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The Role of Implant Surface Modifications, Shape and Material on the Success of Osseointegrated Dental Implants. A Cochrane Systematic Review

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Abstract - *We tested the hypothesis of no difference in implant failures between various dental implant types. We searched for all randomised clinical trials comparing different implant types/systems with a follow up of at least one year on four databases. Screening of eligible trials, quality assessment and data extraction were conducted in duplicate. Thirty-one trials were identified. Twelve trials, reporting results of 512 patients, were included. No significant differences were observed for implant failures. There were minor statistically significant differences for peri-implant bone level changes. Turned surfaces had a 20% reduction in risk of being affected by perimplantitis over a 3-year period.*

KEY WORDS: Metanalysis, Dental implants, Randomised controlled clinical trial

INTRODUCTION

Many different dental implant systems are currently available on the market. It has been estimated that dentists have to choose from more than 1300 types of implants that vary in form, material, dimension, surface properties and interface geometry[1]. In particular, the area of implant surface modifications has been subjected to aggressive marketing aimed at establishing the superiority of a given surface over the others. Numerous surface modifications including turned, blasted, acid-etched, porous-sintered, oxidized, plasma-sprayed, hydroxyapatite coated surfaces, or a combination of these procedures have been developed and are currently used with the aim of enhancing clinical performances. It is therefore important to know whether there are implant systems providing improved clinical results. Since it is difficult to determine the effectiveness and potential harms of various implant systems, it is important to condense the most reliable information in a systematic way, limiting bias[2,3].

The aim of this systematic review was to assess whether there are differences in implant failures among various root-formed osseointegrated dental implants. We were also interested to investigate whether there could be differences in the frequency of early failures and perimplantitis between implant systems having turned (machined) surfaces when compared to implants with roughened surfaces.

Primary objectives

To test the null hypothesis of no difference in clinical performance between various root-formed osseointegrated dental implant types for replacing missing teeth against the alternative of a difference, and in particular that:

(1) There is no difference between implants with different surface preparations, but having similar shape and material.
(2) There is no difference between implants with different shapes, but having similar surface preparation and material.
(3) There is no difference between implants made of different materials, but having similar surface preparation and shape.
(4) There is no difference between various implant types differing in surface preparation and/or shape and/or material.

Secondary objectives

(1) To test the null hypothesis of no difference in the occurrence of early failures between turned and roughened dental implants.
(2) To test the null hypothesis of no difference in the occurrence of perimplantitis between turned and roughened dental implants after three and five years in function.

MATERIALS AND METHODS

To minimise bias[2,3] only randomised clinical trials (RCTs) comparing different implant systems with a follow-up of at least one year in function were included.

Primary outcome measure was implant failure defined as: Implant mobility or removal of stable implants dictated by progressive marginal bone loss or infection (biological failures). Biological failures were divided in early (failure to establish osseointegration) and late failures (failure to maintain the established osseointegration). Failures that occurred before prosthesis placement or, in the case of immediate or early loaded implants soon after (weeks or a few months) the delivery of the pros-

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Table 1. *Search strategy developed for MEDLINE (OVID) and revised appropriately for each searched database*

1. exp Dental Implants/
2. exp Dental Implantation/ or dental implantation
3. exp Dental Prosthesis, Implant-Supported/
4. ((osseointegrated adj implant$) and (dental or oral))
5. dental implant$
6. (implant$ adj5 dent$)
7. (((overdenture$ or crown$ or bridge$ or prosthesis or restoration$) adj5 (Dental or oral)) and implant$)
8. "implant supported dental prosthesis"
9. ("blade implant$" and (dental or oral))
10. ((endosseous adj5 implant$) and (dental or oral))
11. ((dental or oral) adj5 implant$)
12. OR/1-11

The above search was run with phases 1 & 2 of the Cochrane Sensitive Search Strategy for RCTs as published in Appendix 5b2 of the Cochrane Handbook[3]. http://www.cochrane.org/resources/handbook/hbook.htm #4548] and amended by the Cochrane Oral Health Group as follows:

1. RANDOMIZED CONTROLLED TRIAL.pt.
2. CONTROLLED CLINICAL TRIAL.pt.
3. RANDOMIZED CONTROLLED TRIALS.sh.
4. RANDOM ALLOCATION.sh.
5. DOUBLE BLIND METHOD.sh.
6. SINGLE BLIND METHOD.sh.
7. CROSS-OVER STUDIES.sh.
8. MULTICENTER STUDIES.sh.
9. ("multicentre stud$" or "multicentre trial$" or "multicenter stud$" or "multicenter trial$" or "multi-centre stud$" or "multi-centre trial$" or "multi-center stud$" or "multi-center trial$" or "multi-site trial$" or "multi-site stud$").ti,ab.
10. MULTICENTER STUDY.pt.
11. latin square.ti,ab.
12. (crossover or cross-over).ti,ab.
13. (split adj (mouth or plot)).ti,ab.
14. or/1-13
15. (ANIMALS not HUMAN).sh.
16. 14 not 15
17. CLINICAL TRIAL.pt.
18. exp CLINICAL TRIALS/
19. (clin$ adj25 trial$).ti,ab.
20. ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).ti,ab.
21. PLACEBOS.sh.
22. placebo$.ti,ab.
23. random$.ti,ab.
24. RESEARCH DESIGN.sh.
25. or/17–24
26. 25 not 15
27. 26 not 9
28. 16 or 27

thesis, were considered early failures. Implant mobility could be assessed manually or with instruments such as Periotest or resonance frequency (Osstell). Implant fracture and other mechanical complications not allowing use of the implants (mechanical failures).

Secondary outcome measures were: Radiographic marginal bone level changes on intraoral radiographs taken with a paralleling technique. Occurrence of perimplantitis defined as an implant affected by progressive marginal bone loss with signs of infection.

Search strategy for identification of studies

For the identification of studies to be included or considered for this review, we developed detailed search strategies for each database to be searched. These were based on the search strategy developed for MEDLINE (OVID) but revised appropriately for each database. The search strategy used a combination of controlled vocabulary and free text terms as presented in *Table 1*. The following database were searched:

1) The Cochrane Oral Health Group's Trials Register (to 26 January 2004)
2) The Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library Issue 1, 2004)
3) MEDLINE (1966 to 28 June 2004)
4) EMBASE (1980 to 2 February 2004)

The most recent electronic search was undertaken on 28 June 2004. We checked the bibliographies of all identified RCTs and relevant review articles for studies outside the handsearched journals. There were no language restrictions.

