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Review Article

Treatment outcome of immediate, early and conventional single-tooth implants in the aesthetic zone: a systematic review to survival, bone level, soft-tissue, aesthetics and patient satisfaction

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Abstract

Aim: This study evaluated, through a systematic review of the literature, the outcome of single-implant restorations in the aesthetic zone with natural adjacent teeth, thereby addressing immediate, early and conventional implant approaches.

Material and Methods: MEDLINE (1950–2008), EMBASE (1966–2008), and CENTRAL (1800–2008) were searched to identify eligible studies. Two reviewers independently assessed the methodological quality using specific study-design-related assessment forms.

Results: Out of 86 primarily selected articles, 19 studies fulfilled the inclusion criteria. A meta-analysis showed an overall survival rate of 95.5% [95% confidence interval: (93.0–97.1)] after 1 year. A stratified meta-analysis revealed no differences in survival between immediate, early and conventional implant strategies. Little marginal peri-implant bone resorption was found together with low incidence of biological and technical complications. No significant differences in outcome measures were reported in clinical trials comparing immediate, early or conventional implant strategies.

Conclusion: The included literature suggested that promising short-term results could be achieved for immediate, early and conventional single-implants in the aesthetic zone. However, important parameters as aesthetic outcome, soft-tissue aspects, and patient satisfaction were clearly underexposed. The question whether immediate and early single-implant therapies would result in better treatment outcomes remained inconclusive due to lack of well-designed controlled clinical studies.

Key words: aesthetics; dental implants; immediate loading; immediate placement; patient satisfaction; single-tooth; soft tissue; survival; systematic review

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Conflict of interest and sources of funding statement

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The application of dental implants for single-tooth replacements has evolved into a viable prosthodontic alternative to conventional fixed bridgework, resin-bonded restorations or removable partial dentures. Long-term studies have reported excellent implant survival rates when applied for single-tooth replacements (Scheller et al. 1998, Romeo et al. 2002). Psychological benefits and

tooth structure conservation adjacent to the tooth to be replaced, are among the advantages of implant supported restorations.

In the anterior zone, the success of single-implant therapy is not only determined by high survival rates, but even more by the (long-term) quality of survival, dictated by a mixture of several factors. Preferably, the appearance of the peri-implant soft tissue should be in harmony with the mucosa around the adjacent teeth and the implant crown should be in balance with the neighbouring dentition (Meijer et al. 2005). Various implant treatment strategies have been proposed for the accomplishment of optimal aesthetics. These include approaches to rehabilitate the underlying bone structures by augmentation procedures with autologous bone and/or bone substitutes (Weber et al. 1997, Jensen et al. 2006, Pelo et al. 2007), techniques to manipulate and enhance the architecture of the peri-implant soft tissue (Zetu & Wang 2005, Esposito et al. 2007) and methods for alveolar ridge preservation following tooth extraction (Lekovic et al. 1997, Irinakis & Tabesh 2007). Furthermore, implants and abutments with specific configurations have been introduced to sustain the hard and soft tissues (Wohrle 2003, Morton et al. 2004, Lazzara & Porter 2006, Maeda et al. 2007, Noelken et al. 2007) together with provisionalization techniques to restore the soft tissue contour (Jemt 1999, Al-Harbi & Edgin 2007), and the introduction of ceramic customized abutments and ceramic implant crowns (Canullo 2007, Schneider 2008).

Traditionally, dental implants have been placed in healed extraction sites according to a two-stage surgical procedure and an undisturbed load-free period of 3–6 months. In contemporary implantology, however, installation of implants in fresh extraction sockets and reducing the load-free period by immediate restoring implants after insertion have been adopted. Besides shortening of total treatment time, fewer surgical interventions and eliminating the need for a temporary prosthesis, these immediate approaches could lead to a reduction of peri-implant crestal bone loss and a better soft tissue healing thus possibly improving the aesthetics (Esposito et al. 2006, Glauser et al. 2006, Harvey 2007). On the other hand, there are potential risk factors involved with these techniques such as enhanced possibility of infection, mismatch between socket wall and implant leading to gap creation and induction of fibrous tissue formation around the bone–implant interface caused by implant micromovement during eventful wound healing (Gapski et al. 2003, Esposito et al. 2006). These risk factors may worsen the treatment outcome. This discrepancy needs further study.

The outcome of a single-implant restoration with natural neighbouring teeth may be dissimilar to cases in which multiple adjacent teeth are replaced by dental implants, because dimensions of the hard and soft tissues between adjacent implants differ significantly from dimensions found in single-implant cases. Single-implant cases obviously take benefit of tissue support of the adjacent dentition (Grunder 2000, Kan et al. 2003b, Belser et al. 2004). When considering the heights of interimplant papillae for instance, studies indicated that these papillae might show inadequacy for complete enclosure of the interimplant area with soft-tissue, thereby failing to duplicate the interproximal soft-tissue appearance of the adjacent teeth (Tarnow et al. 1992, 2003, Lee et al. 2005). This deficiency may affect the aesthetic outcome unfavourably. The soft tissue height proximal to single-implants is on average much higher and is related to the interproximal bone level at the side of the adjacent teeth (Grunder 2000, Kan et al. 2003b). Hence, single-implant therapy may lead to more favourable treatment outcomes.

To date, several reviews have been published regarding the clinical outcome of immediate and conventional implant supported single-tooth restorations in partially edentulous patients (Creugers et al. 2000, Berglundh et al. 2002, Belser et al. 2004, Glauser et al. 2006, Jung et al. 2008). Most of these reviews have mainly converged on implant survival and addressed to a lesser degree other outcome measures that determine the quality of survival. Furthermore, none of these reviews systematically analysed the literature concerning the efficacy of single-implants in the aesthetic zone neither did these reviews concentrate explicitly on the outcome of implant restorations for replacement of the isolated missing tooth with natural neighbouring teeth. However, it is worthwhile for patients and clinicians to know whether an immediate or conventional single-tooth implant represents a predictive, reliable and effectual therapy to re-establish function and aesthetics subsequent to the loss of a single anterior tooth. Therefore, the objective of this study was to evaluate, through a systematic review of the literature, the outcome of single-tooth replacements by dental implants in the aesthetic zone in cases in which the adjacent teeth are natural, thereby focussing on immediate, early and conventional implant treatment strategies.

