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Review Article

A systematic review of implant-supported maxillary overdentures after a mean observation period of at least 1 year

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Abstract

Aim: The aim of the present systematic review of implant-supported maxillary overdentures was to assess the survival of implants, survival of maxillary overdentures and the condition of surrounding hard and soft tissues after a mean observation period of at least 1 year.

Material and methods: MEDLINE (1950–August 2009), EMBASE (1966–August 2009) and CENTRAL (1800–August 2009) were searched to identify eligible studies. Two reviewers independently assessed the articles.

Results: Out of 147 primarily selected articles, 31 studies fulfilled the inclusion criteria. A meta-analysis showed an implant survival rate (SR) of 98.2% per year in case of six implants and a bar anchorage. In case of four implants and a bar anchorage, the implant SR was 96.3% per person. In case of four implants and a ball anchorage, the implant SR was 95.2% per year.

Conclusion: In all three treatment options, the SR of the implants is more than 95%. The studies included reveal that a maxillary overdenture supported by six dental implants, which are connected with a bar, is the most successful treatment regarding survival of both the implants and overdenture. Second in line is the treatment option with four implants and a bar. The treatment option with four or less implants and a ball attachment system is the least successful.

Key words: dental implants; edentulous; maxilla; overdentures; survival; systematic review

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Mandibular overdentures have been extensively studied with respect to a number of implants, a variety of clinical items (including implant survival) and patient satisfaction (Meijer et al. 2003, Timmerman et al. 2004, Visser et al. 2005, Stoker et al. 2007). For the majority of patients, an overdenture on two implants is the first choice of treatment when complaining about the lack and stability of their mandibular denture (Batenburg et al. 1998, Feine et al. 2002). However, on implant-retained maxillary overdentures, consensus or a treatment concept is lacking although maxillary overdentures can be considered a favourable treatment in cases of insufficient bone volume and complaints about retention and stability of the full denture (Visser et al. 2009). Next to sufficient retention and stability, proper phonetics, aesthetics and hygiene access can also be achieved with an implant-supported maxillary overdenture. The latter is often not possible with a fixed maxillary prosthesis (Naert et al. 1998). Different numbers of implants to support the maxillary overdenture and different designs of the anchorage systems used are reported (Rodriguez et al. 2000). In addition, there is a lack of randomized controlled trials (RCTs) to compare the outcome of specific questions related to the number of implants or design of the superstructure (Payne et al. 2004).

Systematic reviews are an appropriate method to explore the outcome of studies (Egger et al. 2001). In a recent systematic review, Sadowsky (2007) evaluated maxillary implant-supported overdentures with emphasis on the number of implants and anchorage design. He concluded that a number of four

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implants was the minimum to support a maxillary overdenture and recommended six implants in case of compromised bone. Moreover, he could not detect a difference between the treatment outcome of splinted and unsplinted implants in the literature he assessed. There was no explicit search on bone graft procedures performed, implant systems, opposing dentition, survival rates (SRs) of the overdentures, radiographical bone loss and several clinical items. Finally, a meta-analysis has never been reported on study results concerning implant-supported maxillary overdentures. Therefore, the aim of the present systematic review of implant-supported maxillary overdentures was to assess the survival of implants, survival of maxillary overdentures and the condition of surrounding hard and soft tissues after a mean observation period of at least 1 year.

Material and methods

Design of the study and search strategy

Although RCTs provide high evidence in comparing effectiveness of different therapies, relevant information is not exclusively provided by RCTs. Well-designed cohort studies and case series may also provide valuable information. Therefore, these types of studies were considered for evaluation too. Moreover, no time restrictions were implemented with respect to the year of publication.

A thorough search of the literature was conducted in the databases of MEDLINE (1950–August 2009) (via PUBMED) and EMBASE (1966–August 2009). The search was supplemented with a systematic search in the Cochrane Central Register of Controlled Trials' (CENTRAL) (1800–August 2009). The search strategy was a combination of MeSH terms (Table 1). The search was completed by checking references of the relevant review articles and eligible studies for additional useful publications. Full-text documents were obtained for all articles meeting the inclusion criteria. Full text analysis was performed by two reviewers (W.S., H.M.) independently. Methodological quality was assessed independently by the reviewers using specific study-design-related modified forms designed by the Dutch Cochrane Collaboration (Den Hartog et al. 2008). In case of disagreement, a consensus was reached by discussion, if necessary in consultation with a third reviewer (G.R.).