We wrote to all the authors of the identified RCTs, to more than 55 oral implant manufacturers; we used personal contacts and we asked on an internet discussion group (implantology@yahoogroups.com) in an attempt to identify unpublished or ongoing RCTs.

The following journals have been identified as being important to be handsearched for this review: *British Journal of Oral and Maxillofacial Surgery*, *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *Implant Dentistry*, *International Journal of Oral and Maxillofacial Implants*, *International Journal of Oral and Maxillofacial Surgery*, *International Journal*

Table 2. *Results of quality assessment after correspondence with the authors*

Study ID	*Allocation*	*Blinding of assessor*	*Clear explanation of withdrawals*	*Risk of bias*
Kemppainen[8]	Unclear	Not possible in part	Yes	High
Batenburg 1998[11]	Inadequate	Not possible*	Yes	High
Åstrand 1999[13]	Inadequate	Not possible**	Yes	High
Moberg 2001[17]	Unclear	Not possible	Yes	High
Tawse-Smith 2001[19]	Unclear	Not possible	Yes	High
Åstrand 2002[20]	Inadequate	Not possible	Yes	High
Gatti 2002[21]	Inadequate	Not possible in part	Yes	High
Heydenrijk 2002[23]	Unclear	Not possible	Yes	High
Tawse-Smith 2002[26]	Unclear	Not possible	Yes	High
Friberg 2003[28]	Inadequate	Not possible in part	Yes	High
Payne 2003[31]	Adequate	Not possible	Yes	Low
Payne 2004[35]	Adequate	Not possible	Yes	Low

*Radiographs were not read in sequence and not per patient to minimize bias.
**An independent assessor evaluated all radiographs.

of Periodontics and Restorative Dentistry, *International Journal of Prosthodontics*, *Journal of the American Dental Association*, *Journal of Biomedical Materials Research*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, *Journal of Oral Implantology*, *Journal of Oral and Maxillofacial Surgery*, *Journal of Periodontology*, *Journal of Prosthetic Dentistry*. Where these have not already been searched as part of the Cochrane Journal Handsearching Programme, the journals were handsearched by one reviewer. Details of the journals being handsearched by the Oral Health Group's ongoing programme are given on the web site: http://www.cochrane-oral.man.ac.uk/.

Methods of the review

The titles and abstracts (when available) of all reports identified through the electronic searches were scanned independently by two reviewers. For studies appearing to meet the inclusion criteria, or for which there was insufficient data in the title and abstract to make a clear decision, the full report was obtained. The full reports obtained from all the electronic and other methods of searching were assessed independently by two reviewers to establish whether the studies did meet the inclusion criteria or not. Disagreements were resolved by discussion. Where resolution was not possible, a third reviewer was consulted. All studies meeting the inclusion criteria then underwent validity assessment and data extraction. Studies rejected at this or subsequent stages were recorded in the table of excluded studies, and the reasons for exclusion recorded.

Quality assessment

The quality assessment of the included trials was undertaken independently and in duplicate by two reviewers as part of the data extraction process.

Three main quality criteria were examined:

1) Allocation concealment, recorded as:
   Adequate;
   Unclear
   Inadequate as described in the Cochrane Reviewers' Handbook.[3]
2) Treatment blind to outcome assessors, recorded as:
   Yes
   No
   Unclear
   Not possible.
3) Completeness of follow up (is there a clear explanation for withdrawals and dropouts in each treatment group?) assessed as:
   Yes
   No.

After taking into account the additional information provided by the authors of the trials, studies were grouped into the following categories (*Table 2*):

- Low risk of bias (plausible bias unlikely to seriously alter the results) if all criteria were met.
- Moderate risk of bias (plausible bias that raises some doubt about the results) if one or more criteria were partly met (when authors responded that they had made some attempts to conceal the allocation of patients, to blind the assessors or to give an explanation for withdrawals, but these attempts were not judged to be ideal, these criteria were categorized as "partly").
- High risk of bias (plausible bias that seriously weakens confidence in the results) if one or more criteria were not met as described in the Cochrane Reviewers' Handbook.[3]

Further quality assessment was carried out to assess sample size calculations, definition of exclusion/inclusion criteria, and comparability of control and test groups at entry. The quality assessment criteria were pilot tested using several articles.

Data extraction and synthesis

Two reviewers extracted data independently using specially designed data extraction forms. The data extraction forms were piloted on several papers and modified as required before use. Any disagreement was discussed and a third reviewer consulted where necessary. All authors were contacted for clarification or missing information. Data were excluded until further clarification becomes available if agreement could not be reached.

For each trial the following data were recorded: year of publication, country of origin and source of study funding, details of the participants including demographic characteristics and criteria for inclusion, details of the type of intervention and details of the outcomes reported, including method of assessment and time intervals.

Table 3. *List of eligible RCTs. In the text of the review we referred only to the "primary" reference, i.e. the first published report of the RCT. Follow-up publications are listed here after the "primary" publication. We used extensively unpublished information kindly provided by the authors of the RCTs..*

Primary reference	*Other follow-up publications*
Friberg 1992[5]	
Geertman 1996[6]	[43, 44]
Kemppainen 1997[8]	
Boerrigter 1997[7]	[45–47]
Jones 1997[9]	[48]
Truhlar 1997[10]	[49–59]
Batenburg 1998[11]	[60]
Karlsson 1998[12]	[61]
Åstrand 1999[13]	[62, 63]
Reingewirtz 2000[14]	
Van Steenberghe 2000[15]	
Khang 2001[16]	
Moberg 2001[17]	
Roccuzzo 2001[18]	
Tawse-Smith 2001[19]	[26] and unpublished data
Gatti 2002[21]	
Geurs 2002[22]	[64]
Karabuda 2002[24]	
Mau 2002[25]	
Heydenrijk 2002[23]	[65, 66]
Tawse-Smith 2002[26]	and unpublished data
Tomatis 2002[27]	
Åstrand 2002[20]	[67]
Friberg 2003[28]	
Joly 2003[29]	
Mau 2003[30]	
Payne 2003[31]	and unpublished data
Rocci 2003[32]	
Testori 2003[33]	
Åstrand 2003[34]	
Payne 2004[35]	

For dichotomous outcomes, the estimates of effect of an intervention were expressed as relative risks together with 95% confidence intervals. For continuous outcomes, mean differences and standard deviations were used to summarise the data for each group. The statistical unit was the patient and not the implants.

