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Review

Systematic review of short- (5–10 years) and long-term (10 years or more) survival and success of full-arch fixed dental hybrid prostheses and supporting implants

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ABSTRACT

Objectives: The aim of this systematic review was to investigate the short-term (5–10 year mean follow-up) and long-term (10 year or more) survival and success of fixed full arch dental hybrid prosthesis and supporting dental implants.

Methods: Studies reporting interventions with full-arch fixed dental hybrid prostheses were identified by searching PubMed/Medline (NCBI), Web of Science (Thomson Reuters), the Cochrane Register of Controlled Clinical Trials (EBSCO), and Dentistry and Oral Sciences Source (DOSS; EBSCO) from the earliest available dates through July 17, 2013. Through a series of review process by two examiners, potentially qualifying studies were identified and assessed with respect to the inclusion criteria.

Results: A total of 18 studies were included for the quality assessment and the systematic review. Within the limitation of available studies, high short-term survival rates of full arch fixed dental hybrid prostheses (93.3–100%) and supporting implants (87.89–100%) were found. However, the availability of studies investigating long-term outcomes seemed scarce. Furthermore, the included studies were subjected to potential sources of bias (i.e. publication, reporting, attrition bias).

Conclusions: Despite seemingly high short-term survival, long-term survival of implant supported full arch fixed dental hybrid prosthesis could not be determined due to limited availability of true long-term studies. Although it may be a valuable option for a patient with a completely edentulous ridge(s), the strategic removal of teeth with satisfactory prognosis for the sake of delivering an implant supported full-arch dental hybrid prosthesis should be avoided.

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1. Introduction

Hybrid prosthesis often refers to fixed rehabilitation composed of a metal-based substructure covered with acrylic resin.[1] With the advancement in dental implantology over the years, hybrid prosthesis has been successfully utilized to rehabilitate completely edentulous ridges.[2] In general, an edentulous arch could be rehabilitated in this method, using four to eight endosseous implant fixtures with screw retained hybrid restoration.[3,4] In those cases, a one-piece full-arch hybrid prosthesis consisting of a metal framework, acrylic base and denture teeth is fabricated and screwed onto the implants.[3,4] This treatment modality allows patients to have a completely fixed prosthesis, which can only be removed by the dental professional.[1] Furthermore, by often utilizing a distally cantilevered prosthesis and angulated implant fixtures, it may require lower number of implant fixtures and complicated surgical procedures such as maxillary sinus augmentation and guided bone regeneration, compared to a conventional method (i.e. rehabilitating with full-arch ceramo-metal implant supported fixed partial dentures).[4–7] Previous studies have reported high success rates of the prosthesis as well as supporting dental implants using this concept[6–8]; however many of these studies had reported minimal-short-term interventions with follow-up of less than 5 years.[9–17] Furthermore, to the best of authors' knowledge, there may be no available literature, systemically evaluating the long-term results of this specific treatment modality. Therefore, the aim of this systematic review was to investigate both short (5–10 years) and long-term (10 years or more) survival and success of fixed dental hybrid prosthesis and supporting dental implants used for rehabilitating a completely edentulous ridge.

1.1. Objectives

1. To investigate the short and long-term survival of full arch fixed dental hybrid prostheses and their supporting implants.
2. To investigate mean alveolar bone loss around dental implants, incidence of prosthodontics complications, and patient satisfaction.

1.2. PICOS (Participants, Interventions, Comparisons, Outcomes, Study Designs)

PICOS questions were pre-determined in order to specifically address and achieve the aforementioned aims and objectives (Table 1).[18]

Table 1 – PICOS (Participants, Interventions, Comparisons, Outcomes, Study Designs).

Participants	Generally healthy subjects with completely edentulous arch(s)
Interventions	Implant supported full arch fixed dental hybrid prostheses
Comparisons	Not applicable[a]
Outcomes	1. Cumulative survival of prostheses and their supporting implants 2. Mean alveolar bone loss of supporting implants, incidence of prosthodontic complications, patient reported satisfaction
Study designs	Randomized controlled trial, prospective cohort study, retrospective cohort study, case-series

[a] The primary objectives of the current study were on prognosis.

2. Materials and methods

2.1. Search method and identification of studies

Studies reporting interventions with full-arch fixed dental hybrid prostheses were identified by electronically searching PubMed/Medline (NCBI), Web of Science (Thomson Reuters), the Cochrane Register of Controlled Clinical Trials (EBSCO), and Dentistry and Oral Sciences Source (DOSS; EBSCO) from the earliest available dates through July 17, 2013. The search strategies were assembled from synonyms for All on Four, All on Six, hybrid, or tilted implants and all likely modes of implant or treatment failure (Appendix 1). Medical Subject Headings (MeSH) were included in the PubMed strategy. Supplemental hand-search was conducted by reviewing the reference lists of related papers and review articles. No language limit was applied for the initial search. The authors adhered to the PRISMA standard for reporting systematic reviews.[18] The search was developed and conducted by an experienced reference librarian (PAB). Any duplicates were removed. Through title and abstract review by two independent examiners (TK, LL), potentially qualifying studies were identified. Thereafter, these studies received full text assessment with respect to inclusion criteria. Any disagreement between the examiners was resolved by discussion until agreement was reached. The inter-examiner agreement on study selection was evaluated according to kappa statistics.