Table 1. Search strategy

#1 Search ''Denture, Overlay'' [MeSH]
#2 Search ''Dental Prosthesis, Implant supported'' [MeSH]
#3 Search ''Dental Implants'' [MeSH]
#4 Search ''Dental Implantation, Endosseous'' [MeSH]
#5 Search ''Mouth, Edentulous'' [MeSH]
#6 Search ''Jaw, Edentulous'' [MeSH]
#7 Search ''Maxilla'' [MeSH]
#8 Search #2 OR #3 OR #4
#9 Search #5 OR #6
#10 Search #1 AND #7 AND #8 AND #9
Run data search: 1 August 2009

Criteria for a paper to be included in the study selection were:

- publications must be reporting in the English dental literature;
- detailed information on maxillary overdentures supported by root-form endosseous implants; in case of combined data for implant-supported removable overdentures and implant-supported fixed full dentures, extraction of data for the overdenture must be eligible;
- treatment of the patients has to be initially planned for an overdenture;
- at least five patients should be described in a paper; and
- the follow-up period should be at least 1 year.

Outcome measures

The following outcome measures were assessed:

- survival of implants,
- survival of maxillary overdentures,
- condition of surrounding hard and soft tissues surrounding the implants.

Data extraction

Outcome measures were extracted by two reviewers (W.S., H.M.) independently and recorded in a data sheet. Agreement was reached by a consensus discussion and if necessary, a third reviewer (G.R.) was consulted. A meta-analysis was carried out for outcome measures that could be meaningfully combined.

Statistical analysis

For the meta-analysis, the statistical software package ''Meta-analysis'' was used (Comprehensive Meta-analysis Version 2.2, Biostat, Englewood, NJ, USA). For the calculation of the overall effects for the studies included, weighted rates together with random effect models were used.

Results

Description of the studies

The MEDLINE search provided 92 hits, the EMBASE search seven hits and the CENTRAL search 38 hits. Seven articles appeared to be double. After scanning of titles and abstracts, it was decided to select them all for evaluation as a full-text article, as the abstracts did not always give a clear insight about the method of study and the number of hits was reasonable to assess. This way no article was excluded on beforehand. Reference checking of relevant reviews and included studies revealed 17 additional articles to be screened. This approach resulted in 147 articles to be evaluated by full-text analysis. Three articles of these 147 were excluded because they were not in the English language. Next, 46 articles were excluded because no patients at all or less than five patients were described in those studies. In addition, 62 articles were excluded because there was no detailed information available on the maxillary overdentures as a separate treatment. Two articles were excluded because the treatment with implants was not initially planned for an overdenture. Finally, three articles were excluded because the follow-up was <1 year. In the study of Palmqvist et al. (1994), a planned group and an emergency group were described. The patients in the emergency group were not originally planned for an overdenture but a fixed prosthesis was not possible anymore due to loss of implants. It was decided to include the planned group in the review and to remove the results from the emergency group. The studies of Watson et al. (1997) and Jemt et al. (1996) were suspect to present the same study population. This was, however, not clearly stated and for this reason, doubtful. These studies would deliver the same data for the meta-analysis. For this reason, it was decided to retain the most recent manuscript (Watson et al. 1997). However, both studies were saved for the tables, because, next to survival, the focus was on different evaluation items. A total of 31 articles fulfilled the inclusion criteria and passed the quality assessment. Figure 1 outlines the algorithm of the study selection procedure. Characteristics of the studies included are depicted in Table 2. Two