Clinical heterogeneity was to be assessed by examining the types of participants, interventions and outcomes in each study. Meta-analyses were done only if there were studies of similar comparisons reporting the same outcome measures. Relative risks were combined for dichotomous data, and weighted mean differences for continuous data, using a random effects model. Data from split mouth studies were combined with data from parallel group trials with the method outlined by Elbourne[4].

Description of studies

The first published article ("primary reference") and the follow-up publications of the eligible RCTs are summarized in *Table 3*. Of the 31 eligible trials[5–35], 19 trials[5–7,9,10,12,14–16,18,22,24,25,27,29,30,32–34] were excluded due to problems with the data presented (*Table 4*). Of the 12 included trials[8,11,13,17,19–21,23,26,28,31,35], four were conducted in Sweden[13,17,20,28], four in New Zealand[19,26,31,35], two in The Netherlands[11,23], one in Finland[8] and one in Italy[21]. Ten trials had a parallel group study design and two a split-mouth design[20,28]. Nine trials received support from industry[8,11,13,19,20,26,28,31,35]. All trials were conducted at university dental clinics or hospitals with the exception of one that was conducted in a private practice[21]. All studies included adults only.

Characteristics of the interventions and of the outcome measures

Twelve implant types with different modified surfaces were compared (*Table 5*). Since we found discrepancies about the surface characteristics of the implants described in the reporting of two trials[19,26] and the manufacturer specification, it was decided to independently characterise the surface roughness of these implants.

Implants could be grouped according to their shape in three main categories: screws (Brånemark, Steri-Oss, Astra and Southern implants), hollow screws (ITI implants) and cylinders (IMZ implants).

In two trials[28,36] implants with different shapes, but with similar surfaces and made of the same material were compared. All inserted oral implants were made of machined commercially pure titanium, however they differed in surface preparation, shape, degree of titanium purity and modality of insertion (submerged and non-submerged). Astra, Brånemark turned and IMZ implants were used according to a submerged (two-stage) procedure, i.e. implants were covered by the mucosa during the healing phase (3 to 6 months in the mandible and 6 to 7 months in the maxilla) and a second surgical intervention was necessary to connect the abutments (posts) to the implants. Brånemark TiUnite, ITI, Southern and

Table 4. *Reasons for exclusion.*

Friberg 1992[5]	Study classified as not RCT after author's reply.
Geertman 1996[6]	Data of 2 different RCTs were combined. Asked for separate data. No reply to letter.
Boerrigter 1997[7]	Number of enrolled patients unclear. No reply to letter.
Jones 1997[9]	Study classified as not RCT. No reply to letter.
Truhlar 1997[10]	Due to the extreme complexity of the study design we were unable to extract any meaningful data. No reply to letter.
Karlsson 1998[12]	Not all patients were participating in a split-mouth study. Author reply failed to clarify the issue.
Reingewirtz 2000[14]	Study classified as not RCT since only one Calcitek implant was compared with 23 Microdent. Not written to authors.
van Steenberghe 2000[15]	Split-mouth design. No patient-based paired standard deviation in the report. We could have used data on implant failure as there was only one, however, we did not know, how this was recorded. No reply to letter.
Khang 2001[16]	Sort of "split-mouth" study with unequal number of implants randomly allocated to each patient. Author had no time to reanalyse the data.
Roccuzzo 2001[18]	Problem as time of implant loading was confounded with implant type: ITI SLA implants healed for 6 weeks, whereas ITI TPS implants healed for 12 weeks. Mobile implants not considered failures.
Geurs 2002[22]	Unclear which implant type(s) failed and number of drop outs. Author reply failed to clarify the issue.
Karabuda 2002[24]	Study classified as not RCT after author's reply
Tomatis 2002[27]	Study classified as not RCT after author's reply.
Mau 2002[25]	Unusually high drop out rate often for questionable reasons (only data of 189 of the 313 patients admitted in the trial were presented). Early failures counted as drop-outs. Unclear success criteria. Not all patients followed for five years. No reply to letter.
Joly 2003[29]	Follow-up less than 1 year.
Mau 2003[30]	Problem as number of implants is confounded with implant type: patients having an overdenture supported by 2 IMZ cylinders were compared to patients with an overdenture supported by 4 ITI TPS screws.
Rocci 2003[32]	Not RCT but quasi-random trial with alternate assignment.
Testori 2003[33]	Problem as implant types: Osseotite and Osseotite NT were confounded with early and immediate loading.
Åstrand 2003[34]	Parallel group study in which patients in the test group received Brånemark MkIV implants in bone quality type 3 and 4 and Brånemark MkII or standard implants in bone quality type 1 and 2. Patients in the control group received Brånemark standard or Mk II implants in all bone quality types. In order to use the data we needed only data of implants placed in bone quality type 3 and 4. Written to the author who was unable to provide data in the appropriate form.

Table 5. *Dental implants evaluated in this review and their main characteristics.*

(1)	Astra® TIO2-blast titanium grade three screws (Astra Tech AB, Mölndal, Sweden).
(2)	Brånemark® Standard turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(3)	Brånemark® Mark II type turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(4)	Brånemark® conical transmucosal turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(5)	Brånemark® Mark IV type (prototype) turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(6)	Brånemark® TiUnite oxidized titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(7)	IMZ® TPS (titanium plasma-sprayed) titanium grade two cylinders (Friedrichsfeld AG, Mannheim, Germany).
(8)	ITI® TPS hollow titanium grade four screws and cylinders (Institut Straumann AG, Waldenburg, Switzerland).
(9)	ITI® TPS solid titanium grade four screws (Institut Straumann AG, Waldenburg, Switzerland).
(10)	ITI® SLA solid sand-blasted large-grit acid-etched titanium grade four screws (Institut Straumann AG, Waldenburg, Switzerland).
(11)	Southern® sand-blasted acid-etched titanium grade four screws (Southern Implants Irene, South Africa).
(12)	Steri-Oss® HL series, 3.8 mm in diameter acid-etched titanium grade four screws (Steri-Oss, Yorba Linda, California, USA).

Steri-Oss implants were placed according to a non-submerged (one-stage) protocol, i.e. the abutments were directly connected to the implants, thus a second operation was avoided. In two trials, Brånemark Mark II and transmucosal conical implants[21] and IMZ implants[23] were used according to a one-stage protocol.

