Bragger 2005	0.227	0.098	0.444	-2.405	0.016	13.08		3.62		
Kindberg 2001	0.078	0.041	0.144	-7.103	0.000	28.09		1.60		
Nickenig HJ 2006	0.003	0.000	0.053	-3.990	0.000	1.69		-1.93		
	0.050	0.036	0.071	-15.969	0.000					



(Figure 16)

FDP Failed/ Loss I-T

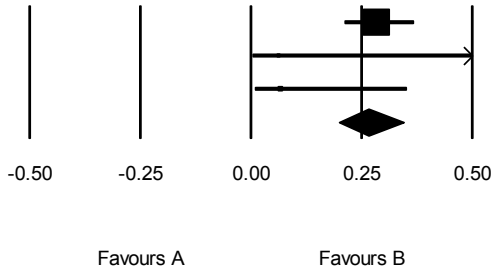
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.056	0.008	0.307	-2.753	0.006	2.55		-0.63		
Olsson 1995	0.100	0.025	0.324	-2.948	0.003	4.86		-0.00		
Gunne 1999	0.024	0.001	0.287	-2.594	0.009	1.32		-1.07		
Naert Pt 1 2001	0.021	0.007	0.064	-6.548	0.000	7.92		-2.91		
Nickenig HJ 2008	0.107	0.069	0.161	-8.752	0.000	45.80		0.39		
Bragger 2005	0.318	0.160	0.534	-1.665	0.096	12.88		3.35		
Kindberg 2001	0.049	0.012	0.175	-4.097	0.000	5.13		-1.10		
Nickenig HJ 2006	0.095	0.048	0.179	-6.057	0.000	19.53		-0.17		
	0.100	0.075	0.133	-13.356	0.000					



(Figure 17)

Veneer Fracture I-I

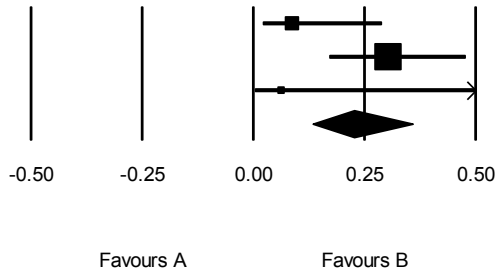
Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Wittneben 2014	0.283	0.212	0.368	-4.710	0.000	94.84		2.00		
Kreissl 2007	0.063	0.004	0.539	-1.854	0.064	1.72		-1.17		
Wolleb 2012	0.067	0.009	0.352	-2.550	0.011	3.43		-1.59		
	0.266	0.199	0.345	-5.303	0.000					



(Figure 18)

Screw Loosening I-I

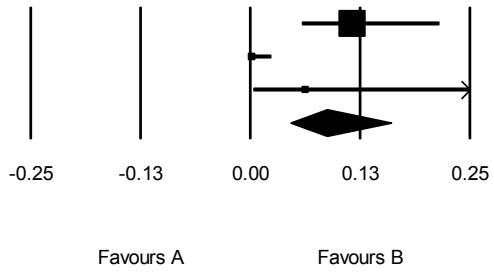
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	0.087	0.022	0.289	-3.177	0.001	19.71		-1.70		
Bragger 2005	0.303	0.171	0.477	-2.199	0.028	75.23		2.09		
Kreissl 2007	0.063	0.004	0.539	-1.854	0.064	5.06		-1.04		
	0.227	0.133	0.358	-3.735	0.000					



(Figure 19)

Periimplantitis I-I

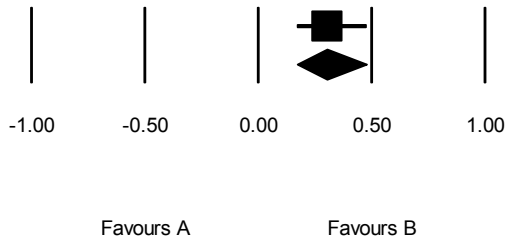
Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2005	0.116	0.059	0.215	-5.402	0.000	87.96		2.42		
Naert Pt 1 2001	0.002	0.000	0.024	-4.586	0.000	6.21		-3.02		
Kreissl 2007	0.063	0.004	0.539	-1.854	0.064	5.83		-0.25		
	0.087	0.046	0.160	-6.657	0.000					