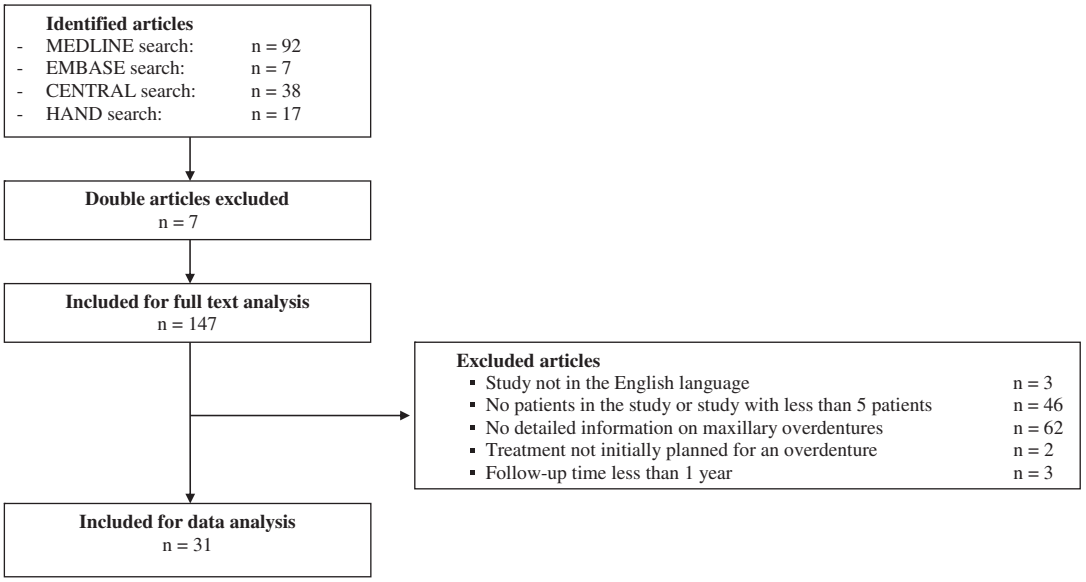

Fig. 1. Algorithm of study selection procedure.

Table 2. Characteristics of included studies

Study	Year of publication	Study design	Follow-up in months	Number of patients in study
Sanna et al.	2009	Retrospective (bar group 4–6 implants)	84	32
		Retrospective (ball group 2 implants)	180	8
Visser et al.	2009	Retrospective	120	39
Raghoebar et al.	2006	Prospective	22	8
Raghoebar et al.	2005	Prospective	20	5
Widbom et al.	2005	Retrospective	60	13
Payne et al.	2004	Randomized controlled trial (Brånemark group)	12	20
		Randomized controlled trial (southern group)	12	19
Raghoebar et al.	2003	Prospective	12	10
Ferrigno et al.	2002	Prospective	120	35
Fortin et al.	2002	Retrospective	60	45
Mericske-Stern et al.	2002	Retrospective	49	41
Kiener et al.	2001	Retrospective	38	41
Närhi et al.	2001	Retrospective	27	16
Rodriguez et al.	2000	Retrospective	36	100
Zitzmann & Marinello	2000a	Prospective	12	10
Zitzmann & Marinello	2000b	Prospective	27	10
Keller et al.	1999	Retrospective	81	13
Smedberg et al.	1999	Retrospective (pilot group)	82	20
		Retrospective (routine group)	35	14
Bergendal & Engquist	1998	Randomized controlled trial (bar group)	60	10
		Randomized controlled trial (ball group)	50	8
Kaptein et al.	1998	Retrospective	70	35
Naert et al.	1998	Prospective	48	13
Watzek et al.	1998	Retrospective	39	15
Ekfeldt et al.	1997	Retrospective	30	7
Watson et al.	1997	Prospective	60	30
Jemt et al.	1996	Prospective	60	30
Hutton et al.	1995	Prospective	36	30
Jemt & Lekholm	1995	Retrospective	60	33
Jemt et al.	1994	Prospective	12	6
Palmqvist et al.	1994	Retrospective	40	19
Smedberg et al.	1993	Retrospective	24	20
Johns et al.	1992	Prospective	12	30
Krämer et al.	1992	Retrospective	19	11