Implants were placed in edentulous mandibles[11,13,17,19,23,26,31] and maxillae[13,35]. Partially edentulous maxillae were treated in one trial[20]. Another study included fully and partially edentulous mandibles and maxillae, however, the majority were edentulous maxillae[28]. Single implants were used in both maxillae and mandibles in one study[8].

In one trial[35] maxillae were treated either with a ridge expansion osteotomy or a combined ridge split and osteotomy procedure, depending on the ridge bucco-palatal width and the degree of ridge resorption. Autogenous bone grafts were used to fill intraosseous grooves of the ridge split-cases.

In general, final prostheses were inserted 4 to 8 months after implant placement in mandibles and 7 to 10 months in maxillae. However, in one study[35] maxillary overdentures were attached to implants 12 weeks after implant placement. In another study[26] mandibular overdentures were attached to the implants 6 weeks after implant placement. In another trial mandibular overdentures were placed on the implants 2 weeks postoperatively[31] whereas in another trial implants were immediately loaded[21].

Cross-arch fixed prostheses were retained by screws on four to six implants[13,17,28]. Removable overdentures were retained by clip attachments to a bar supported by two[11,23] or four implants[21], or were retained by two[19,26,31] or three[35] ball attachments. Partial maxillary bridges were screw-retained on two to four implants[20,28]. Crowns were cemented on single implants[8].

The main or primary outcomes (biological and mechanical failures) as well as secondary outcomes (bone level measurements) were recorded in all studies. However, in two trials[17,21] peri-implant bone level measurements were partly performed on panoramic radiographs. Such bone level measurements were considered to be inaccurate and were not included in the present analyses. In another trial[23] insufficient data on the bone level assessment were presented (it was not clear if the standard deviations were calculated on a patient or site basis) and the authors were not able to supply the required data. The 5-year data of another trial[13] were not used since the authors published separate data for maxillae and mandibles, while we requested combined data. The 3-year data of another split-mouth study[20] could not be used since we did not have the standard deviation of the difference. No information on the occurrence of perimplantitis was provided in one trial[11].

The follow-ups of the included trials, including unpublished data kindly provided by the investigators, were: One year[8,28,35]. Two years[21,23]. Three years[17,20,31]. Five years[11,13,19,26]. However we just analysed data at 1, 3 and 5 year time-points after implant loading.

Methodological quality of included studies

The agreed quality of the included trials after having incorporated the information provided by the authors is summarized in *Table 2*. For each trial we assessed whether it was at low, medium or high risk of bias. All studies were rated as at high risk of bias with the exception of two RCTs[31,35], that were judged to be at low risk of bias.

Allocation concealment

Two trials reported that the randomisation procedure was concealed[31,35]. The method of allocation concealment was considered unclear for all the remaining trials despite author clarifications, with four exceptions[11,20,21,28]. According to the information provided by these authors, the randomisation procedure was not concealed to clinicians. No reply was obtained for two trials[17,23].

Blinding

In general, it was not possible to blind the outcome assessors to the interventions in any of the included trials since in all cases the different shapes of implants and abutments were easily recognizable. However, in one trial[13] an independent assessor made the radiographic evaluations. In another trial radiographs[11] were read not in sequence per patient. In other three trials implant stability could have been measured by blinded assessors but this was not done[8,21,28].

Withdrawals

The reporting of withdrawals was adequate for all trials with two exceptions[11,35]. However, authors supplied the missing information.

Sample size

Only one study[13] undertook an a priori calculation for the sample size to detect a true difference of 0.4 mm in marginal bone levels thought to be of clinical significance.

Main inclusion criteria

- Edentulous mandibles of at least 13 mm of bone height[19,26].
- Edentulous mandibles allowing placement of implant at least 9 mm long[21].
- Edentulous mandibles[17].
- Severely resorbed edentulous mandibles[11,23].
- Edentulous maxillae[35].
- Edentulous mandibles and maxillae not needing augmentation procedures[13].
- Partially edentulous jaw bone of at least 10 mm in height and 6 mm wide[8].
- Partially edentulous maxillae not needing augmentation procedures[20].
- Healed edentulous distal jaws (premolar/molar regions) of soft type bone quality[28] (type 3 or 4 according to the Lekholm and Zarb classification)[37].

Main exclusion criteria

- Radiotherapy in the head and neck region[8,11,19–21,23,26,31].
- Severe intermaxillary skeletal discrepancy[21].
- Severe clenching and bruxism[20,21].
- Any history of bruxism[19,26,31,35].
- Drug and/or alcohol abuse[8,17,20,21].
- Uncontrolled diabetes[8,21].
- Any evidence of previous and current smoking[19,26,31,35].
- Smoking more than 10 cigarettes per day[21].
- Smoking more than 20 cigarettes per day[20].
- Current steroid treatment[20,21].
- Current chemotherapy treatment[20,21].
- Very soft bone (type 4[37])[19,26].
- Grafted or regenerated bone[28,35].
- Extremely resorbed maxillae[35].

Comparability of control and test groups at entry level

The control and test groups seemed comparable in all trials with two exceptions: In one trial[13], eight patients treated with Brånemark implants were scored as having type 4 bone quality (very soft bone) according to the Lekholm and Zarb classification[37] versus one patient in the Astra group. In another trial[8], ITI hollow screws were only placed in posterior mandibles. For one additional trial the amount of information presented was insufficient to judge on the comparability of controls and test groups at entry[23].

The percentage agreement and kappa scores between the two raters were: 92%, 0.63 for allocation concealment and 75%, 0.25 for withdrawals.