(Figure 20)

Retention Loss I-I

Statistics for each study	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2005	0.303	0.171	0.477	-2.199	0.028	100.00				
	0.303	0.171	0.477	-2.199	0.028					



(Figure 21)

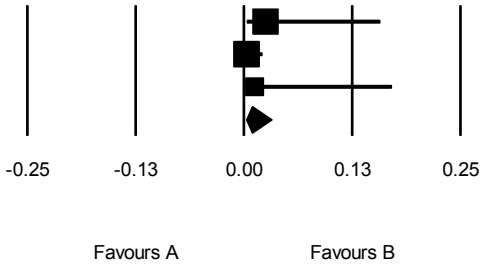
Abutment Fracture I-I

Study name	Statistics for each study: Event rate	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Naert Pt 1 2001	0.006	0.002	0.024	-7.186	0.000	67.59		-1.62		
Kreissl 2007	0.063	0.004	0.539	-1.854	0.064	15.94		1.29		
Wolleb 2012	0.031	0.002	0.350	-2.390	0.017	16.47		0.77		
	0.012	0.004	0.036	-7.618	0.000					

(Figure 22)

Implant Fracture I-I

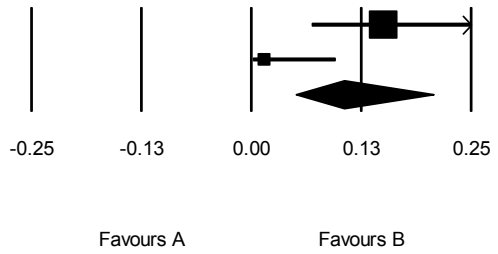
Study name	Statistics for each study: Event rate	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.025	0.004	0.157	-3.617	0.000	39.54		1.27		
Naert Pt 1 2001	0.003	0.000	0.021	-5.784	0.000	40.43		-1.46		
Wolleb 2012	0.013	0.001	0.171	-3.070	0.002	20.02		0.23		
	0.009	0.003	0.032	-7.327	0.000					



(Figure 23)

Biological Complications I-I

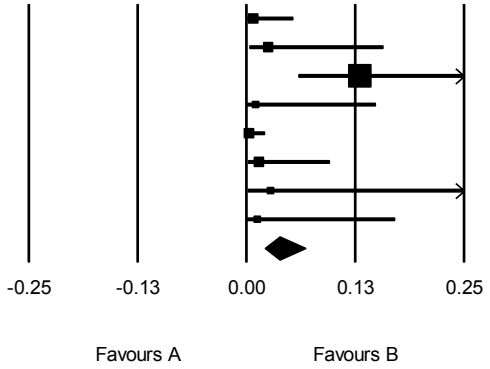
	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	0.150	0.069	0.296	-3.917	0.000	83.81		2.26		
Bragger 2005	0.014	0.002	0.096	-4.189	0.000	16.19		-2.26		
	0.106	0.051	0.207	-5.272	0.000					



(Figure 24)

Implant Loss I-I

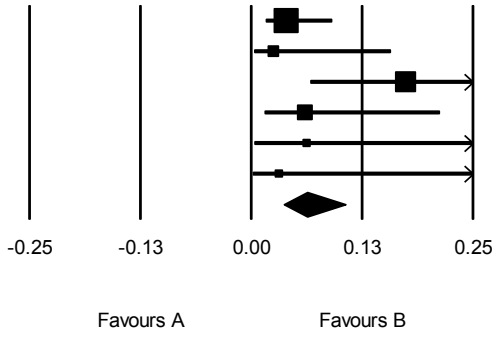
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Wittneben 2014	0.008	0.001	0.054	-4.817	0.000	9.32		-1.68		
Bragger 2001	0.025	0.004	0.157	-3.617	0.000	9.16		-0.45		
Olsson 1995	0.130	0.060	0.261	-4.333	0.000	49.03		4.25		
Gunne 1999	0.011	0.001	0.149	-3.188	0.001	4.65		-0.94		
Naert Pt 1 2001	0.003	0.000	0.021	-5.784	0.000	9.37		-2.69		
Bragger 2005	0.014	0.002	0.096	-4.189	0.000	9.26		-1.04		
Kreissl 2007	0.028	0.002	0.322	-2.479	0.013	4.57		-0.24		
Wolleb 2012	0.013	0.001	0.171	-3.070	0.002	4.64		-0.82		
	0.038	0.021	0.068	-10.524	0.000					