Table 3. Treatment procedures in included studies

Study	Year of publication	Implants per patient	Bone graft procedure	Implant system	Anchorage design	Opposing dentition
Sanna et al.	2009	4–6	Yes/no	Brånemark	Bar	All kinds of opposing dentition
		2	No	Brånemark	Ball	All kinds of opposing dentition
Visser et al.	2009	6	Sinusfloor augmentation	Brånemark	Bar	Complete denture, implant supported overdenture or natural dentition
Raghoebar et al.	2006	6–8	Sinusfloor augmentation and onlay block	Brånemark	Bar	#
Raghoebar et al.	2005	6	Sinusfloor augmentation	Brånemark	Bar	#
Widbom et al.	2005	4	No	Brånemark	Bar	#
Payne et al.	2004	3	No	Brånemark	Ball	Two implant overdenture
		3	No	Southern implant system	Ball	Two implant overdenture
Raghoebar et al.	2003	6–8	Sinusfloor augmentation	Osseotite (3i)	Ball	Complete denture, implant supported overdenture or removable partial denture
Ferrigno et al.	2002	4–6	Some	ITI	Bar	#
Fortin et al.	2002	3–7	No graft procedures	Brånemark	Bar	#
Mericske-Stern et al.	2002	4–6	No graft procedures	ITI	Bar	All kinds of opposing dentition
Kiener et al.	2001	4–6	None	ITI	Bar and Ball	All kinds of opposing dentition
Närhi et al.	2001	2–6	Yes/No	Brånemark and IMZ	Bar and Ball	All kinds of opposing dentition
Rodriguez et al.	2000	5–6	#	#	Bar	#
					Bar	#
					Ball	#
Zitzmann & Marinello	2000a	6–8	#	#	Bar	#
Zitzmann & Marinello	2000b	6–8	No graft procedures	Brånemark	Bar	#
Keller et al.	1999	3–6	Onlay block bone graft	Brånemark	Bar and Ball	All kinds of opposing dentition
Smedberg et al.	1999	#	No	Brånemark	Bar	#
		#	Partly bone grafts	Brånemark	Bar	#
Bergendal & Engquist	1998	2–5	No	Brånemark	Bar	All kinds of opposing dentition
		2–3	No	Brånemark	Ball	All kinds of opposing dentition
Kaptein et al.	1998	#	Yes	IMZ	#	#
Naert et al.	1998	4	No	Brånemark	Bar	All kinds of opposing dentition
Watzek et al.	1998	6–8	Sinusfloor augmentation	Frialen and IMZ	Bar	All kinds of opposing dentition
Ekfeldt et al.	1997	1–4	No	Brånemark	Bar and Ball	#
Watson et al.	1997	3–4	#	Brånemark	Bar	Natural teeth or implant supported prosthesis
Jemt et al.	1996	3–4	#	Brånemark	Bar	Natural teeth, implant supported prosthesis or conventional denture
Hutton et al.	1995	#	No	Brånemark	Bar	All kinds of opposing dentition
Jemt & Lekholm	1995	#	No	Brånemark	Bar	#
Jemt et al.	1994	4–6	#	Brånemark	Bar	#
Palmqvist et al.	1994	2–4	No	Brånemark	Bar	All kinds of opposing dentition
Smedberg et al.	1993	2–6	No	Brånemark	Bar	#
Johns et al.	1992	#	No	Brånemark	Bar	All kinds of opposing dentition

studies were RCTs. In the study of Payne et al. (2004), two different implant systems were analysed and in the article of Bergendal & Engquist (1998), the difference between a bar and a ball anchorage design was studied. The remaining 29 studies described, in fact, retrospectively or prospectively analysed case series. The number of patients in the studies varied from five patients (Raghoebar et al. 2005) to 100 patients (Rodriguez et al. 2000). The follow-up period varied from 12 months (Johns et al. 1992, Jemt et al. 1994, Zitzmann & Marinello 2000a, Raghoebar et al. 2003, Payne et al. 2004) to 180 months (Sanna et al. 2009). Table 3 summarizes the treatment procedures of the studies included. The number of implants placed to support the overdenture varied from one implant to eight implants. Onlay block graft procedures and elevation of the floor of the maxillary sinus were carried out in some studies, but implant insertion without bone graft procedures was also described. The position of the implants, in relation to the availability of a bone volume sufficient to reliably insert endosseous implants was often not well described. Different implant systems were used; the majority were Brånemark implants. As an anchorage system, both splinted (bar) and unsplinted (ball) designs were used. With six and more implants, the