RESULTS

In total, 1480 implants (550 turned and 930 implants with roughened surfaces) were originally placed in 512 patients (317 mandibles and 195 maxillae) in the 12 trials. During the follow-up period considered in this review (1, 3 and 5 years) there were 55 implant failures (two due to implant fracture in the same patient). Thirty-two of the failed implants had a roughened surface and 23 had a turned surface. In particular, there were 37 early

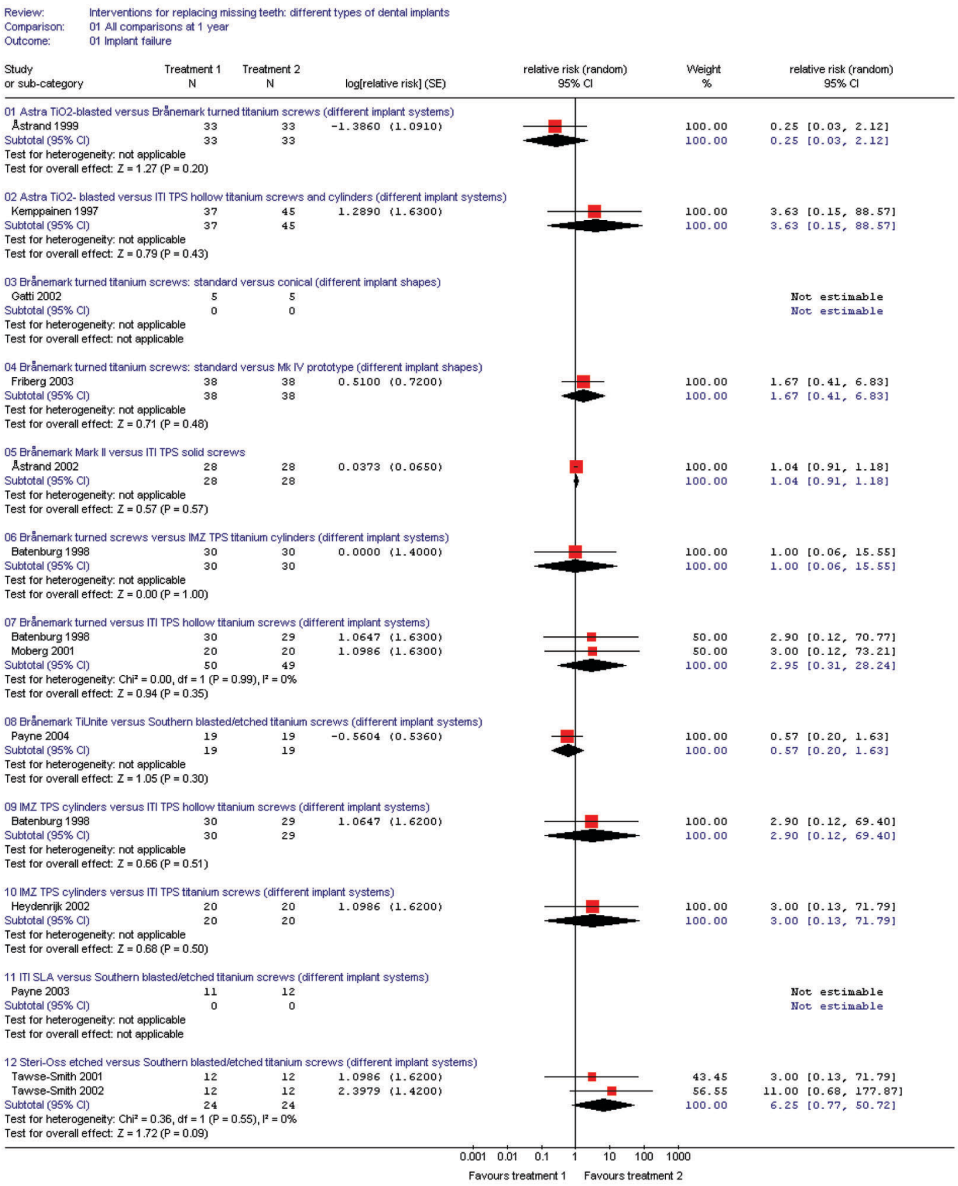

Figure 1. *Forest plot comparing implant failures of different implant types at 1 year.*

implant failures (21 implants had a roughened surface) and 18 late failures (11 implants had a roughened surface and two of these fractured). Perimplantitis (advanced marginal bone loss with signs of infection such as suppuration where the investigators have justified its diagnosis) affected 13 implants (12 implants had a roughened surface). Four implants were successfully treated, for five the outcome was uncertain and four implants failed.

Primary hypotheses

Implant failures and marginal bone level changes at one, three and five years are presented in *Figures 1–2, 3–4* and *5–6*, respectively.

(1) Trials comparing implants with different surface preparations, but having similar shape and material

No trials were included.

(2) Trials comparing implants with different shapes, but having similar surface preparation and material

Two trials were included in the following comparisons:

Brånemark Mark II type versus Brånemark conical transmucosal implants

One trial with a parallel group design[21] compared four Brånemark Mark II type screws with four Brånemark conical transmucosal screws supporting mandibular overdentures for two years. The implants were immediately loaded. Five patients were included in each study group. No baseline differences for sex, age and length of the implant used appeared between the two groups. No withdrawals nor failures occurred during the study period and the relative risk value was therefore inestimable (*Figure 1*).

Brånemark Standard versus Brånemark Mark IV prototype implants

One trial with a split-mouth design[28] compared one Brånemark standard type screw with one Brånemark Mark IV type screw placed in posterior jaws of soft bone quality supporting fixed prostheses for 1 year. Forty-four patients (39 maxillae and five mandibles) were originally included. There did not appear to be any baseline differences for implant length, bone quality and quantity.