2.2. Inclusion criteria

This review was based on reports from randomized controlled studies, prospective cohort studies, retrospective cohort studies, case–control studies and case series, which were identified by the systematic literature searches as described above. The additional inclusion criteria for study selection were:

- The publications must be reported in English, Hebrew, Korean or German.
- The studies involve human subjects.
- The studies must have a mean follow up time of 5 years or more.
- The studies must have minimum of 10 subjects who completed 5 year follow-up.
- All study subjects must have received full arch fixed dental hybrid prosthesis/prostheses.

2.3. Type of outcome measurements

The primary outcome measurements were cumulative survival rates of dental implants and prostheses. The secondary outcome measurements were mean alveolar bone loss (in

mm) around dental implants, incidence of prosthetic complications (number of events) and patient reported satisfaction.

2.4. Data collection

The following information were collected from each included study and inserted into a specifically designed electronic spreadsheet: names of the authors, year of publication, study design, total number of subjects at baseline, total number of implants at baseline, total number of subjects at follow-up, total number of implants at follow-up, number of implant fixtures per arch, years of mean follow-up, loading protocols (immediate; loading within 24 h following implant placement, early; loading after 24 h and before 2 months following implant placement, delayed; loading after 2 months following implant placement), types, surface (machined/rough), and manufacturer of inserted implants, cumulative implant survival, cumulative prosthesis survival, mean alveolar bone loss (mm/years of follow-up), incidence of prosthetic complications (number of events), and patient-reported satisfaction. Lastly, based on mean follow-up years, the studies were categorized into either short-term (mean follow-up between 5–10 years) or long-term (mean follow up of 10 years or longer) group, and their results were presented separately.

2.5. Quality and risk for bias assessment

The quality and risk for bias of the included studies were assessed by the authors (TK, LL). A 9-question checklist, which was modified from Annibali et al.[19] was completed for each study. The following quality criteria were assessed. Any disagreement between the examiners was resolved by discussion until agreement was reached. The inter-examiner agreement was evaluated according to kappa statistics.

1. Number of study centre (single-centre study; multi-centre study)
2. Setting of study centre (university; private clinic)
3. Clear description of study aim (yes; no)
4. Clear definition of inclusion and exclusion criteria (yes; no)
5. Clear definition of study outcome measures (yes; no)
6. Prospective data collection (yes; no)
7. Clear description of main study findings (yes; no)
8. Completeness of follow-ups and explanations for dropouts/withdrawals (yes; no)
9. Conflicts of interest/industrial support (yes; no)

The examiners assessed the presence of conflict of interest by reviewing the authors' disclosures and acknowledgements in the manuscript according to the criterion used by Friedman and Richter.[20] The conflict of interest was defined as all financial relationships with companies whose products the researchers are evaluating in the manuscript.[20]

3. Results

3.1. Search results

Fig. 1 describes the flow chart of the search results. A total of 1992 records were identified using the four databases. Thirty-nine studies were identified for full-text assessment after duplicate removal, and title and abstract assessment. Bibliography or references of these 39 studies were reviewed, and additional 5 studies were identified for full-text assessment. Therefore, a total of 44 studies received full-text assessment, after which twenty-six studies were excluded (Table 2). The remaining 18 studies were finally included for the quality assessment and the systematic review (Table 3). Among 18 studies, the results from two studies were combined as they reported implant and prosthetic outcomes from the same cohort of the subjects in two phases.[21,22] The agreement between the two examiners on the study selection as evaluated by kappa statistics was 0.82.

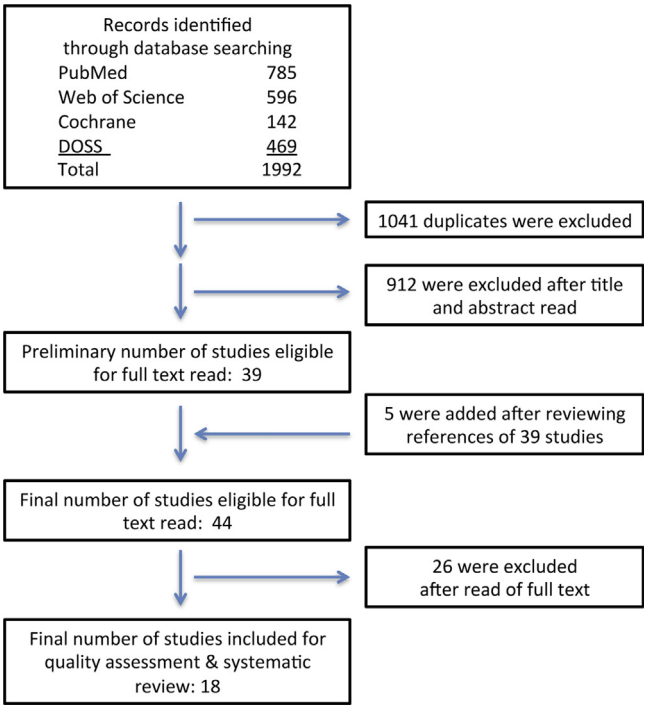

Fig. 1 – Search strategy and history.