(Figure 25)

FDP Failed/Loss I-I

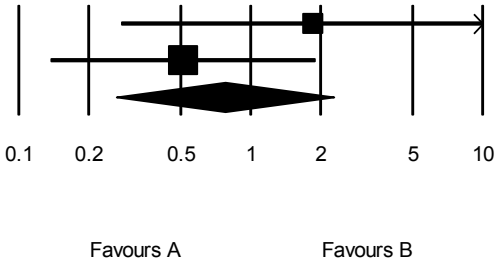
Study name	Statistics for each study					Weight (Fixed)				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Wittneben 2014	0.039	0.016	0.091	-7.001	0.000	40.31		-1.41		
Bragger 2001	0.025	0.004	0.157	-3.617	0.000	8.18		-0.99		
Olsson 1995	0.174	0.067	0.382	-2.832	0.005	27.73		2.44		
Bragger 2005	0.061	0.015	0.212	-3.757	0.000	15.77		-0.06		
Kreissl 2007	0.063	0.004	0.539	-1.854	0.064	3.93		-0.01		
Wolleb 2012	0.031	0.002	0.350	-2.390	0.017	4.07		-0.52		
	0.063	0.037	0.106	-9.313	0.000					



(Figure 26)

Screw Loosening Comparison

	Statistics for each study					Weight (Fixed)				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Gunne 1999	1.853	0.277	12.389	0.636	0.525	32.33		1.09		
Bragger 2005	0.511	0.137	1.901	-1.002	0.317	67.67		-1.09		
	0.775	0.263	2.283	-0.462	0.644					



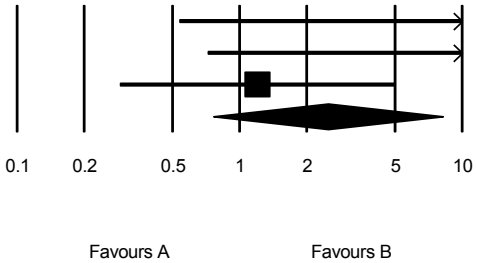
(Figure 27, A)

Model		Effect size and 95% interval			Test of null (2-Tail)		Heterogeneity			
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared
Fixed	2	0.775	0.263	2.283	-0.462	0.644	1.194	1	0.274	16.276
Random	2	0.804	0.241	2.686	-0.354	0.723				

(Figure 27, B)

Periimplantitis Comparison

Study name	Statistics for each study					Weight (Fixed)				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	13.703	0.537	349.848	1.583	0.113	13.43		1.11		
Naert Pt 1 2001	12.844	0.721	228.915	1.737	0.082	16.99		1.22		
Bragger 2005	1.204	0.290	4.997	0.256	0.798	69.58		-1.82		
	2.495	0.761	8.180	1.509	0.131					



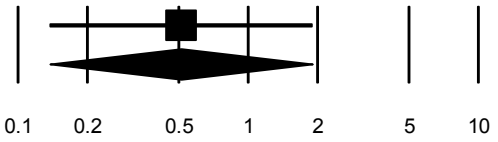
(Figure 28, A)

Model		Effect size and 95% interval			Test of null (2-Tail)		Heterogeneity			
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared
Fixed	3	2.495	0.761	8.180	1.509	0.131	3.312	2	0.191	39.608
Random	3	3.750	0.637	22.057	1.462	0.144				

(Figure 28, B)

Loss of Retention Comparison

Statistics for each study	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2006	0.511	0.137	1.901	-1.002	0.317	100.00				
	0.511	0.137	1.901	-1.002	0.317					