Material and Methods

Types of studies

Longitudinal studies [randomized-controlled trials (RCTs), clinical trials, cohort-studies and case series] were considered for evaluation. Retrospective studies were excluded. Only case series that investigated at least five patients were contemplated for inclusion. No time restrictions were implemented. Language was restricted to papers published in English, German, French, Spanish, Italian and Dutch.

Type of participants

Patients who were treated with an implant-retained single tooth replacement in the aesthetic zone neighboured with natural teeth, could be included. The aesthetic zone was defined as the region in the maxilla or mandible, ranging from second premolar to second premolar (teeth 15–25 and teeth 35–45).

Types of intervention

- Immediate implant placement: defined as implant placement immediately following extraction of a tooth.
- Early implant placement: defined as installation of the implant 4–8 weeks after extraction.
- Conventional implant placement: implant placement $\geqslant 8$ weeks post-extraction.
- Immediate loading: application of a load by means of a restoration within 48 h of implant placement.
- Early loading: application of a load by means of a restoration after 48 h but < 3 months after implant placement.
- Conventional loading: application of a load by means of a restoration $\geqslant 3$ months after implant placement (Laney 2007).

For studies to be eligible in this review, they had to evaluate endosseous root-form dental implants with a follow-up of at least 1 year after implant restoration.

Types of outcome measures

- Implant survival, defined as presence of the implant at time of follow-up examinations.
- Changes in marginal peri-implant bone level assessed on radiographs.
- Aesthetics evaluated by dental professionals.
- Aspects of the peri-implant structures, i.e. level of marginal gingiva, papilla index (Jemt 1997), probing depth, presence of plaque, bleeding on probing.
- Patient satisfaction including aesthetics.
- Biological and technical complications.

Search strategy

For this review, a thorough search of the literature was conducted in databases of MEDLINE (1950–2008 (via PUBMED) and EMBASE (1966–2008). The search was supplemented with a systematic search in the ''Cochrane Central Register of Controlled Trials'' (CENTRAL) (1800–2008). The search strategy used, was a combination of MeSH terms and free text words and is summarized in Table 1. The search was complemented by checking references of relevant review articles and eligible studies for additional useful publications. Titles and abstracts of the searches were scanned independently by two examiners. Full-text documents were obtained for all possibly relevant articles. Full-text analysis was performed for second selection by two reviewers independently against the stated inclusion criteria. In case of disagreement, consensus was reached by discussion, if necessary in consultation with a third reviewer.

Table 1. Search strategy

#1 Search ''**Dental Implants**''**[MeSH] OR** ''**Dental Implantation**''**[MeSH] OR implant***
#2 Search ''**single implant***'' **OR** ''**single tooth**'' **OR** ''**single teeth**'' **OR** ''**single crown***'' **OR** ''**single restoration***''
#3 Search **aesthetic* OR esthetic* OR anterior* OR front* OR incisor***
#4 Search **#1 AND #2 AND #3**
Run data search: June 2008

Quality assessment

Methodological quality was assessed using specific study-design related forms designed by the Dutch Cochrane Collaboration. As there was no checklist available for the assessment of the quality of case series, a quality-assessment tool was specifically developed for this review, adapted from the quality form used for clinical trials (Table 2). Two observers independently generated a score for the included articles, expressed in the number of plusses given. It was decided that studies scoring 5 or more plusses were considered to be methodological ''acceptable''.

Data extraction and synthesis

For each study the following data were extracted by two review authors independently and recorded in a data sheet:

- Number of patients, implants placed, drop-outs and follow-up time. For all included longitudinal studies of more than 1 year, follow-up time was calculated as person-years.
- Details of type of intervention.
- Details of the outcomes stated, including method of assessment.

Agreement was reached by a consensus discussion and if necessary a third reviewer was consulted. If feasible, a meta-analysis was carried out if the outcome measures could be meaningfully combined.

Statistical analysis

With respect to the quality assessment, agreement between both reviewers was calculated using Cohen's κ statistics.

For the meta-analysis the statistical software package ''Meta-analysis'' was used [Comprehensive Meta-analysis Version 2.2, Biostat, Englewood NJ (2005), www.meta-analysis.com]. For the calculation of the overall effects for the included studies, weighted rates together with random effects models were used. Stratification procedures were applied for follow-up time and type of intervention. Within each stratum, heterogeneity between included studies was checked by human eyeball criteria.

Results

Description of studies

The MEDLINE search provided 610 hits, the EMBASE search 23 hits and the CENTRAL search 27 hits. After scanning of titles and abstracts, 86 articles were selected and screened as full text articles. Reference-checking of relevant reviews and included studies revealed one additional article (Hall et al. 2006). However, this report showed to be a shortened version of a later publication (Hall et al. 2007), and did not contain any new information. A number of 41 studies did not satisfy the inclusion criteria because data of single implants in anterior and posterior zones was not presented separately or adjacent implants were also included, making it not possible to extract proper data. Furthermore, 14 studies were excluded due to improper study design (not longitudinal or not prospective) and five studies because of a follow-up <1 year. A total of 26 articles fulfilled the inclusion and exclusion criteria and were assessed methodologically. Of these 26 studies, seven studies were excluded. Reasons for exclusion are depicted in Table 3. The κ-value for inter-assessor agreement on the methodological quality

Table 2. Quality assessment of case series

Item	+	–	?
1. Are the characteristics of the study group clearly described?			
2. Is there a high risk of selection bias? Are the inclusion and exclusion criteria clearly described?			
3. Is the intervention clearly described? Are all patients treated according to the same intervention?			
4. Are the outcomes clearly described? Are adequate methods used to assess the outcome?			
5. Is blinding used to assess the outcome?			
6. Is there a sufficient follow-up?			
7. Can selective loss-to follow-up sufficiently be excluded?			
8. Are the most important confounders or prognostic factors identified and are these taken into consideration with respect to the study design and analysis?			

Five or more plusses = methodologically acceptable.