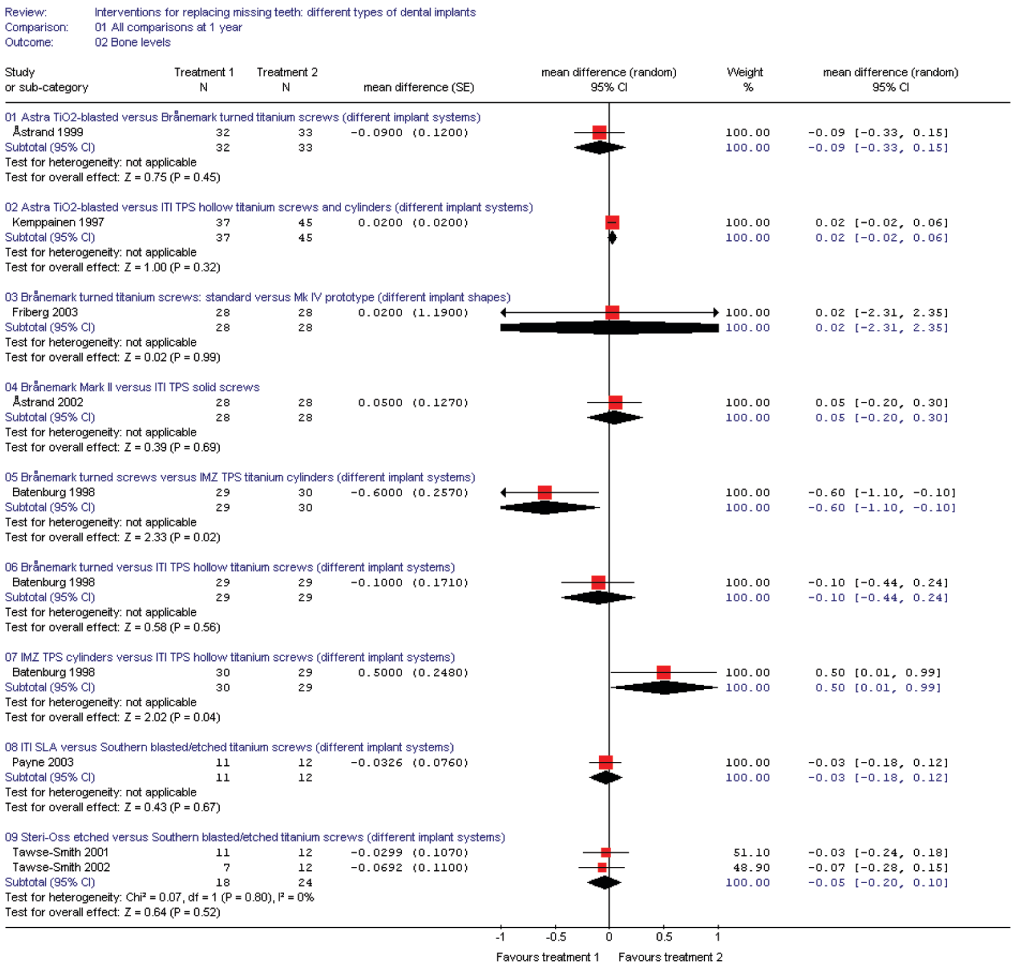

Figure 2. *Forest plot comparing mean marginal bone level changes measured on intraoral radiographs of different implant types at 1 year.*

Eight withdrawals occurred (three due to death, two due to poor compliance and three patients wished to be excluded). Eight implants failed: five MkII (three early failures) and three MkIV (three early failures) in eight different patients. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figure 1*) and marginal bone level changes (*Figure 2*) of the different implants after 1 year of function.

(3) Trials comparing implants with different materials, but having similar surface preparation and shape

No trials were included.

(4) Trials comparing implants with different surface preparation and/or shape and/or material

Ten trials were included in the following comparisons:

Astra versus Brånemark implants

One trial[13] with a parallel group design compared submerged Astra versus submerged Brånemark screws in totally edentulous patients for 5 years. Thirty-three fully edentulous patients (17 maxillae and 16 mandibles) were originally included in each group. No baseline differences for sex, bone quantity, and length of the implant used appeared between the two groups. However, eight patients treated with Brånemark implants were scored as having type 4 bone quality (very soft bone) according to the Lekholm and Zarb classification[37] versus one patient in the Astra group. Two withdrawals occurred after the third year due to death from the Astra group. Baseline radiographs were missing for one mandible in the Astra group. According to a sample size calculation a minimal number of 15 patients were to be included and followed in order to detect a true difference of 0.4 mm in marginal bone level changes between the tested implants with 90% power in mandibles. Ten Brånemark implants failed in five patients (one patient lost five implants and the bridge) versus three Astra implant failures in two patients (two failures in the same patient were due to implant fracture: one occurred between 1- and 3-year follow ups and the other thereafter). Two additional Astra implants were successfully treated for perimplantitis (suppuration combined with advanced bone loss). Considering the patient as the unit for the analysis, there were no statistically significant differences for failures (*Figures 1, 3* and *5*) nor for marginal bone level changes between the implant systems after 5 years of function (*Figures 2* and *4*).

Astra versus ITI implants

One trial[8] with a parallel group design compared submerged Astra versus non-submerged ITI hollow cylinders and screws for single tooth replacement for 1 year. Thirty-seven patients received 46 Astra implants (36 maxillary and 10 mandibular implants) and 45 patients had 56 ITI implants (34 maxillary and 22 mandibular implants; 18 hollow screws were placed in

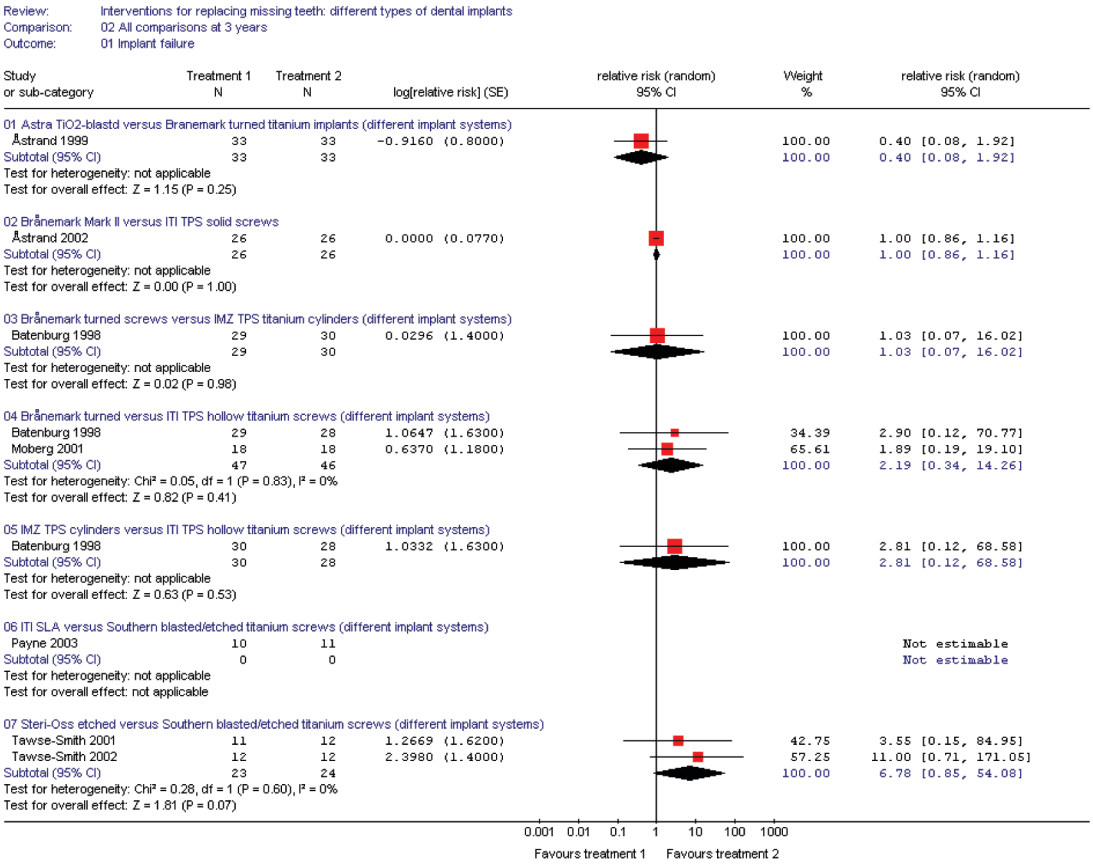

Figure 3. *Forest plot comparing implant failures of different implant types at 3 years.*