(Figure 29, A)

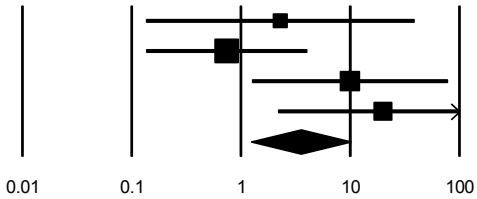
Favours A Favours B

Model	Number Studies	Effect size and 95% interval: Point estimate	Lower limit	Upper limit	Test of null (2-Tail): Z-value	P-value	Heterogeneity: Q-value	df (Q)	P-value	I-squared
Fixed	1	0.511	0.137	1.901	-1.002	0.317	0.000	0	1.000	0.000
Random	1	0.511	0.137	1.901	-1.002	0.317				

(Figure 29, B)

Implant Loss Comparison

Study name	Statistics for each study: Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	2.294	0.135	38.864	0.575	0.565	13.68		-0.32		
Olsson 1995	0.741	0.136	4.031	-0.347	0.728	38.16		-2.30		
Naert Pt 1 2001	9.970	1.269	78.324	2.186	0.029	25.78		1.14		
Bragger 2005	20.000	2.190	182.649	2.655	0.008	22.39		1.74		
	3.534	1.241	10.065	2.364	0.018					



(Figure 30, A)

Favours A Favours B

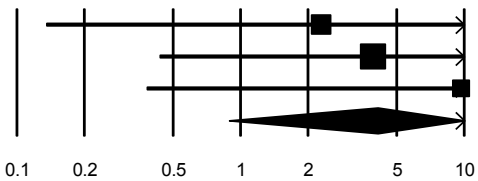
Model	Number Studies	Effect size and 95% interval: Point estimate	Lower limit	Upper limit	Test of null (2-Tail): Z-value	P-value	Heterogeneity: Q-value	df (Q)	P-value	I-squared
Fixed	4	3.534	1.241	10.065	2.364	0.018	6.689	3	0.083	55.147
Random	4	4.065	0.816	20.254	1.711	0.087				

(Figure 30, B)

Implant Fracture Comparison

Study name	Statistics for each study					Weight (Fixed)				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	2.294	0.135	38.864	0.575	0.565	29.21		-0.48		
Naert Pt 1 2001	3.916	0.435	35.225	1.218	0.223	48.47		-0.06		
Bragger 2005	9.698	0.381	246.863	1.376	0.169	22.32		0.59		
	4.102	0.889	18.928	1.809	0.070					

Odds ratio and 95% CI



(Figure 31, A)

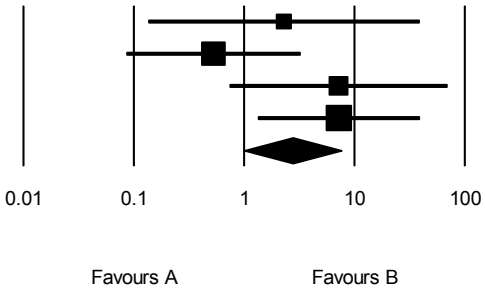
Model		Effect size and 95% interval			Test of null (2-Tail)		Heterogeneity			
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared
Fixed	3	4.102	0.889	18.928	1.809	0.070	0.435	2	0.804	0.000
Random	3	4.102	0.889	18.928	1.809	0.070				

(Figure 31, B)

FDP Failed/Loss Comparison

Study name	Statistics for each study					Weight (Fixed)				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	2.294	0.135	38.864	0.575	0.565	12.84		-0.14		
Olsson 1995	0.528	0.086	3.243	-0.690	0.490	31.18		-2.15		
Naert Pt 1 2007	7.182	0.741	69.657	1.701	0.089	19.91		0.92		
Bragger 2005	7.233	1.337	39.125	2.297	0.022	36.07		1.40		
	2.756	1.000	7.595	1.960	0.050					