3.2. Quality and risk for bias assessment of included studies

The agreement between the two examiners as evaluated by kappa statistics was 0.91. The detailed assessment of quality and risk of bias for all included studies are presented in Table 4. It was noteworthy that eleven studies were conducted in a private setting,[21–31] among which five studies were conducted in a clinic, specializing in implant supported full arch dental hybrid prosthesis.[25,27–29,31] Eleven studies were believed to have potential conflict of interest related to their studies.[2,4,5,21,22,25–29,31,32]

3.3. Systematic assessment of included studies

3.3.1. Availability of literature

There were twelve short-term (Table 5) and six long-term studies (Table 6), which fulfilled the pre-determined inclusion criteria. Ten studies were prospective cohort studies while the remaining six studies were retrospective cohort studies. There

Table 2 – Excluded studies and reasons for the exclusion.

Author	Reason for exclusion
Balshi et al. (2005)[9]	Mean follow up < 5 years
Browaeys et al. (2011)[40]	Not specific for full-arch fixed dental hybrid prosthesis
Cavalli et al. (2012)[10]	Mean follow up < 5 years
Ferrigno et al. (2002)[41]	Not specific for full-arch fixed dental hybrid prosthesis
Fischer et al. (2008)[42]	The same cohort subjects as Fischer and Stenberg [21,22]
Francetti et al. (2008)[11]	Mean follow up < 5 years
Francetti et al. (2010)[12]	Mean follow up < 5 years
Gualini et al. (2009)[43]	< 10 subjects analyzed at minimum of 5 years
Heydecke et al. (2012)[8]	Review
Ibanez et al. (2005)[44]	Not specific for full-arch fixed dental hybrid prosthesis
Ji et al. (2012)[13]	Mean follow up < 5 years
Larsson and Von Steyern (2013)[45]	Not specific for full-arch fixed dental hybrid prosthesis
Lethaus et al. (2011)[46]	Not specific for full-arch fixed dental hybrid prosthesis
Malo et al. (2003)[14]	Mean follow up <5 years
Menini et al. (2012)[6]	Review
Miglioranca et al. (2011)[15]	Mean follow up <5 years
Minoretti et al. (2012)[47]	<10 subjects analyzed at minimum of 5 years
Papaspyridakos et al. (2012)[35]	Review
Patzelt et al. (2013)[7]	Review
Peñarrocha et al. (2012)[48]	Not specific for full-arch fixed dental hybrid prosthesis. Mean follow up <5 years
Polizzi and Cantoni (2013)[49]	Not specific for full-arch fixed dental hybrid prosthesis. Mean follow up <5 years.
Pomares (2009)[50]	Mean follow up time not specified
Real-Osuna et al. (2012) [1]	Mean follow up time not specified
Schwarz et al. (2010) [16]	Mean follow up <5 years
Testori et al. (2004)[17]	Mean follow up <5 years
Wolfinger et al. (2003)[51]	Not specific for full-arch fixed dental hybrid prosthesis

Table 3 – Included studies.

Author	Title
Attard and Zarb (2004)[3]	Long-term treatment outcomes in edentulous patients with implant-fixed prostheses: the Toronto study
Brånemark et al. (1995)[4]	Ten-year survival rates of fixed prostheses on four or six implants ad modum Brånemark in full edentulism
Degidi et al. (2013)[24]	A six-year follow-up of full-arch immediate restorations fabricated with an intraoral welding technique
Ekelund et al. (2003)[25]	Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years
Eliasson et al. (2000)[23]	Five-year results with fixed complete-arch mandibular prostheses supported by 4 implants
Fischer and Stenberg (2012)[21]	Prospective 10-year cohort study based on a Randomized Controlled Trial (RCT) on implant-supported full-arch maxillary prostheses. Part 1: Sandblasted and acid-etched implants and mucosal tissue
Fischer and Stenberg (2013)[22]	Prospective 10-year cohort study based on a Randomized, Controlled Trial (RCT) on implant-supported full-arch maxillary prostheses. Part II: Prosthetic outcomes and maintenance
Gallucci et al. (2009)[2]	Five-year results of fixed implant-supported rehabilitations with distal cantilevers for the edentulous mandible
Heschl et al. (2012)[33]	Immediate rehabilitation of the edentulous mandible with screw type implants: results after up to 10 years of clinical function
Jemt et al. (2002)[26]	Implant-supported welded titanium frameworks in the edentulous maxilla: a 5-year prospective multicenter study
Krennmair et al. (2013)[5]	Clinical outcome and peri-implant findings of four-implant–supported distal cantilevered fixed mandibular prostheses: five-year results
Malo et al. (2012)[28]	"All-on-4" immediate-function concept for completely edentulous maxillae: a clinical report on the medium (3 years) and long-term (5 years) outcomes
Malo et al. (2011)[27]	A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up
Malo et al. (2011)[29]	The rehabilitation of completely edentulous maxillae with different degrees of resorption with four or more immediately loaded implants: a 5-year retrospective study and a new classification
Mertens and Steveling (2011)[32]	Implant-supported fixed prostheses in the edentulous maxilla: 8-year prospective results
Oliva et al. (2012)[30]	All-on-three delayed implant loading concept for the completely edentulous maxilla and mandible: a retrospective 5-year follow-up study
Örtorp et al. (2009)[31]	Early laser-welded titanium frameworks supported by implants in the edentulous mandible: a 15-year comparative follow-up study
Rosén and Gynther (2007)[34]	Implant treatment without bone grafting in edentulous severely resorbed maxillas: a long-term follow-up study

Table 4 – Quality and risk of bias assessment.