Table 3. Studies excluded after quality assessment and reasons for exclusion

Study	Study design	Reasons for exclusion
Henriksson & Jemt (2004)	Clinical trial	Heterogeneity in clinical procedure (different implants, different load-free periods), in/exclusion criteria unclear, no blinding used, prognostic factors/confounders not considered
Lorenzoni et al. (2003)	Case series	Patients not treated according to same intervention (immediate and conventional placement included), in/exclusion criteria unclear, no blinding used, prognostic factors/confounders not considered
Ferrara et al. (2006)	Case series	High risk of selection bias (implants with insufficient primary stability were excluded; method to assess stability not clear), outcomes not clearly described, methods used to assess the outcome unclear, no blinding used, prognostic factors/ confounders not considered
Grunder (2000)	Case series	Patients characteristics unclear, in/exclusion criteria unclear, no blinding used, prognostic factors/confounders not considered
Locante (2004)	Case series	Patients not treated according to same intervention (immediate and conventional placement included), high risk of selection bias (implants with insufficient primary stability were excluded; method to assess stability not clear), in/exclusion criteria unclear, no adequate methods used to assess the outcome, no blinding used, follow-up routine unclear, prognostic factors/ confounders not considered.
Groisman et al. (2003)	Case series	Patient characteristics unclear, high risk of selection bias (only favourable cases selected), method of assessment not clear, no blinding used, prognostic factors/confounders not considered, follow-up routine unclear
Barone et al. (2006)	Case series	Patient characteristics not clear, high risk of selection bias (only favourable cases selected), no blinding used, prognostic factors/ confounders not considered.

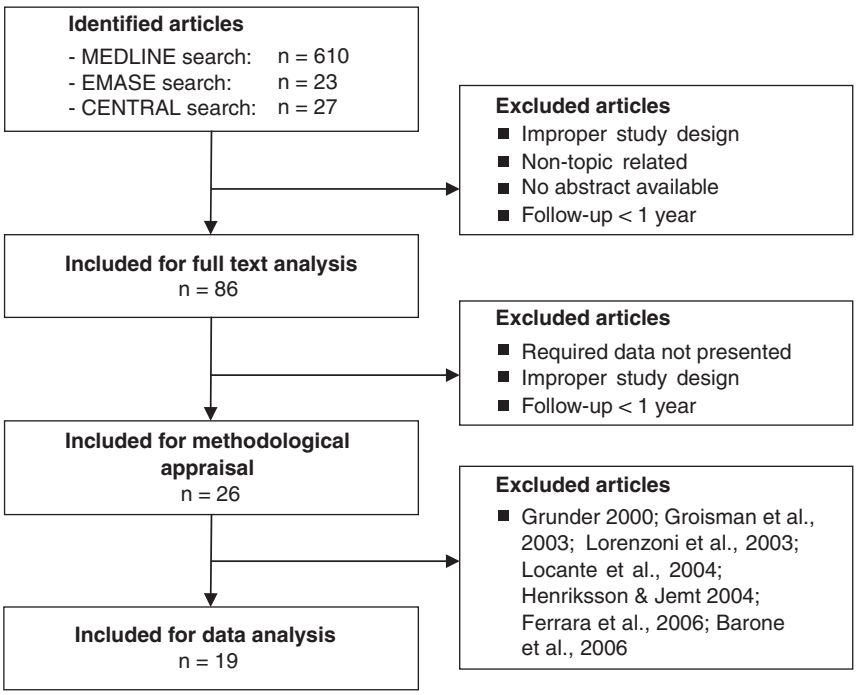

Fig. 1. Algorithm of study selection procedure.

was 0.89. Disagreements were generally caused by slight differences in interpretation and were easily resolved in a consensus meeting. Finally, 19 publications remained for data extraction. Figure 1 outlines the algorithm of the study selection procedure. Of the included studies, five were RCTs, two were clinical trials and 12 were case series. Six publications presented outcomes of the same patient population, but differed in follow-up (Palmer et al. 1997, 2000, Cooper et al. 2001, 2007, Jemt & Lekholm 2003, 2005) and results of one study group were reported in two different publications addressing different topics (Schropp et al. 2005a, b).

Most of the studies only evaluated maxillary implants, but three studies did also include implants placed in the mandible (38 implants in total) (Schropp et al. 2005a, b, Romeo et al. 2008). Furthermore, implants were installed mostly in completely healed extraction sockets or early after extraction (10 days to 4 weeks) and subsequently restored according to immediate, early (1–3 weeks after implant placement) or conventional loading protocols. Restorations that were seated immediate or early after implant placement, were all kept out of direct occlusal contact. Two studies reported on immediately restored implants placed directly after tooth extraction. All clinical trials except one compared the outcome of immediate or early implant placement and immediate or early implant loading with conventional approaches. This RCT focused on different bone augmentation procedures and all implants were placed and restored conventionally according to the same protocol (Meijndert et al. 2007). Characteristics of the included studies are presented in Table 4 and are arranged according to type of intervention and study design.

Because of the methodological diversity of the ''acceptable'' studies, only data on implant survival and to a limited degree marginal bone resorption could be meaningfully combined in a meta-analysis. Therefore, the outcomes are mainly presented as a descriptive review in the subsequent sections and are depicted in Tables 4 and 5.

Implant survival

The implant survival rate was defined as the percentage of implants that was still present at follow-up. All implants that were lost, failed within the first 6 months after installation. In some studies implant mobility was detected at second stage surgery (seven implants) (Schropp et al. 2005b, Lindeboom et al. 2006, Meijndert et al. 2007) or occurred following placement of the provisional restoration (one implant) (Cooper et al. 2001), whereas other implants were

Table 4. Study characteristics and outcomes of included studies, arranged according to type of intervention and study design