Table 4. Outcomes in included studies

Study	Year of publication	Number of implants in study	Number of lost implants	Number of lost patients in study	Survival rate implants (%)	Survival rate overdentures (%)	Change in mean marginal bonelevel ± SD (mm)	Gingival index (mean (SD))	Bleeding index (mean (SD))	Probing depth (mm) (mean (SD))
Sanna et al.	2009	138	1	0	99.2	*	*	*	*	3.3
		16	3	0	73.5	*	*	*	*	3.6
Visser et al.	2009	252	35	0	86.1	74.4	*	*	*	*
Raghoebar et al.	2006	56	0	0	100	100	*	*	*	*
Raghoebar et al.	2005	30	1	0	96.7	100	*	*	*	*
Widbom et al.	2005	53	13	0	77	100	*	*	*	*
Payne et al.	2004	60	5	0	92	*	*	*	*	*
		57	10	1	82	*	*	*	*	*
Raghoebar et al.	2003	68	3	0	95.6	100	0.3 (0.7)	0.5 (0.7)	0.7 (0.9)	3.4 (1.3)
Ferrigno et al.	2002	114	3	*	92.2 (Milled bar)	94.7 (Milled bar)	*	*	*	*
		64	6	*	86.9 (Dolder bar)	87.5 (Dolder bar)	*	*	*	*
Fortin et al.	2002	245	7	6	97.0	100	*	*	*	*
Mericske-Stern et al.	2002	173	9	0	94.2	97.6	0.7	*	*	2.9 (0.8)
Kiener et al.	2001	173	8	0	95.5	95	*	*	*	*
Närhi et al.	2001	88	8	*	90	*	0.23	*	0.7	2.8
Rodriguez et al.	2000	*	*	*	94.6	*	*	*	*	*
		*	*	*	86.7	*	*	*	*	*
		*	*	*	81.8	*	*	*	*	*
Zitzmann & Marinello	2000a	*	*	0	*	*	*	*	*	*
Zitzmann & Marinello	2000b	71	4	0	94.4	100	0.92	54% (SD 26%)	*	*
Keller et al.	1999	70	17	2	76	77	*	*	*	*
Smedberg et al.	1999	86	14	6	83.7	75	0.97	*	4%	*
		68	10	0	85.3	100	1.29	*	6%	*
Bergendal & Engquist	1998	29	6	*	79	90	1.25	*	*	*
		18	7	*	61	88	1.0	*	*	*
Kaptein et al.	1998	162	29	0	82.1	*	*	*	*	*
Naert et al.	1998	53	6	6	88.6	85	0.5	*	0.2 (0.7)	3.6 (0.9)
Watzek et al.	1998	115	6	0	95	100	*	*	*	*
Ekfeldt et al.	1997	19	2	0	84.3	85.7	*	*	*	*
Watson et al.	1997	117	30	14	72.4	77.9	*	*	*	*
Jemt et al.	1996	117	30	14	72.4	77.9	0.8 (0.8)	*	*	*
Hutton et al.	1995	117	29	*	72.4	72.4	*	*	*	*
Jemt & Lekholm	1995	127	36	3	71.6	81.2	0.89	*	*	*
Jemt et al.	1994	32	0	0	100	100	Mesial side 0.30 (0.25) Distal side 0.34 (0.11)	*	*	*
Palmqvist et al.	1994	59	4	0	93.2	100	*	*	*	*
Smedberg et al.	1993	86	7	0	86	90	0.71	*	*	*
Johns et al.	1992	117	21	5	82.2	86.3	0.5	*	*	*
Krämer et al.	1992	66	4	*	94	100	2.45	*	*	0.21

*No (detailed) information provided.

anchorage design was splinted in all cases. With four or less implants, both designs were used. In the majority of the studies, the kind of opposing dentition was not described; other studies described that there were all kinds of opposing dentition. Only in the RCT of Payne et al. (2004), it was mentioned that all patients had a two-implant overdenture in the mandible. Table 4 gives the outcomes of the studies included.

Because of the methodological diversity of the studies, only the number of implants, anchorage design, survival of implants and the survival of the overdenture could be meaningfully combined in a meta-analysis. It was chosen to include six or more implants and four or less implants in the meta-analysis to have a clear distinction between these two groups. Statistical heterogeneity of the group with six or more implants and a bar is Cochrane's $Q = 9.77$ (df = 6), $I^2 = 38.611$. For four implants or less and a bar, it is Cochrane's $Q = 6.15$ (df = 3), $I^2 = 51.237$. For four implants or less and a ball, it is Cochrane's $Q = 4.27$ (df = 2), $I^2 = 53.167$. In Table 5 and Figs 2–4, the results of the weighted meta-analysis, expressed as event rates (ERs) per year, are presented. ERs were used to describe failures and were calculated by the ratio of the number of failures or complications (e.g. events) to the total exposure time of the construction. The exposure time was the time the implants or the overdenture was followed. Distinct ERs were calculated for both implants and dentures. In case of a failure of implants or dentures that were lost during the observation time, the time to the event was used for analysis. SR was the complement of the ER, and was calculated as SR = 1 − ER.

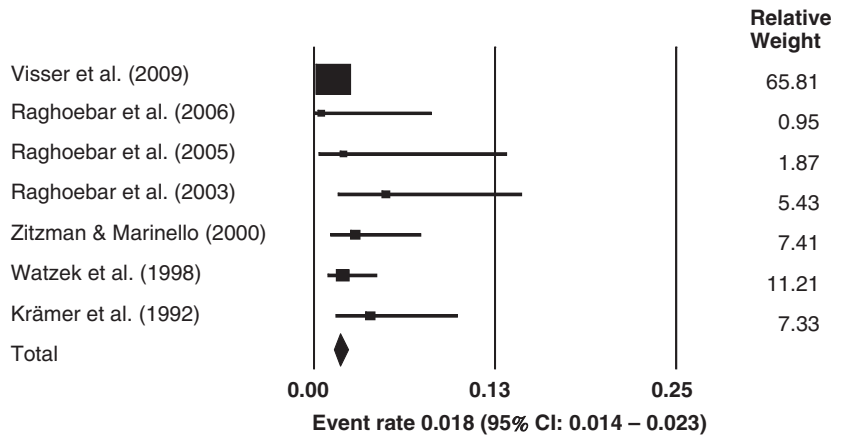

Fig. 2. Meta-analysis of implant loss in case of six implants and bar superstructure.