Entry	References																
	Attard and Zarb (2004)[3]	Brånemark et al. (1995)[4]	Degidi et al. (2013)[24]	Ekelund et al. (2003)[25]	Eliasson et al. (2000)[23]	Fischer and Stenberg (2012,2013) [21,22]	Gallucci et al. (2009)[2]	Heschl et al. (2012) [33]	Jemt et al. (2002)[26]	Krennmair et al. (2013)[5]	Malo et al. (2012)[28]	Malo et al. (2011)[27]	Malo et al. (2011)[29]	Mertens and Steveling (2011)[32]	Oliva et al. (2012)[30]	Örtorp et al. (2009)[31]	Rosén and Gynther (2007)[34]
Are patients collected in more than one centre?	No	No	No	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No	No
Where was the study conducted? (university; private clinic)	Univ	Univ	Private	Private	Private	Private	Univ	Univ	Private	Univ	Private	Private	Private	Univ	Private	Private	Univ
Is the aim of the study clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are the inclusion and exclusion criteria clearly reported?	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Is there a clear definition of the outcomes reported?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were data collected prospectively?	Yes	No	Yes	Yes	Yes	Yes	No[a]	Yes	Yes	No	No	Yes	No	Yes	No	No	No
Are the main findings of the study clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are losses to follow-up clearly described?	Yes	No	Yes	Yes	Yes	Yes	No[b]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No[b]	Yes	Yes
Are conflicts of interest/ industrial support present?	NR	Yes	No	Partially[b]	NR	Yes	Yes	NR	Yes	No	Partially[b]	Partially[b]	Partially[b]	Yes	No	Partially[b]	No

NR: Not reported; Univ: University; Private: Private clinic.

[a] Subjects, who were enrolled in a multi-clinical study to assess the safety and efficacy of the ITI dental implant system, were "retrospectively" selected.

[b] The study was conducted by Brånemark clinic, using Brånemark implants or by a clinic mainly involving with All-on-4 treatment concept.

Table 5 – Summary: studies with mean follow-up time between 5 and 10 years.

Author (year)	Study design	Jaw[a]	Total # of subjects/ total # of implants at baseline	Total # of subjects/total # of implants at analysis	Number of fixtures per arch	Follow-up period in years (range)	Loading protocol[b]	Implant type, surface, and manufacturer	Cumulative implant survival (%)	Cumulative prosthesis survival (%)	Mean alveolar bone loss (mm/years of follow up) and other biologic complications (unit of measure is implant unless specified)	Prosthetic complications	Patient satisfaction
Degidi et al. (2013)[24]	Prospective cohort	Mx Md	Mx:24/144 Md:28/112	Mx: 124 implants Md: 87 implants	NR; Varied among cases	6	Immediate	Rough Dentsply	Overall 90.31% Mx 92.12% Md 87.89%	NR	Mx: 1.39 mm/6 years Md: 1.29 mm/6 years Others: Soft tissue adverse events (15.16%) Peri-mucositis (11.85%) Peri-implantitis (3.31%) Transient nerve disturbance (1 subject)	Small fracture of the acrylic resin suprastructure (5 subjects) Complete fracture of the resin portion of the distal cantilever (1 subject) Fracture of the fixing screws (1 subject) Minor relining procedure (9 subjects)	NR
Eliasson et al. (2000)[23]	Prospective cohort	Md	119/476	53/212 (≥5 year)	4	1–11	Delayed	Machined Brånemark	98.6% (≥5 year)	100%	0.5 mm/≥5 year Mesially placed implants only 0.6 mm* Distally placed implants only 0.3 mm* (*$P < 0.05$)	Mobile prostheses that required tightening of the screw joints (3 subjects) Framework fracture all of which occurred at or posterior to the distal abutment (5 subjects) Fracture of resin teeth 25 subjects, 61 occasions)	NR
Gallucci et al. (2009)[2]	Prospective cohort, multi-centre trial	Md	NR	45/237	4–6	5	Delayed	Rough Straumann	100%	95.5% (success = 86.7%)	NR Others: biological complications (25 times; reversible numbness of mental nerve, inflammation around an implant, inflammation under prosthesis, hypertrophy or hyperplasia of tissue, etc.)	Technical complications (54 times; fracture of acrylic tooth or denture base, fracture upper denture, final screw fracture)	All subjects rated ability to chew, ability to taste, appearance, and general satisfaction as good/excellent. (scale used: excellent, good, fair, poor)
Heschl et al. (2012)[33]	Prospective cohort	Md	45/180	84 implants (5 year) 8 implants (10 year)	4	5, 10	Immediate	Rough Dentsply	5 year Survival = 98.3% Success = 95% 10 year Survival = 98.3% Success = 95%	NR	1.73 mm/5 years 1.78 mm/10 years	NR	NR

Table 5 (*Continued*)