Study	Intervention	Design		No. of patients/ implants	Implant system	Reason(s) for tooth loss (no.)	Follow-up period (years)	No. of implant drop-outs**	Survival rate (%)	Change in marginal bone level ± SD (mm)
Kan et al. (2003a)	Immediate placement and immediate loading	CS		35/35	Replace Select	Fracture (15), endodontic failure (12), root resorption (8)	1	0	100	$-0.24 \pm 0.35^{*,\dagger}$
De Rouck et al. (2008)	Immediate placement and immediate loading	CS		30/30	Replace Select	Fracture (10), caries/endodontic (9), periodontal (7), root resorption (4)	1	1	97	$-0.88 \pm 0.52^{*,\dagger}$
Lindeboom et al. (2006)	Immediate placement *versus* conventional placement	RCT	T C	25/25 25/25	Frialit-2	NR	1	2 0	92 100	$-0.51 \pm 0.12^{*,\dagger}$ $-0.52 \pm 0.15^{*,\dagger}$
Schropp et al. (2005a)	Early placement *versus* conventional placement	RCT	T C	23/23 22/22	3i	Root fracture (NR), endodontic failure (NR), periodontitis (NR), advanced caries lesions (NR)	2	NR	NR	NR
Schropp et al. (2005b)	Early placement *versus* conventional placement	RCT	T C	23/23 23/23	3i	Root fracture (NR), endodontic failure (NR), periodontitis (NR), advanced caries lesions (NR)	2	3 2	91 96	$-0.8 \pm$ NR‡ $-0.7 \pm$ NR‡
Gotfredsen (2004)	Early placement *versus* conventional placement	CT	T C	10/10 10/10	Astra Tech	Root fracture (15), agenesis (3), trauma (2)	5	0 0	100 100	$-0.34 \pm 0.57^{\|}$ $-0.26 \pm 0.38^{\|}$
Romeo et al. (2008)	Immediate placement	CS		48/48	ITI	Caries/endodontic with root or crown fracture (NR)	1	0	100	NR
Hall et al. (2007)	Immediate loading *versus* conventional loading	RCT	T C	14/14 14/14	Southern Implants	NR	1	1 2	93 100	$-0.63 \pm 1.00^{\|}$ $-0.78 \pm 1.01^{\|}$

Table 4. (Contd.)

Study	Intervention	Design		No. of patients/ implants	Implant system	Reason(s) for tooth loss (no.)	Follow-up period (years)	No. of implant drop-outs**	Survival rate (%)	Change in marginal bone level ± SD (mm)
Ericsson et al. (2000)	Immediate loading *versus* conventional loading	CT	T	14/14	Brånemark	NR	1.5	2	85.7	−0.14 ± 0.36‖
			C	8/8				0	100	−0.07 ± 0.79‖
Cooper et al. (2001)	Early loading	CS		48/54	Astra Tech	NR	1	3	94.4	−0.4 ± NR§
Cooper et al. (2007)	Early loading	CS		48/54	Astra Tech	NR	3	11	94.4	−0.42 ± 0.59§
Andersen et al. (2002)	Early loading	CS		8/8	ITI	NR	5	0	100	+0.53 ± NR§
Meijndert et al. (2007)	Conventional	RCT		93/93	ITI	NR	1	2	97.8	NR
Jemt & Lekholm (2003)	Conventional	CS		10/10	Brånemark	Trauma (10)	3	1	100	−0.3 ± 0.36‖
Jemt & Lekholm (2005)	Conventional	CS		10/10	Brånemark	Trauma (10)	6	2	100	−0.3 ± 0.24‖
Zarone et al. (2006)	Conventional	CS		30/34	ITI	Agenesis (30)	2–3.2	1	100	−1.2 ± 0.61§
Palmer et al. (1997)	Conventional	CS		15/15	Astra Tech	NR	2	1	100	+0.01 ± 0.50*,‖
Palmer et al. (2000)	Conventional	CS		15/15	Astra Tech	NR	5	1	100	+0.12 ± 0.49*,‖
Cardaropoli et al. (2006)	Conventional	CS		16/16	Brånemark	NR	1	5	100	−1.6 ± 0.57*,‡

*SD calculated.
**Defined as implants that did not survive and implants lost to follow-up.
†From implant placement.
‡From healing abutment placement.
§From temporary crown placement.
‖From definitive crown placement.
RCT, randomized controlled trial; CT, clinical trial; CS, case series. T, test group; C, control group; NR, not reported.

Table 5. Outcomes of included studies, arranged according to type of intervention and study design

Study		Aesthetics (range)	Patient satisfaction (range)	Papilla index	Level of marginal gingiva ± SD (mm)	Probing depth ± SD (mm)	Presence of plaque	Bleeding on probing	Complications
Kan et al. (2003a)		NR	9.9 (9–10)	NR	$-0.55 \pm 0.53^{\dagger}$	NR	26%	NR	4 fistula, 2 temporary abutments loosened
De Rouck et al. (2008)		NR	9.3 (8.2–10)	NR	$-0.53 \pm 0.76^{\dagger}$	3.46 ± 0.69	17%	41%	1 crown loosened
Lindeboom et al. (2006)	T	NR	NR	22% score 2, 78% score 3	61% proper level	NR	NR	NR	NR
	C			28% score 2, 72% score 3	84% proper level				
Schropp et al. (2005a)	T	NR	NR	resp. 8%, 35%, 57% score 0, 1, 2*	83% proper level	NR	NR	NR	NR
	C			resp. 3%, 34%, 63% score 0, 1, 2*	50% proper level				
Schropp et al. (2005b)	T	NR	NR	NR	NR	$4.2 \pm 1.4^{\#}$	NR	NR	1 fistula, exposure of metal margins in 4 cases
	C					$4.1 \pm 1.1^{\#}$			
Gotfredsen (2004)	T	5.9 (2.9–9.5)	9.6 (7.1–10)**	NR	$-0.3 \pm 0.5^{\S}$	NR	21% (pooled data)	38% (pooled data)	2 soft tissue dehiscences, 1 fistula, 2 abutments loosened
	C	8.4 (6.1–9.7)	9.1 (5.1–10)**		$+0.3 \pm 0.6^{\S}$				
Romeo et al. (2008)		NR	NR	67% score 3*	NR	NR	NR	NR	No complications
Hall et al. (2007)	T	NR	NR	resp. 18%, 51%, 31% score 1, 2, 3 (pooled data) No sign. diffs.	$-0.67 \pm 0.49^{\ddagger}$	No sign. diffs.	No sign. diffs.	No sign. diffs.	1 temporary crown fractured
	C				$-0.33 \pm 0.78^{\ddagger}$				
Ericsson et al. (2000)	T	NR	All patients satisfied	NR	NR	NR	25%	17%	1 temporary crown loosened twice
	C		All patients satisfied				25%	25%	
Cooper et al. (2001)		NR	NR	NR	$+0.34 \pm 0.94^{\ddagger}$	NR	0.5% of sites examined	NR	1 adjacent tooth migrated, 1 peri-implant mucositis, 1 implant discomfort, 3 crowns loosened; 4 fractured

Table 5. (Contd.)