Odds ratio and 95% CI



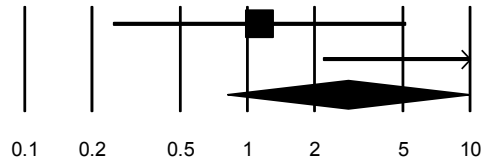
(Figure 32, A)

Model		Effect size and 95% interval			Test of null (2-Tail)		Heterogeneity			
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared
Fixed	4	2.756	1.000	7.595	1.960	0.050	5.138	3	0.162	41.606
Random	4	2.772	0.709	10.838	1.466	0.143				

(Figure 32, B)

Biological Complications Comparison

Statistics for each study	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Bragger 2001	1.133	0.250	5.147	0.162	0.871	68.12		-2.10		
Bragger 2005	25.000	2.190	182.649	2.655	0.008	31.88		2.10		
	2.830	0.812	9.868	1.633	0.103					



(Figure 33, A)

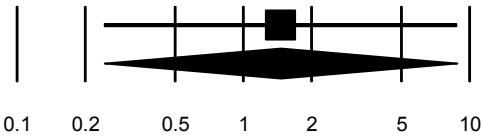
Favours A Favours B

Model	Number Studies	Effect size and 95% interval: Point estimate	Lower limit	Upper limit	Test of null (2-Tail): Z-value	P-value	Heterogeneity: Q-value	df (Q)	P-value	I-squared
Fixed	2	2.830	0.812	9.868	1.633	0.103	4.407	1	0.036	77.311
Random	2	4.231	0.256	69.828	1.008	0.313				

(Figure 33, B)

Abutment Fracture Comparison

Study name	Statistics for each study: Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Weight (Fixed) Relative weight	Relative weight	Std Residual	Std Residual	Std Residual
Naert Pt 1 2001	1.460	0.242	8.793	0.413	0.680	100.00		0.00		
	1.460	0.242	8.793	0.413	0.680					



(Figure 34, A)

Favours A Favours B

Model	Number Studies	Effect size and 95% interval: Point estimate	Lower limit	Upper limit	Test of null (2-Tail): Z-value	P-value	Heterogeneity: Q-value	df (Q)	P-value	I-squared
Fixed	1	1.460	0.242	8.793	0.413	0.680	0.000	0	1.000	0.000
Random	1	1.460	0.242	8.793	0.413	0.680				

(Figure 34, B)

SUMMARY

Based on the information gathered from the results:

1) 4/30 studies mentioned that I-I FDPs have the same complication rates as I-T, 3 studies mentioned that at 5 years they both have the same complications however, at 10 years I-T has more complications, 2 studies mentioned that I-I have less complications than I-T and only 1 study mentioned that at 5 years complications are seen in both, however at 10 years there are no more complications seen in I-T FDPs.
2) The complications that were significantly worse for I-T in this study were "Implant loss" and " Failed FDP" in which it showed more incidences than I-I FDPs.
3) There are types of complications that are common between both I-T and I-I which are mainly the technical types, however, the "intrusion of the natural tooth" phenomena plays a big role in increasing the biological complication rates of the I-T, in addition to caries, vitality loss, tooth loss, periapical radiolucencies, periodontal disease, and marginal bone loss. These complications are all tooth-related which demarcates the main difference between the two groups.
4) To avoid the intrusion of the natural tooth in I-T FDPs; 7/12 studies concluded that using a "rigid" connector when connecting teeth to implants will eliminate intrusion and most complications that are seen when connecting I-T, however 4 studies recommended not to use "non-rigid" connectors but did not actually state that "rigid" connectors are a solution, and one study recommended using

the IMZ Protocol, which is a mix of rigid and non rigid connectors, and finally only one study concluded that patients with reduced periodontal support do not experience intrusion, however patients with healthy periodontium are more susceptible to intrusion.