Author (year)	Study design	Jaw[a]	Total # of subjects/ total # of implants at baseline	Total # of subjects/total # of implants at analysis	Number of fixtures per arch	Follow-up period in years (range)	Loading protocol[b]	Implant type, surface, and manufacturer	Cumulative implant survival (%)	Cumulative prosthesis survival (%)	Mean alveolar bone loss (mm/years of follow up) and other biologic complications (unit of measure is implant unless specified)	Prosthetic complications	Patient satisfaction
Jemt et al. (2002)[26]	Prospective cohort, multi-centre study	Mx	58/349 Titanium framework group = 28 subjects Cast gold framework group = 30 subjects	50 subjects	≥5	5	Delayed	Machined Brånemark	Titanium framework group = 91.4% (from implant placement), 94.9% (from prosthesis delivery) Gold alloy framework group – 94% (from implant placement), 95.6% (from prosthesis delivery)	Titanium framework group = 96.4% Gold alloy framework group = 93.3%	0.59 mm/5 years	Titanium framework group showed; Fractures: resin teeth, resin material (20 times in a total of 11 prosthesis) Mobile/unstable prosthesis (1 time in 1 prosthesis) Loose gold screws (4 times in a total of 4 prosthesis) Cast gold alloy framework group showed; Fractures: resin teeth, resin material (24 times in a total of 12 prosthesis) Loose gold screws (2 times in a total of 2 prosthesis)	NR
Krennmair et al. (2013)[5]	Retrospective cohort	Md	42/168	38/152	4	66.5 months (60–84)	Delayed	Rough Camlog	Survival = 100% Success = 98.6%	100%	1.21 mm/66.5 months	256 prosthodontic complications; Denture discoloration (109) denture Rrebasing/ reduction (43) Resin tooth fracture/ repair (38) Others (66)	NR
Malo et al. (2012)[28]	Retrospective cohort	Mx	242/968	24/105	4	5	Immediate	Rough Brånemark	98% (patient level = 93%)	100%	1.95 mm/5 years	Fractures of the provisional acrylic prosthesis (5 subjects) Abutment screw loosening of the provisional acrylic prosthesis (2 subjects) Prosthetic screw loosening of the provisional acrylic prosthesis (1 patient)	NR

Malo et al. (2011)[27]	Prospective cohort	Md	245/980	203/812 (5 year) 6/24 (10 year)	4	5,10	Immediate	Rough Brånemark	Implant success (5 year) Patient level 94.81% Implant level 98.1% Implant success (10 year) Patient level 93.8% Implant level 94.8%	99.2% (10 year)	NR	Prosthetic screw loosening in the provisional prosthesis (12 subjects) Abutment loosening in the definitive prosthesis (2 subjects) Excessive wear marks in the definitive prosthesis occurred (1 subject)	NR
Malo et al. (2011)[29]	Retrospective cohort	Mx	221/995	173/846	4–6	5	Immediate	Rough Brånemark	Implant level 95.8% Patient level 88.6%	98.6%	NR Other findings: biological complications (129 times in 66 subjects); Peri-implant pathology (probing pocket depth of 6 mm, bleeding on probing associated with marginal bone loss; 27 subjects) Excessive marginal bone loss (more than 2.8 mm; 37 subjects)	170 mechanical complications (170 times in 71 subjects); Fracture of the prosthesis (12 patients) Porcelain crown fracture (56 patients) Abutment loosening (2 subjects) Prosthetic screw loosening (2 subjects)	NR
Mertens and Steveling (2011)[32]	Prospective cohort	Mx	17/106	15/99	6–8	8.34	Delayed	Rough Astra Tech	99%	Survival = 100% Success = 82.4%	0.3 mm/8 years	Chipping of resin acrylic teeth (3 subjects) Ageing of the acrylic base, or discolorations at the contact area between the teeth and the acrylic base (6 subjects).	All subjects reported either "very satisfied" or "satisfied" in terms of function involving both chewing and phonetics, aesthetics, and overall satisfaction
Oliva et al. (2012)[30]	Retrospective cohort	Mx Md	NR.	17/72 (7 subjects received both Mx and Md prostheses)	3	5	Delayed (except 1 case where the patient did not accept any temporary removal denture)	Rough Straumann Osstem	100%	100%	Internal connection implants = 0.53 mm/5 years External connection implants = 0.84 mm/5 years	No fractures of zirconia restorations Fixation screw of the restoration was loose after the 3 months of loading (1 subject) Porcelain chipping after 1 year of implant loading (1 subject)	NR
Rosén and Gynther (2007)[34]	Retrospective cohort	Mx	33 subjects (implant # was not reported)	19/103	4–6	8–12	Delayed	Rough, Brånemark	Success = 97.08%	NR	Bone resorption upto 4.8 mm (mean = 1.2 mm) at 8–12 year follow up (10 implants in 5 subjects)	Speaking problem 42.1% (8 subjects) Aesthetic problems 36.8% (7 subjects)	42.1% reported having speaking problems. 36.8% reported having aesthetic problems

[a] Mx: maxilla; Md: mandible.
[b] Loading.
- Immediate loading: implants being in function within 24 h of placement.
- Delayed: after 2 month following implant placement.

Table 6 – Summary: studies with mean follow-up time of 10 or more years.