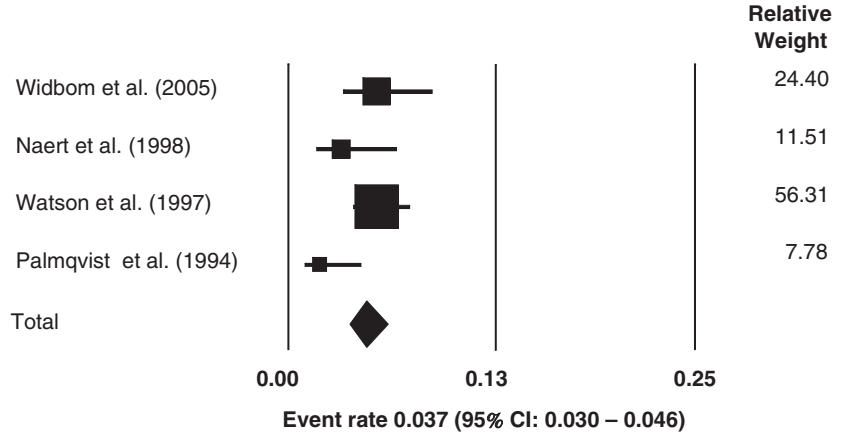

Fig. 3. Meta-analysis of implant loss in case of four implants and bar superstructure.

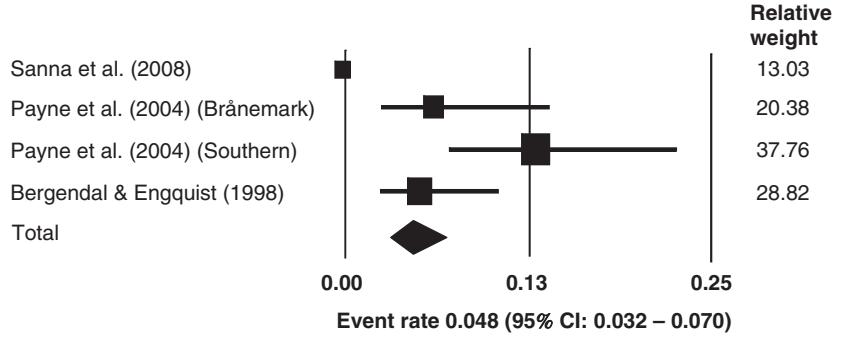

Fig. 4. Meta-analysis of implant loss in case of four implants and ball superstructure.

Survival of implants

Implant survival was defined as the percentage of implants initially placed that was still present at follow-up. In total, 3116 implants were placed in 796 patients, whereas in two studies (Rodriguez et al. 2000, Zitzmann & Marinello 2000a, b), the number of implants was not mentioned (totally 110 patients). The SR of the implants varied from 100% (Jemt et al. 1994, Raghoebar et al. 2006) to 61% (Bergendal & Engquist 1998). Results of the weighted meta-analysis of implant loss, expressed as ERs, are shown in Table 5. The ER for implant loss in case of six or more implants and a bar anchorage was 0.018, which can be expressed as a SR of 98.2% per year. The ER for implant loss in case of four or less implants and a bar anchorage was 0.037, which can be expressed as a SR of 96.3% per year. The ER for implant loss in case of four or less implants and a ball anchorage was 0.048, which can be expressed as a SR of 95.2% per year.

Survival of maxillary overdentures

Survival of maxillary overdentures was defined as the percentage of overdentures initially placed that was still present at follow-up. The SR of the overdentures varied from 100% (Krämer et al. 1992, Jemt et al. 1994, Palmqvist et al. 1994, Watzek et al. 1998, Smedberg et al. 1999, Zitzmann & Marinello 2000b, Fortin et al. 2002, Raghoebar et al. 2003, 2005, 2006, Widbom et al. 2005) to 72.4% (Hutton et al. 1995). Results of the weighted meta-analysis (for person years and for study size) of overdenture loss, expressed as ERs, are shown in Table 5. The ER for overdenture loss in case of six or more implants and a bar anchorage was 0.026, which can be expressed as a SR of 97.4% per year. The ER for overdenture loss in case of four or less implants and a bar anchorage was 0.035, which can be expressed as a SR of 96.5% per year. The ER for overdenture loss in case of four or less implants and a ball anchorage could not be calculated because only in one study, the SR of the overdentures was mentioned (Bergendal & Engquist 1998: SR overdentures 88%).