Study	Aesthetics (range)	Patient satisfaction (range)	Papilla index	Level of marginal gingiva ± SD (mm)	Probing depth ± SD (mm)	Presence of plaque	Bleeding on probing	Complications
Cooper et al. (2007)	NR	NR	NR	+0.51 ± 1.42[‡]	NR	NR	NR	See above. No new complications reported
Andersen et al. (2002)	NR	NR	NR	NR	NR	NR	NR	1 fistula, 3 crowns loosened
Meijndert et al. (2007)	66% acceptable	8.5 (6–10)	NR	NR	NR	NR	NR	NR
Jemt & Lekholm (2003)	NR	NR	50% score 2, 50% score 3	NR	NR	NR	NR	No complications
Jemt & Lekholm (2005)	NR	NR	NR	− 0.1 ± NR[§]	NR	NR	NR	No complications
Zarone (2006)	3% not satisfactory	NR	resp. 6%, 12%, 82% score 1, 2, 3	− 0.6 ± NR[‡]	2.6 ± 0.2[#]	18%	No bleeding	No implant-related complications
Palmer et al. (1997)	NR	NR	NR	No recession	NR	NR	No bleeding	No soft tissue complications, 1 crown loosened, 1 porcelain fracture
Palmer et al. (2000)	NR	NR	NR	No recession	NR	NR	Rare	See above. No new complications reported
Cardaropoli et al. (2006)	NR	NR	resp. 14%, 68%, 18% score 1, 2, 3	− 0.6 ± 0.7[§]	2.4 ± 0.8	NR	9%	NR

[*]Modification of papilla index.
[**]Mean VAS-scores for aesthetic appearance and general function.
[#]SD calculated.
[†]From implant placement.
[‡]From temporary crown placement.
[§]From definitive crown placement.
T, test group; C, control group; NR, not reported.

already in function when they appeared not to be osseointegrated and subsequently were removed (six implants) (Ericsson et al. 2000, Cooper et al. 2001, Hall et al. 2006, De Rouck et al. 2008). Altogether, a total number of 509 single tooth implants was originally installed in 499 patients of which 13 patients and 13 implants were lost to follow-up and no information on survival was available regarding these implants. A total of 14 implants did not survive.

Because it is generally known that implant loss is most often observed early after implant installation and/or implant restoration, event rates and survival rates were calculated in a stratified manner. To that end, results are presented for implants that were followed up to 1 year after implant restoration (including implants that were lost before restoration and consequently were not yet in function) and implants with an observation period of more than 1 year after restoration (with a correction for implants that were lost within the first year after restoration). Results of the weighted meta-analysis (for study size) of implant loss within 1 year, expressed as event rates, are shown in Fig. 2. The overall event rate was calculated as 0.045 [95% confidence interval (CI): (0.029–0.070)] and can be expressed as a survival rate of 95.5% [95% CI: (93.0–97.1)]. The weighted meta-analysis (for person-years and study-size) regarding loss of implants that are more than 1 year in function, showed an event rate of 0.007 [95% CI: (0.003–0.019)].

Globally four different treatment strategies could be identified. In this matter, survival outcomes of immediate and early placed implants that were restored conventionally were combined as well as implants that were installed conventionally but were restored immediately or early. Results of the weighted (for study-size) stratified meta-analysis are presented in Table 6, revealing no differences in survival rate after 1-year follow-up. Focussing on the studies individually, no statistically significant differences in implant survival were found in clinical trials comparing immediate or early implant procedures with conventional ones.

Marginal bone level changes

All articles except three reported on changes in marginal peri-implant bone levels determined radiographically. Most of the studies used intra-oral radio-