Author (year)	Study design	Jaw[a]	Total # of subjects/ total # of implants at baseline	Total # of subjects/total # of implants at analysis	Number of fixtures per arch	Follow-up period in years (range)	Loading protocol[b]	Implant type, surface, and manufacturer	Cumulative implant survival (%)	Cumulative prosthesis survival (%)	Mean alveolar bone loss (mm/years of follow up) and other biologic complications (unit of measure is implant unless specified)	Prosthetic complications	Patient satisfaction
Attard and Zarb (2004)[3]	Prospective cohort	Mx Md	45/265	31/220	4–8	20.67 (18–23)	Delayed	Machined Brånemark	86.76%	Success rate = 84.34%/ 20 year, however success was defined as an unmodified original prosthetic treatment plan. The longevity of the first prosthesis was 6.57 years. The longevity of the prostheses inserted after the first ones was 8.39 years. On average, a patient received 2.27 implant-supported prostheses (range 1–4) throughout the study period	0.05 mm/year	Tissue hyperplasia/ inflammation (34 times in 16 patients) Broken gold screws (56 times in 10 patient) Broken abutment screw (20 times in 8 patients) Fractured denture teeth (19 times in 9 patients) Fractured opposing denture (3 times in 2 patients) Laboratory reline of opposing denture (45 times in 12 patients) Fractured framework (13 times in 7 patients) Remake of fixed prosthesis (46 times in 31 patients) Fabrication of new opposing denture (22 times in 16 patients)	NR
Brånemark et al. (1995)[4]	Retrospective cohort	Mx Md	NR	156/882 Mx 4 implants 14/56 6 implants 70/420 Md 4 implants 13/52 6 implants 59/354	4 or 6	10	Delayed	Machined, Brånemark	Mx 4 implants 80.3% 6 implants 78.3% Md 4 implants 88.4% 6 implants 93.2%	Mx 4 implants 92.8% 6 implants 91.4% Md 4 implants 100% 6 implants 100%	NR	Some repairs of the veneering material, loosening or fractures of the gold screws that connect the prostheses with the abutment	NR
Ekelund et al. (2003)[25]	Prospective cohort	Md	47/273	30/179 at 20-year follow-up examination.	6 (43 subjects) 5 (4 subjects)	21.4 [20–23]	Delayed	Machined, Brånemark	98.9%	95.6%	1.6 mm/20 years	During last 5 years (16–20 y), 17% of patients had prosthetic complications. Loose gold screws needed to be retightened (2 subjects) Lost fillings in the screw holes (1 subject)	

Fischer and Stenberg (2012, 2013)[21,22]	Prospective cohort	Mx	24/142	23 subjects 18/102 available for radiographic analysis to evaluate alveolar bone loss	5 or 6	10 years	Early/ Delayed	Rough, Straumann	93%	Prosthetic survival 82% Prosthetic success 9% Prosthetic failure 9%	1.07 mm/10 years	Resin-related technical complications (4.7 times per prosthesis); re-cementing of teeth, installation of new teeth, filling of tooth fracture, and filling of retention hole Failure of prosthesis, due to framework fracture and problem with the framework design retaining the resin material respectively (2 times, 9%)	NR
Örtorp et al. (2012)[31]	Retrospective cohort	Md	Titanium frameworks group = 155/821 Gold alloy frameworks group = 53/278	Titanium frameworks group 52/282 at 15 years Gold alloy framework group = 13/65	4–6 (mean = 5.3)	15 years	Delayed	Machined, Brånemark	98.7%	91.7% Titanium frameworks group = 89.2% Gold alloy frameworks group = 100%	Titanium frameworks group = 0.59 mm/15 year Gold alloy frameworks group = 0.98/15 year	The most common complications for both groups were resin or veneer fractures and soft tissue inflammation. Fractures of the titanium metal frame (15.5% of the subjects). Fractures of the gold alloy frame fracture (5.6% of the subjects) NR Loose and fractured implant screw components (2.4% of the subjects)	NR

[a] Mx: maxilla; Md: mandible.
[b] Loading.
- Immediate loading: implants being in function within 24 h of placement.
- Delayed: after 2 month following implant placement.
- Early loading: implants being in function before 2 months following placement.
NR: not reported.

were considerable heterogeneity among the included studies in terms of their study design, outcomes of interest, types of implant used (i.e. manufacturer, surface tomography), and prosthodontic protocols (i.e. loading protocol, number of implant fixtures per arch; Tables 5 and 6). Considering the limited availability of papers and potential heterogeneity among them, meta-analysis was not attempted.