Condition of surrounding hard and soft tissues

In 14 out of the 31 studies, a change in mean marginal bone level was mentioned. Measurements were performed on either non-standardized rotational panoramic radiographs and intra-oral radiographs, or on standardized intra-oral radiographs. The loss of marginal bone varied from 0.23 mm in 27 months to 2.45 mm in 19 months. In two studies, the condition of the peri-implant mucosa was mentioned, both with a different index. In four studies, bleeding on probing was noted. Finally, in six studies, the probing depth was mentioned, varying from 0.21 mm in the study of Krämer et al. (1992) to 3.6 mm in the studies of Naert et al. (1998) and Sanna et al. (2009).

Table 5. Stratified meta-analysis of implant survival and overdenture survival

Treatment	Number of studies included	Number of patients/ implants	Mean follow-up in years	Number of implants that not survived	Calculated loss of implants per year per person (event rate; 95% CI)	Number of overdentures that not survived	Calculated loss of overdentures per year (event rate; 95% CI)
Six or more implants with a bar anchorage design	7	98/658	4.5	53	0.018 (0.014–0.023)	10	0.026 (0.015–0.044)
Six or more implants with a ball anchorage design	0	–	–	–	–	–	–
Four or less implants with a bar anchorage design	4	75/934	4.4	53	0.037 (0.030–0.046)	9	0.035 (0.022–0.069)
Four or less implants with a ball anchorage design	3	55/151	3.7	23	0.048 (0.032–0.070)	–	Not possible*

*In only one study the loss of overdentures was reported; not possible to carry out a meta-analysis.

Discussion

This systematic review assessed the outcome of implant-supported maxillary overdentures in terms of survival of implants, survival of maxillary overdentures, condition of surrounding hard and soft tissues, technical complications and patient satisfaction. ''Success'' is a better outcome measure (if the same criteria are used) than ''survival''. However, only ''survival'' has been reported in the analysed literature. Despite this shortcoming, it has been chosen to perform the analysis with the ''survival'' data. On basis of these outcome parameters, it was tried to select the treatment concept for the edentulous upper jaw with implant-supported overdentures that is in favour over other concepts published in the literature, with respect to the number of implants and the kind of attachment system. Unfortunately, we could not draw firm conclusions regarding the most preferable treatment strategy, due to a lack of controlled clinical trials and the limited number of studies suitable for the meta-analysis.

Because of different implant systems used, different number of implants placed in the maxilla to support the overdenture, different surgical procedures applied, different anchorage designs used and differences in opposing dentition, it is hard to calculate reliable figures for the survival of implants. For example the SR might be related to the type of endosseous implant placed as both implants with a machined surface (especially in the studies from the early 1990s) and implants with a roughened surface were used. Also, the number of implants used to support the maxillary overdenture could affect the SR because forces on the overdenture have to be carried by the bone surrounding the implants. With more implants, the forces are distributed on more bone. Moreover, a variety of surgical procedures was used either with or without bone grafts and/or bone substitutes. Not only the number of implants placed, but also the design of the anchorage system might affect the SR because the loading of surrounding bone is dependent on the anchorage system used. If a bar between implants is loaded, the load is mainly distributed to the bone surrounding the two neighbouring implants. In case of solitary attachments (ball attachments), the load is distributed to the surrounding bone of that one implant (Meijer et al. 1992). Finally, the kind of opposing dentition could have an effect on survival of implants because the kind of occlusion is different. With an edentulous occlusion concept, there is a balanced tooth contact and evenly distributed forces on the overdenture, while with a (partially) dentate mandible, an occlusion concept with evenly distribution of the forces on the overdenture is often not possible to achieve. This means that there is also no even distribution of forces on the bone surrounding the implants.

It is striking that there is such a wide range in SRs between studies. The study with the lowest SR used two to three implants to support the overdenture and the implants were not splinted with a bar, while studies reporting high SRs commonly used four or more implants per patient and the implants were splinted with a bar. Comparison with the SRs of implants to support an overdenture in the mandible shows much better data for the mandibular overdenture, with most studies reporting SRs of implants of 95% and higher (Feine et al. 2002). These higher rates can be addressed to the much better bone quality in the lower jaw compared with the upper jaw.