DISCUSSION

It is evident from this study that more long-term studies need to be conducted on this topic. No randomized control trials were found and conclusions were all drawn based on prospective and retrospective studies. The inconsistent data gathered from these studies had a negative affect on the data extraction and data analysis. This inconsistent data and lack of quality in reporting could have a serious effect on the result of systematic reviews and meta-analyses *(Pjetersson,2012)*(5). One of the difficulties that was faced while extracting data is trying to associate different terminologies that were used to describe the same type of complication. Although the common reader would assume that two terminologies are similar, one cannot actually consider them as the same complication unless the author has stated it. This means we could have 10 reports on "Loss of retention", 7 reports on "screw loosening" and 5 reports on "decementation", knowing that "loss of retention" is actually the end result of both "screw loosening" and "decementation", but is it permissible to combine these reports under one category to yield a positive result? . One of the shortcomings of the studies is (Bragger,2001) in fact had cases of I-I and I-T however the results of the study showed pooled data of both under one result, this however was mentioned by the author and therefore (Bragger,2005) yielded single results for both I-I and I-T. Another shortcoming of this study was the authors of different studies using different

sample sizes to measure event rates. For example; the complications on veneer fracture: one study used number of FDPs as the sample size, while another study used the number of implants, how do we compare 5/10 implants with veneer fracture to 5/10 FDPs with veneer fracture? In this study, this variation in reporting was overlooked otherwise the results would be too scattered. Two complications were eliminated from the results "decementation" and "marginal bone loss". Decementation was eliminated from the I-I group due to all prospective and retrospective studies not reporting on it since they all used screw-retained prostheses. Marginal bone loss – on the other hand – had 3 studies from each group I-I and I-T reporting on it. However, the inconsistent units of measurement, the lack of precise tools, and the lack of standard deviations lead to fear of giving unreliable false positive or false negative results in this study, therefore it was eliminated as a whole. In terms of the information gathered from this review, the majority of the studies understand that the complication rates of I-T are the same if not slightly more than I-I however, the type of complications with I-T are more detrimental; biological. The majority of the studies conclude that using non-rigid attachments could have a negative association on the abutment tooth causing it to intrude. However, in contrast, a portion of studies conducted with surveys, models or animals report that there is no difference between rigid and non rigid attachments(28)(29); One survey by (Reider,1993) was done to assess if the rate of intrusion had a correlation with the clinician's experience , or with the connector type that was used. This study was excluded from this systematic review due to not mentioning the follow up period, which would be difficult to document in a survey. However, 31 responses from 45 distributed surveys reported on intrusion, and 14 responded with no intrusion. Of these respondents, the percentage of intrusion was low for those clinicians who had fabricated 100 or more I-T FDPS (3%) as compared

to a rate of (40%) cases of intrusion seen with clinicians who had limited experience in restoring these type of situations. Although, the author does say it is difficult to draw any conclusion or association. On the other hand, the type of connector was documented here, and all types of connections were used; precision, semi precision, rigid, T-block assemblies, and with cases of no intrusion, there was no specific type of connection that was seen. However for most cases of intrusion, a highly stated preference towards using a semi-precision attachment or a coping and super-structure was used. The next study that mentioned no difference in connectors is one that used a finite element analysis using a 3D model with implant and tooth in place to simulate the mandible, non-rigid connectors were used using a friction slot-like precision attachment., the results of this study concluded that the load itself whether centric or lateral was the main factor in affecting the distribution of stress in the different components (prosthesis, bone and implant) not the connectors, yet they did mention that using non-rigid connectors yielded 3-folds the stress on the prosthesis than a rigid connector. This next study was conducted an on a dog (30) to measure the effect of using rigid connectors in I-T FPS. This study measured the histologic response of the periodontal tissues of the teeth that were used as abutments for these prostheses and this was measured using a light-emitting microscope. The results were lack of inflammation and actual stability of the periodontal tissues. Another study measured the effects of using non-rigid connectors using an in vitro photo elastic stress analysis and the results indicate that the perceived “stress-breaking” effect of non-rigid connectors in face are no beneficial in preventing teeth from intruding.(31) In the end the meta-analysis done by (Weber,2010) concluded that after an observation period of 5 years, I-I and I-T had similar survival rates, however after 10 years the I-T significantly decreased in survival rate as compared with the I-I group.

CONCLUSION

More thorough clinical documentation must be done to be able to extract valid data in future studies regarding this topic, otherwise it would be impossible to attain valid quantitative data from these studies.

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