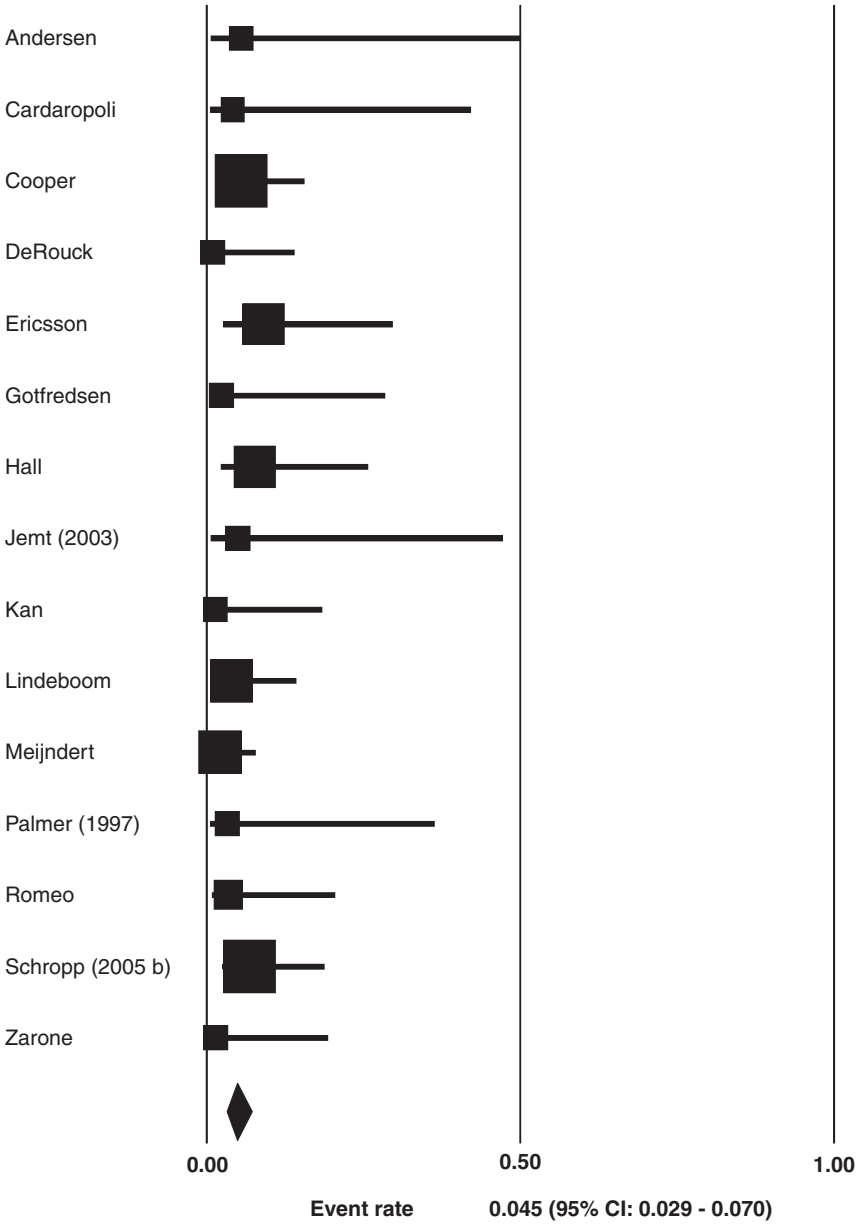

Fig. 2. Meta-analysis of implant loss within 1 year after restoration.

Table 6. Stratified meta-analysis of implant survival after 1 year

Intervention	No. of patients/ implants	No. of studies included	No. of implants lost to follow-up*	No. of implants that not survived	Calculated survival rate (%) [95% CI]
Immediate placement and immediate loading	65/65	2	1	1	97.5 [88.3–99.5]
Immediate/early placement, conventional loading	106/106	4	1	4	93.6 [85.4–97.3]
Conventional placement, immediate/early loading	84/90	4	0	6	92.4 [84.4–96.4]
Conventional placement, conventional loading	244/248	11	11	3	92.8 [82.7–97.2]

*These implants were not included in the analysis.

graphs obtained according to a standardized paralleling technique, although it was questionable whether Cooper et al. (2001, 2007), Jemt & Lekholm (2003, 2005), Palmer et al. (1997, 2000) and Gotfredsen (2004) used standardized radiography for their measurements. There was variety in the peri-implant bone level evaluation over time because studies used different starting points for their analysis. In the various studies, the first radiographic examinations had been performed just after implant placement, after healing abutment connection, at temporary crown placement or at definitive crown placement. Because of this heterogeneity, it was not possible to perform an analysis from which conclusions could be drawn concerning differences in marginal bone changes between the several treatment strategies. However, some insight could be gained into crestal bone changes occurring from definitive crown placement to 1 year thereafter in patients treated conventionally. The five studies included for this weighted (for study-size) meta-analysis (viz. Palmer et al. 1997, Ericsson et al. 2000, Gotfredsen 2004, Jemt & Lekholm 2005, Cardaropoli et al. 2006) (in total 52 implants) revealed a mean marginal bone loss of 0.20 mm [95% CI: (0.034–0.36)] during the first year after installation of the definitive crown (see Fig. 3). Data from radiographic examinations were mostly presented as mean values and consequently no frequency distributions were given. Cooper et al. (2001) considered the incidence of cortical bone loss of 48 implants 1 year after insertion. The latter authors found that after 1 year eight implants showed a cortical bone loss of 1.0–2.0 mm and three implants even more than 2.0 mm. Finally, the bone level changes detected in the experimental and conventional study groups of the included clinical trials revealed not significantly different.

Aesthetics

Albeit all implants reviewed were inserted in the aesthetic zone, only three studies included the aesthetics of the implant-supported single-tooth replacements in their analysis. Zarone et al. (2006) considered one implant not being satisfactory because of exposure of the titanium neck. It was, however, unclear how the aesthetics were measured. At the 3-year control visit Gotfredsen (2004) asked an independent dentist to evaluate the aesthetic appearance of the single implant crowns using a visual analog scale (VAS) ranging from ''very unsatisfied'' (score 0) to ''very satisfied'' (score 10). In the study by Meijndert et al. (2007), a prosthodontist rated the aesthetics on colour photographs using an objective rating index. It appeared that 34% of the cases were judged as poor aesthetics.

Peri-implant structures

To evaluate the quantity of the interproximal gingival papillae, some studies made use of the papilla index according to Jemt (1997) or a slight modification of this classification (Schropp et al. 2005a, Romeo et al. 2008). It revealed that in these studies an increase of tissue volume in the embrasures could be observed during follow-up. For instance, Jemt & Lekholm (2003) found a mean papilla index of 1.1 at crown placement (score 1 and 2 denote, respectively, less than half of the height and at least half of the height of the proximal area filled by soft tissue) while at 2 year follow-up a mean score of 2.4 was found (score 3: complete closure of proximal space with soft tissue). The majority of the papillae analysed were associated with papilla index scores of 2 or 3 after follow-up, but no significant differences were observed between the different test and control groups.

With respect to the level of marginal peri-implant mucosa, Schropp et al. (2005a) reported that the clinical crown height was acceptable in significantly more cases in the early placement group than in the conventional group at follow-up; of the latter almost two-thirds of the crowns were assessed to be too short. The same difference was found by Gotfredsen (2004), although not reported as significant. Lindeboom et al. (2007) observed that gingival recession was more prominent in the immediately-placed implant group, but the sample size was too small to demonstrate a significant difference. Hall et al. (2007) found no statistical significant differences between immediately or conventionally restored implants. Jemt & Lekholm (2005) reported that implant crowns were on average 0.7 mm longer than the contralateral natural crowns after 5-year follow-up. The same value was recorded by Gotfredsen (2004) after 5-year and he found that 17 of the 20 implant crowns were too long. The studies by De Rouck et al. (2008) and Kan et al. (2003a) measured the levels of the midfacial gingival level before tooth removal and after immediate implant placement and restoration. After 1 year follow-up, both studies reported a significant soft tissue loss of respectively 0.53 and 0.55 mm at the midfacial aspect.