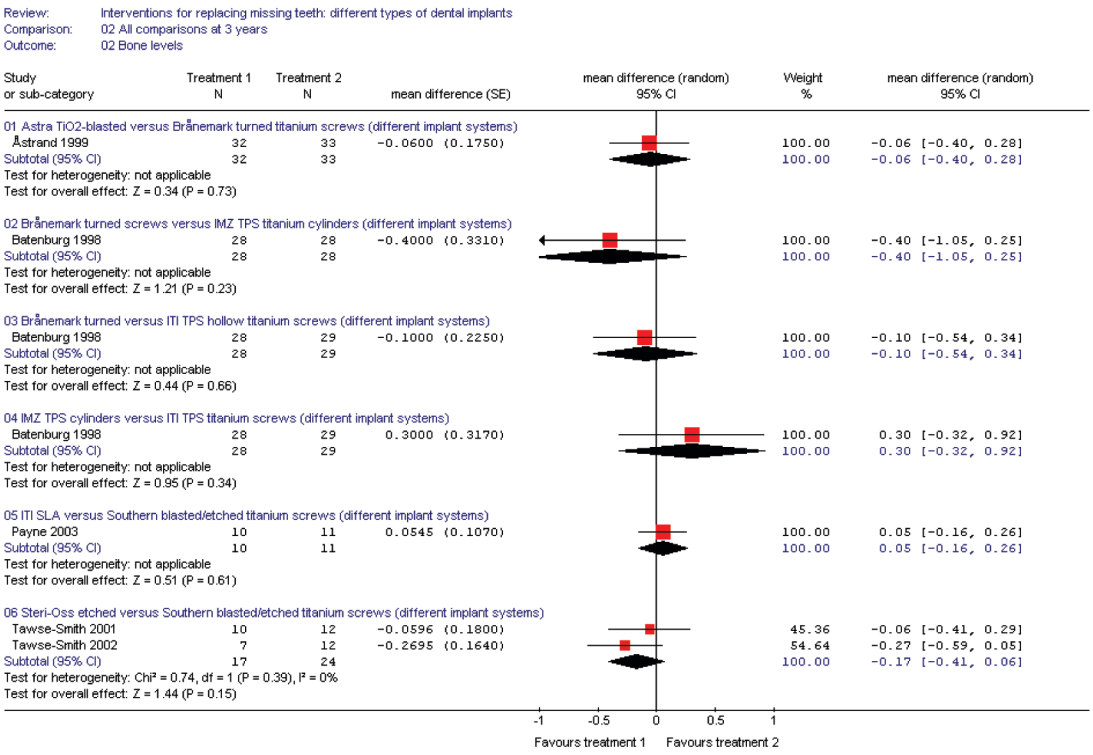

Figure 4. *Forest plot comparing mean marginal bone level changes measured on intraoral radiographs of different implant types at 3 years.*

mandibular posterior areas). It was unclear whether there were baseline differences between the two groups since ITI hollow screws were only placed in posterior mandibles. No patient dropped out. One maxillary Astra implant failed to integrate (early failure). All ITI implants were successful. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figure 1*) and marginal bone level changes between the implant systems after 1 year of function (*Figure 2*).

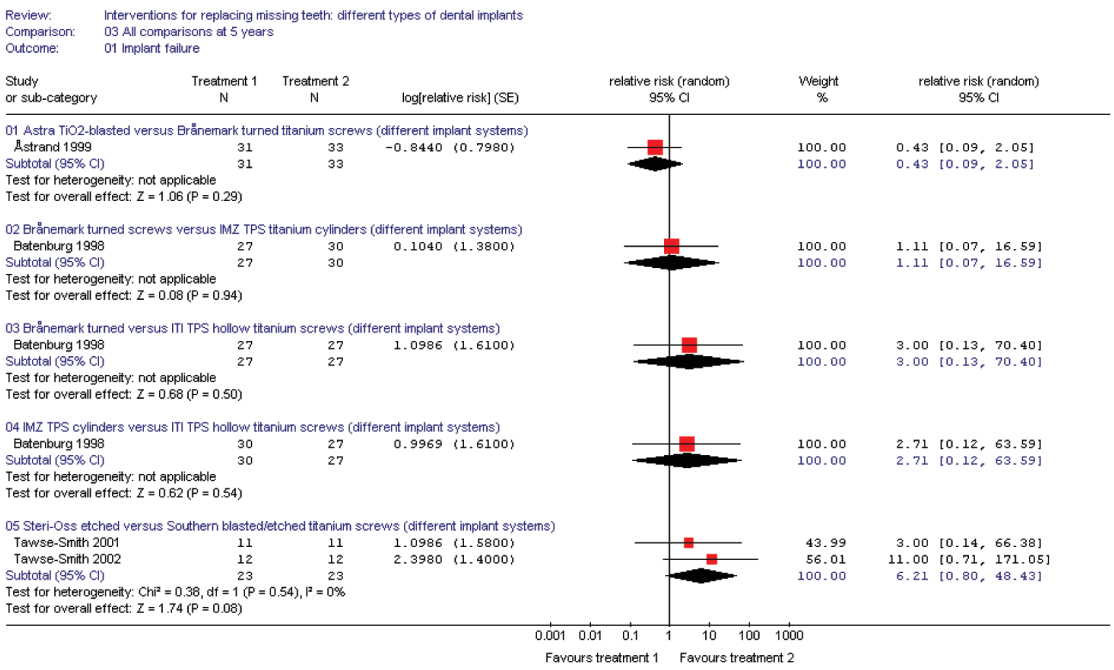

Figure 5. *Forest plot comparing implant failures of different implant types at 5 years.*