3.3.2. *Studies with 5–10 year mean follow up (short-term)*

All studies except one reported using rough surface implants, while Jemt et al. used machined surface implants.[26] The cumulative implant survival rates varied among studies from 87.89% to 100%. In two studies, less than 50% of included implants were available for their survival analysis at 5 year or more.[23,33] In one study, only 105 of 968 implants had 5 years or more of follow-up and were included in the cumulative survival analysis.[28] Mean alveolar bone loss was reported up to 1.95 mm in nine studies. The prosthetic cumulative survival rates varied from 93.3% to 100%. The most commonly reported prosthetic complications were fracture or loosening of abutments or prosthesis screws, fracture of acrylic resin supra-structures and fracture of acrylic resin teeth. The highest incidence was reported by Krennmair et al.,[5] where they reported a total incidence of 256 prosthetic complication in 42 subjects. The patient reported satisfaction was evaluated in three studies.[2,32,34] Satisfactory outcomes in terms of aesthetics, function, and phonetics were reported in two studies.[2,32] In contrast, the study by Rosén and Gynther reported 42.1% having speaking problems and 36.8% having aesthetic problems.[34]

3.3.3. *Studies with 10 year or more mean follow up (long-term)*

In comparison to the studies with short-term follow up predominantly reporting the outcomes of rough surface implants, all long-term studies except one group[21,22] used machined surface implants. All included implants except for those in Fischer and Stenberg[21,22] studies were loaded at least 2 months following their placement. The cumulative survival rates of implants varied among the studies from 78.3% to 98.9%. In one study, only 347 among 1099 implants were included in their cumulative survival analysis at 15 years.[31] The mean alveolar bone loss varied between 0.59 and 1.6 mm. The cumulative prosthetic survival rates ranged from 82 to 100% among the studies. Similar to the short-term studies, the most commonly reported prosthetic complications were fracture or loosening of abutment or prosthesis screws, fracture of acrylic resin supra-structure and fracture of acrylic resin teeth. None of the long-term studies reported any patient centred outcome.

4. Discussion

4.1. *Key findings (strength and limitations of the evidence, primary and secondary outcomes)*

Based on the systematic analysis of twelve short-term studies, implants and their supporting full arch fixed dental hybrid prostheses showed high short-term survival rates.

Similarly, high long-term survival rates of implants and prostheses with a slight decreasing trend were found; however, they were derived from the six identified studies, only three of which had more than 15-year mean follow-up. Despite the intervention was initially described approximately 20 years ago by Brånemark et al.,[4] the availability of true long-term studies is surprisingly limited. Alveolar bone loss and prosthodontics complications involving screws for implant/abutment and abutment/prosthesis complexes, and resin structures within the prostheses were commonly reported in both short-term and long-term aspect. There was an obvious lack of attempt to measure patient centred outcome (i.e. patient satisfaction). There were only three studies available for this outcome measure and the results from them seemed inconclusive.

4.2. *Comparison of findings with other systematic reviews*

There were two identified systematic reviews, specifically investigating implant supported full arch fixed dental hybrid prostheses.[6,7] They reported high implant survival rates of 98.62%[6] and 99%,[17] and corresponding high prosthetic survival rates of 99.9%[7] in their meta-analysis, which were higher than most of our included studies. However, the majority of their studies that were used in meta-analysis had mean follow-up of less than 5 years, and, thus, were not included in the current review, which may partly explain the observed difference in survival rates. When truly evaluating a procedure such as dental implant supported rehabilitation, long-term results are of utmost importance in order to avoid bias and misleading.

Papapyridakos et al.[35] specifically investigated biologic and technical complications in implant supported full arch fixed dental hybrid prostheses. Similar to our findings, in their analysis, the most common biologic complication associated with the supporting implants was peri-implant bone loss greater than 2 mm at a rate of 20.1% after 5 years and 40.3% after 10 years. Furthermore, technical complications involving screws (i.e. loosening or fracture) were reported at a rate of 10.4% after 5 years and 20.8% after 10 years. Another common complication was chipping or fracture of veneering materials, which occurred at a rate of 30.3% and 66.6% at 5 and 10 years respectively. They concluded that biologic and technical complications after the delivery of implant supported full arch fixed dental hybrid prostheses would occur continuously over time.[35] This was also in agreement with our findings, where many of the short-term and long-term studies commonly reported alveolar bone loss around the implants as well as prosthodontics complications.

Neither of the recent reviews by Menini et al. and Patzelt et al. included any patient centred outcome (i.e. patient satisfaction) in their objectives of the studies, therefore, no comparison could be made.

4.3. *Implications for clinical practice and implications for research*

The availability of evidence on long-term survival of implant supported full arch fixed dental hybrid prosthesis is substantially scarce. Within the limitation of available literature, clinicians may expect high survival rates of full arch fixed dental hybrid prostheses and supporting implants in short-term. However, the availability of only six studies investigating

long-term outcomes (10 years or more) seemed insufficient to draw sound clinical decisions. Furthermore, although relatively high prosthetic survival rates were reported in the selected long-term studies, clinicians should be aware that there was heterogeneity in defining the success or survival of the prosthesis. For instance, Attard and Zarb defined the success of prosthesis as no change in original prosthodontic treatment plan.[3] In other words, the longevity of the initially delivered prostheses was only 6.57 years, and, as long as the subjects received the same treatment modality subsequently, they were still considered as success. As a result, during the study period of approximately 20 years, each patient received on average 2.27 repeated prostheses.[3]

According to another long-term study by Fischer and Stenberg, despite the reported 82% survival rates of the original prostheses over 10 year observation period, only 9% of the prostheses were considered successful.[21,22] In their two-phase study, prosthesis was considered as success only if it remained unchanged and did not require any intervention during the entire observation period.