Only a few studies recorded peri-implant probing pocket depths. Schropp et al. (2005b) observed a mean reduction in probing depth of 0.5 mm during the 2-year observation period to a mean probing depth of 4.2 mm. The mean probing depths presented by other studies were clearly lower. Studies that assessed the presence of plaque on the surfaces of the implant restoration showed high variance in outcome from 0.5% to 61% of sites examined. According to bleeding on probing, the same phenomenon could be observed.

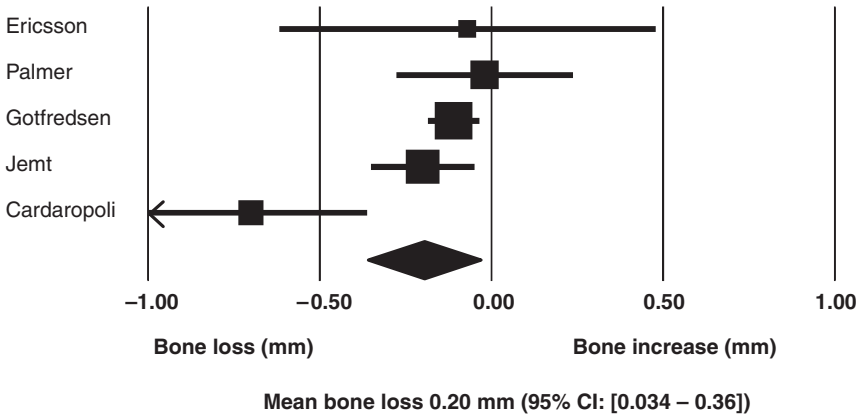

Fig. 3. Meta-analysis of marginal bone level changes 1 year after installation of the definitive crown.

Patient satisfaction

Four studies assessed patient satisfaction regarding the final aesthetics and one study (Gotfredsen 2004) also evaluated the general functioning of the

implant restoration. High satisfaction scores were reported. Three studies (Gotfredsen 2004, Meijndert et al. 2007, De Rouck et al. 2008) made use of a VAS (range 0–10), one study (Kan et al. 2003a) of a scale ranging from very unsatisfied (score 0) to very satisfied (score 10), and in one study (Ericsson et al. 2000) patients were asked about their satisfaction with the aesthetic outcome.

Complications

The complications described in the various articles were subdivided in biological and technical ones. With respect to biological complications, the authors reported on fistula formations, peri-implant mucositis and soft tissue dehiscences. All fistula subsided after placement of the definitive restoration (Andersen et al. 2002, Kan et al. 2003a) or after non-invasive therapy (Gotfredsen 2004, Schropp et al. 2005b). In the study by Schropp et al. (2005b) exposure of metal margins was found in four patients. In three cases, the margin became exposed during the observation period because of soft-tissue recession. In one case, the metal margin of the crown was present just after crown placement, but became covered with peri-implant mucosa during function.

Technical complications that were notified were loosening of (temporary) abutments and loosening or fractures of (temporary) crowns. In most of the cases, abutments could be retightened and crowns could be recemented easily. In the study by Andersen et al. (2002) three out of eight definitive crowns loosened after approximately 1 year. In two of these cases, this was a direct result of a new trauma.

It could be noticed that not all studies provided data regarding complications other than implant loss and crestal bone resorption. Concerning the comparative studies, only Gotfredsen (2004) found more complications in the experimental ''early placement'' study group. However, these implants were restored with standard abutments, while preparable abutments were used for the conventional implants and the author believed that the technical complications were probably more related to this difference.

Discussion

This systematic review assessed the outcome of implant-supported single-tooth replacements in terms of implant survival, crestal bone changes, aesthetics, soft-tissue aspects, patient satisfaction and complications. Aside from the traditional approaches of implant installation and restoration, more progressive treatment strategies of immediate or early implant placement and immediate or early loading were considered for evaluation. Unfortunately, we could not draw firm conclusions regarding the most preferable treatment strategy, owing to the lack of controlled clinical trials. Notwithstanding these limitations, promising results were reported for immediate, early and conventional single-implant procedures in the aesthetic zone.

The implant survival meta-analysis on implants in the aesthetic zone up to 1 year after implant restoration, revealed an overall survival rate of 95.5% [95% CI: (93.0–97.1)] irrespective of the type of intervention. It should be stated that, with respect to the loss of implants that are more than 1 year in function, a very low event rate was calculated as 0.007 [95% CI: (0.003–0.019)]. In general, late implant losses are attributed to fracture of the implant, overload and peri-implantitis in particular (Quirynen et al. 2007). In reference to the last, the strict in- and exclusion criteria implemented in most of the included trials such as good oral hygiene, uncontrolled periodontal disease or smoking concomitant with close follow-up routines, could limit the development of peri-implantitis and thereupon late implant failure. Of course, in this view, the relative short follow-up periods of the included studies have to be taken into account.

The high implant survival rate (95.5% after 1 year) reported in the present review, are in line with other reviews reporting on survival rates of single-implants (Creugers et al. 2000, Berglundh et al. 2002, Jung et al. 2008). However, the last two reviews only included studies with follow-up periods of at least 5 year, justifying that a comparison with our calculated survival rate should only be made with caution. Furthermore, these reviews aggregated implant survival of diverging indications, including anterior and posterior, and maxillary and mandibular single-tooth replacements. Particularly the posterior maxilla constitutes an area of challenge due to the presence of the maxillary sinus and the low bone density frequently found here. Long-term implant survival studies have even indicated that the posterior maxilla presents the lowest survival rate (Graziani et al. 2004). Apparently, this does not count for the survival of maxillary anterior single implants. The more progressive protocols, where implants are immediately installed in fresh extraction sockets or immediately loaded, scored comparable survival percentages as the conventional protocol of installation and restoration. Although no differences were noted neither in the stratified meta-analysis nor in the included clinical trials, these results should only be conceived as a tendency, because these were based on only a few RCTs and a low number of patients.