For the meta-analysis, it was chosen to include six or more implants and four or less implants to have a clear distinction between two groups. The ER for implant loss in case of six or more implants and a bar anchorage was 0.018, which can be expressed as a SR of 98.2% per year. The ER for implant loss in case of four or less implants and a bar anchorage was 0.037, which can be expressed as a SR of 96.3% per year. The ER for implant loss in case of four or less implants and a ball anchorage was 0.048, which can be expressed as a SR of 95.2% per year. It must be noted that the total number of patients is not that much in this meta-analysis. Also, the kind of implant system, surgical procedure and the kind of opposing dentition were not accounted for. In the group of six implants and more in the majority of cases, six implants were present. In the groups with four implants or less in the majority of cases four implants were present. Therefore, it was chosen to present the conclusions in terms of six implants and four implants. The SR is $>95\%$ for all three treatment options. Although there is a small difference in SRs, one could conclude that a maxillary overdenture, supported by six dental implants, which are connected with a bar, is the most successful treatment regarding survival of both the implants and overdenture. Second in line is the treatment option with four implants and a bar. The treatment option with four or less implants and a ball attachment system is the least successful.

Survival of the overdenture is a very important item for the patient. One of the implants may get lost, but as long as the overdenture functions, there is no acute problem. This is understandable from the patients view. The patient asks for help because of a denture with lack of retention and stability; as long as the overdenture functions and gives no pain,

the treatment is a success. SR of the overdentures was measured in 25 of the 30 selected studies. The SR varied from 100% to 72.4%. In 15 of the studies, the SR was 90% or more. Of course, there are more reasons to decide to make a new overdenture, but loss of implants is certainly an important one. There is a rationale that with less implants inserted, in case of loss, the overdenture is more prone to large revisions or remake than with more inserted implants. Analysing the studies, this is confirmed. There seemed to be a correlation between loss of overdentures and the number of implants per patient. The weighted meta-analysis (for person years and for study size) of overdenture loss revealed a low ER for both groups with a bar anchorage. It must be noted, however, that the total number of patients is not that much in this meta-analysis. Again, the results of the meta-analysis seem to be in favour from a perspective of cost-effectiveness to use four implants and a bar to support a maxillary overdenture.

The condition of hard tissues can be analysed with radiographs. As progressive marginal bone loss is a predictor for future implant loss, it is very important to analyse this marginal bone level in a standardized and reliable way. Changes are small and depiction of implant and surrounding bone is often very difficult. Only in the two RCTs (Bergendal & Engquist 1998, Payne et al. 2004), an attempt was made to standardize the intra-oral radiographs. In the other studies, it was not uncommon to use panoramic radiographs, while it is known that a clear depiction of bone in the (frontal part of the) maxilla is very difficult on these type of radiographs. Because of the different kind of radiographs, it was not possible to provide an overall insight in marginal bone stability or progressive bone loss. Mucosa indices, bleeding indices and pocket probing depth gave an insight into the health of the peri-implant soft tissues. In the studies covering this aspect, the soft tissues appeared relatively healthy.

Finally, because of the low number of RCTs available in the literature, a major drawback of the reviewed literature is the variety in methods used to analyse a patient population. Guidelines should be developed (perhaps through a consensus meeting), published and recommended to investigators who are involved in clinical implant-related dentistry.

Conclusion

In all three treatment options, the SR of the implants is >95%. The studies included reveal that a maxillary overdenture, supported by six dental implants, which are connected with a bar, is the most successful treatment regarding survival of both the implants and overdenture. Second in line is the treatment option with four implants and a bar. The treatment option with four or less implants and a ball attachment system is the least successful.

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Clinical Relevance

Scientific rationale for the study: Endosseous implants are frequently used to support a maxillary overdenture. It is beneficial for clinicians to know what number of implants and which design of the superstructure represents a reliable procedure.

Principal findings: In all three treatment options, the SR of the implants is >95%. The studies included reveal that a maxillary overdenture supported by six dental implants, which are connected with a bar, is the most successful treatment regarding survival of both the implants and overdenture. Second in line is the treatment option with four implants and a bar. The treatment option with four or less implants and a ball attachment system is the least successful.

Practical implications: Given the low number of patients in this meta-analysis and differences in the implant system, surgical procedure and the kind of opposing dentition, it is not wise to give a practical implication at this moment.