Considering the observation that long-term studies predominantly used machined surface implants, clinical significance of these studies on current implant dentistry using implants with rough surface seems to be limited. It was suggested that implants with rough surface tomography may have better osseous healing compared to their machined counterparts.[36] Despite seemingly promising short-term results using rough surface implants and earlier loading protocol, clinicians should be aware that there is only one study group investigating rough surface implants with 10 year or more.[21,22] Clinicians should note that alveolar bone loss around supporting implants might continuously occur after the delivery of the prostheses. Rough surface texture utilized in current implant dentistry may even further predispose these implants for bacterial adhesion and peri-implant bone loss.[37] This recent shift in implant topography may, in part, account for the fact that some of the short-term studies exhibited higher alveolar bone loss compared to their long-term counterparts.[5,24,28,33,34] Treating clinicians should carefully design their prostheses, to allow ease access for patient's daily oral hygiene practice, an issue that is often overlooked in the hybrid prosthesis design. Clinicians should also continuously monitor patient's compliance with oral hygiene instruction,[52] assess conditions of inserted implants and provide regular peri-implant maintenance care in order to prevent or minimize peri-implant inflammation and bone loss.

Although the included studies reported seemingly high survival rates of delivered prostheses, clinicians should be aware that prosthetic complication is common after the delivery and, thus, should inform the patients in advance regarding the repair and maintenance needed, and accompanying time and cost.[35] Preciado et al. had reported recently that Screwed implants restorations provide better oral health-related quality of life than do fixed-detachable hybrid prostheses.[53,54]

Clinicians should note that patient satisfaction associated with the therapy seemed inconclusive and lack long-term data.

The selected studies seemed to be susceptible to potential bias sources. There were considerable differences between numbers of subjects/implants at baseline and at their follow-up partially due to loss of follow-up or their drop-out, resulting in potential attrition bias.[7] It was also interesting note that most studies were conducted in private clinical settings, and were speculated to have conflict of interest or industrial financial support associated with the studies. According to Brignardello-Peterson et al.,[38] there was an association between reporting positive study results and conflict of interest disclosure in dental clinical trials. Upon their meta-analysis, a study with conflict of interest disclosure was 9.19 times more likely to present positive clinical outcomes compared to a study without any conflict of interest disclosure,[38] resulting in potential reporting bias.[18] Also, industrial financial support, especially when a study is conducted in a private sector, may suppress or delay in reporting negative outcomes[39] resulting in potential publication bias.[18] Therefore, the positive results from the included studies with potential conflict of interest or financial support should be interpreted with cautions.

4.4. *Strength and limitation of the study*

This was the first study to systemically appraise both short and long-term evidence on implant supported full arch fixed dental hybrid prostheses specifically, and to report their implant and prosthetic survival. Due to lack of long-term studies, strong evidence on this treatment modality could not be obtained. However, it must be noted that literature search was conducted primarily using electronic databases, and supplemental hand search was limited only to reviewing references of the included studies. Despite the fact that these electronic searches include the majority of peer-reviewed dental journal,[7] the current systematic review may not have identified all relevant literature, which may be a limitation of the study. Furthermore, meta-analysis was not attempted in this systematic review due to marked heterogeneity among studies in terms of their study designs and protocols, which was another limitation of the study. Therefore, there is a need for future studies with long-term follow-up.

5. Conclusions

Within the limitation of the current study, implants and full arch fixed dental hybrid prostheses showed rather high short-term survival rates. However, due to limited available literature, their long-term survival rates could not be obtained. Furthermore, selected studies were vulnerable to potential bias sources (i.e. reporting bias, publication bias and attrition bias). Therefore, clinicians should be aware of aforementioned limitations in existing literature, and apply this treatment concept in clinical practice on carefully selected cases. Although an implant supported fixed dental hybrid prosthesis may be a valuable option for a patient with a completely edentulous ridge(s), the strategic removal of teeth with satisfactory prognosis for the sake of delivering an implant supported full-arch dental hybrid prosthesis should also be avoided.

Conflict of interest

The authors declare that there are no conflicts of interest in this study

Appendix 1: Complete Search Strategies

PubMed

(full arch[tiab] OR fixed hybrid[tiab] OR hybrid implant*[tiab] OR hybrid prosthesis[tiab] OR hybrid prostheses[tiab] OR hybrid restorations[tiab] OR hybrid restoration[tiab] OR all on four[tiab] OR all on 4[tiab] OR all on six[tiab] OR all on 6[tiab] OR tilted implant*[tiab] OR angled implant*[tiab] OR angulated implant*[tiab] OR inclined implant*[tiab] OR four implant*[tiab] OR six implant*[tiab])

AND

(''Dental Restoration Failure''[mesh] OR ''Treatment Failure''[Mesh] OR ''Survival Analysis''[Mesh] OR ''Survival Rate''[Mesh] OR ''Alveolar Bone Loss''[Mesh] OR ''Peri-Implantitis''[Mesh] OR fail*[tiab] OR success*[tiab] OR surviv*[tiab] OR fracture*[tiab] OR loos*[tiab] OR bone resorption[tiab] OR bone loss[tiab] OR bone atrophy[tiab] OR bone level*[tiab] OR alveolar resorption[tiab] OR peri implantitis[tiab] OR periimplantitis[tiab] OR peri mucositis[tiab])

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