Two studies were included investigating the most escalating approach, viz. immediately loading of immediately placed implants. All implants integrated successfully. In these case series only patients were enrolled satisfying strict inclusion and exclusion criteria like presence of adequate bone volume without the necessity of bone grafting, an intact labial bony plate after tooth extraction, complementary soft tissue dimensions and ability to achieve good implant stability. It implies that this modality should be implemented with caution and should be preceded by careful patient selection and treatment planning. The same hold true for immediate or early implant loading of implants placed in healed sites. Studies investigating this approach, pointed out the importance of good initial implant stability before loading and all temporary crowns were cleared from occlusion.

It was only possible to combine the outcome measures of implant survival and to a limited degree crestal bone changes in a stratified meta-analysis. Reasons were that different outcomes or time points were used or some variables were not taken into consideration. With reference to the clinical trials, for only one outcome measure a significant difference was observed. Schropp et al. (2005a) reported that the level of the marginal peri-implant mucosa was acceptable in significantly more cases where implants were installed in early healed extraction sites compared with conventionally healed sites; of the latter almost two thirds of the crowns were assessed to be too short. All other clinical trials failed to show any significant differences.

Remarkably, only three studies assessed the aesthetic outcome of which

only one study made use of an objective aesthetic index. The lack of documentation of well-defined aesthetic parameters in anterior implant research was demonstrated earlier by Belser et al. (2004). Nowadays, two instruments are available that aim to objectify the aesthetic outcome of single-tooth implant crowns, namely the Implant Crown Aesthetic Index to measure the aesthetics of crown and mucosa (Meijer et al. 2005) and the Pink Esthetic Score (Furhauser et al. 2005) which focuses on soft tissue solely. It was concluded that both indexes showed reproduciblity, based on calculations of intra- and interobserver agreement. However, the validity of these indexes was not investigated and although they show good face validity, the construct validity in particular needs further research. Because these indexes were developed fairly recently, this could be a prominent reason that only Meijndert et al. (2007) used the Implant Crown Aesthetic Index, apart from the fact that the latter authors introduced this index (Meijer et al. 2005). Meijndert et al. (2007) reported that in 34% of the cases, the aesthetics were not acceptable, which is a rather high percentage. It must be noted, however, that in all cases a local bone augmentation procedure was needed before implantation because of severe bone deficiencies. This implies again the significance of the aesthetic appearance before implant treatment and that the final aesthetics might be strongly related to that appearance. To illustrate, when the starting point is favourable, favourable aesthetics could be expected from an implant based single-tooth replacement, both from the patients' and professionals' perspectives, while an unfavourable starting point might lead to satisfactory results from the patients' perspective while the professionals objective judgement might be unfavourable. This incongruity might lead easily to bias in aesthetic implant research.

It is widely accepted that RCTs provide ''gold standard'' evidence of the effectiveness of therapies. However, there is scarcity of existing RCTs in implant research, probably caused by medical–ethical reasons, costs or workload involved in this type of research. Nevertheless, relevant information is not exclusively provided by RCTs for matters of longevity. Cohort-studies, case series and clinical trials could also provide valuable longitudinal information. Therefore, these types of studies were considered for evaluation too. It appeared that seven eligible comparative trials could be included, of which four studies examined immediate or early implant placement, two studies immediate implant loading and one study focussed on different bone augmentation procedures before implantation. Sample sizes were relatively small and presumably underpowered to demonstrate significant differences between experimental and conventional single-implant approaches. Furthermore, not all clinical trials randomly allocated patients to the study groups and for three trials it was unclear if the outcome assessors were blinded. Probably, some trials were confounded by the type of prosthetic restoration as Schropp et al. (2005b) and Gotfredsen (2004) made use of different types of abutments and Ericsson et al. (2000) reported that ceramic or metal–ceramic crowns were utilized. Probably, these variances could have their influence on parameters like the aesthetic outcome and patient satisfaction.

The remaining studies included for this review, could be classified as case series and as a consequence were of a lower level of evidence. Although these studies were well documented and methodological acceptable within their framework, results of these studies should be interpreted with caution. Selection and measurement bias will always be present in case series, together with a potential risk of incorporation bias, favouring the final outcome of the intervention. Moreover, for most of the case series it was not reported or unclear whether consecutive recruitment was used. Non-consecutive enrolment may lead to selection of patients with more favourable preoperative conditions.

Besides the low number of RCTs and small study groups, one of the major drawbacks of the reviewed literature was the lack of sufficient follow-up. Eight of the included studies followed their patients for only 1 year. It is noteworthy that, on the other hand, only a small number of patients were lost to follow-up. In our opinion, the follow-up periods were too short to lead to definitive conclusions as to whether a single-implant in the aesthetic zone is a reliable therapy over the long term. However, because there is sufficient evidence in present implantology that implant losses predominately occur within the first months after placement, the favourable short-term survival rates of single-implant replacements in the anterior zone might justify the expectations of a successful long-term survival. For other parameters including aspects of the peri-implant mucosa, aesthetic outcome and patient satisfaction, more long-term research is needed, such as cohort studies.

In conclusion, evidence from the included literature suggested that an implant-supported single-tooth replacement in the aesthetic zone with natural adjacent teeth would lead to (short-term) successful treatment outcomes regarding implant survival, marginal bone level changes and incidence of biological and technical complications. However, with reference to quality of study design, number of patients included and follow-up duration, the included studies showed inadequacies. Moreover, other parameters of utmost importance as the aesthetic outcome, soft-tissue aspects, and patient satisfaction were clearly underexposed. The question whether immediate and early implant placement or immediate and early implant loading would result in comparable – or even better – treatment outcomes than conventional implant protocols of installation and restoration, remains inconclusive. Thus, more well-designed (randomized) comparative trials are needed investigating objective aesthetic and satisfaction parameters in particular, to verify these treatment strategies.

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Clinical Relevance

Scientific rationale for the study: Immediate, early and conventional single-implant therapy are applied to restore a lost anterior tooth. It is beneficial for patients and clinicians to know whether this therapy represents a reliable procedure to re-establish function and aesthetics in this region.

Principal findings: Anterior single-implants show favourable short-term outcomes regarding survival, complications and crestal bone loss.

Practical implications: Application of anterior single-implants has been shown to be reliable in the short-term, but regarding aesthetics and patient satisfaction, more research is needed. The same applies for the choice of strategy: immediate, early or conventional.