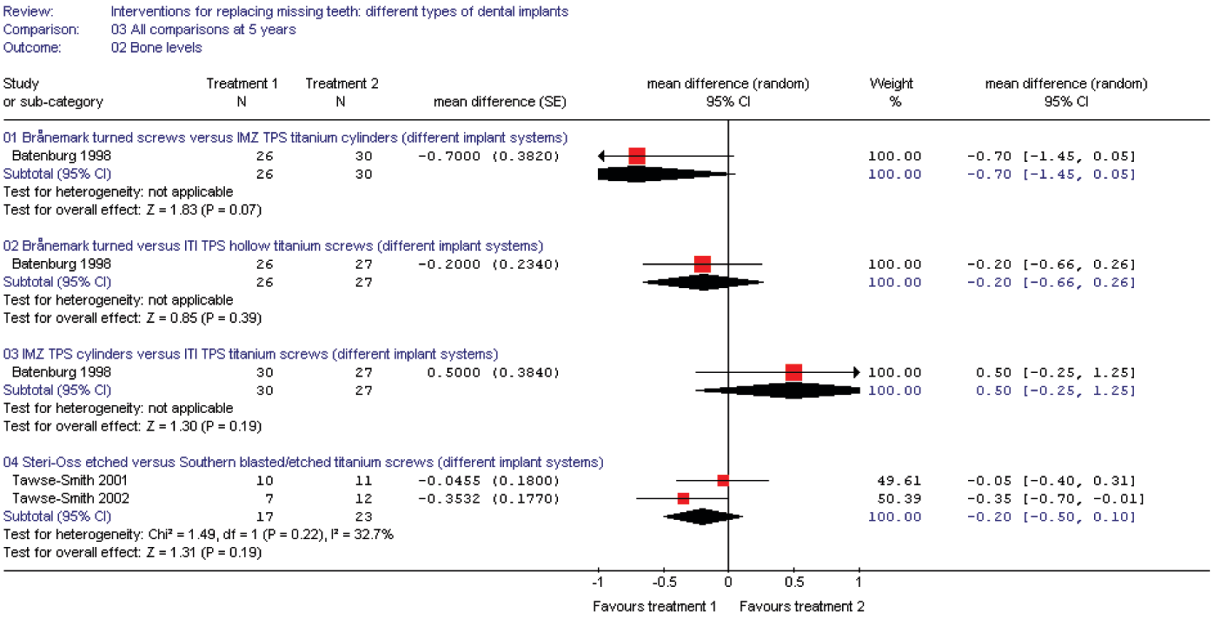

Figure 6. *Forest plot comparing mean marginal bone level changes measured on intraoral radiographs of different implant types at 5 years.*

Brånemark versus IMZ implants

One trial[11] with a parallel group design compared two submerged Brånemark versus two IMZ submerged implants supporting overdentures in edentulous mandibles for 5 years. Thirty patients were included in each group. No baseline differences for sex, mean edentulous period, mandibular bone quantity and height appeared between the two groups. Three patients in the Brånemark group could not attend the 5-year examination due to sickness. One Brånemark and one IMZ implant failed prior to the abutment connection operation. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1, 3* and *5*). However there was significantly more bone loss for the IMZ implant group at 1 year with mean difference 0.60 mm (95% CI 0.10 to 1.10) (*Figure 2*), but no significant differences at years 3 and 5 (*Figures 4* and *6*).

Brånemark versus ITI implants

Three trials compared submerged Brånemark versus non-submerged ITI TPS implants[11,17,20].

One trial with a parallel group design[11] compared two implants (Brånemark Mark II screws and ITI TPS hollow screws) supporting mandibular overdentures for 5 years. Thirty patients were included in each group. No baseline differences for sex, mean edentulous period, mandibular bone quantity and height appeared between the two groups. Two patients of the ITI group died one prior to

the 1-year examination and the other prior to the 3-year examination. Three patients in the Brånemark group and one in the ITI group could not attend the 5-year examination due to sickness. One Brånemark implant failed prior to the abutment connection operation. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1, 3* and *5*) and marginal bone level changes (*Figures 2, 4* and *6*) between the implant systems after 5 years of function.

One trial with a parallel group design[17] compared implants (Brånemark Mark II screws and ITI TPS hollow screws) supporting a mandibular fixed bridge for 3 years. Twenty patients were included in each group. There did not appear to be any baseline differences for patient sex, age and location of implants. Three patients died prior to the 3-year examination (one in the Brånemark and two in the ITI group). One patient with Brånemark implants did not attend the 3-year radiographic examination. Two Brånemark implants failed (one early failure and one for perimplantitis between year 1 and 2). One ITI implant failed for perimplantitis at 2 years. However, two additional ITI implants were found to be affected by perimplantitis at the 3-year examination and were under treatment. Their outcome was unknown at the time of reporting. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures between the implant systems after 3 years of function (*Figures 1* and *3*).

A meta-analysis of the two above studies[11,17] was done. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures between the implant systems after 3 years of function (*Figures 1* and *3*).

One split mouth trial[20] compared implants (Brånemark Mark II screws and ITI TPS solid screws) supporting maxillary partial screw-retained bridges for 3 years. Twenty-eight patients were included. There did not appear to be any baseline differences for implant length, bone quality and quantity. Two patients died before the 3-year follow up. Two Brånemark failed (early failures) in the same patient and two ITI implants failed for perimplantitis: one implant failed at 1 year and the other after 3 years. Additional 5 ITI implants showed clinical signs of perimplantitis and the fate of two of these ITI implants was considered to be questionable. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1* and *3*) after 3 years of function and for the marginal bone level changes between the implant systems after 1 year of function (*Figure 2*).

Brånemark TiUnite versus Southern implants

One trial[35] with a parallel group design compared non-submerged narrow diameter implants with roughened surfaces (Brånemark TiUnite versus Southern screws) for the treatment of totally edentulous maxillae using three unsplinted implants supporting an overdenture for 1 year. Maxillae were treated either with a ridge expansion osteotomy or a combined ridge split and osteotomy procedure, depending on the ridge bucco-palatal width and the degree of ridge resorption. Autogenous bone grafts were used to fill intraosseous grooves of the ridge split-cases. The implants were early loaded 12 weeks after placement. Twenty patients were included in each group. It is unclear whether important baseline differences existed among the two groups. Two patients dropped out: one from the Brånemark group (only one implant of three could be placed) and one from the Southern group (death). Fifteen implants failed in 11 patients (5 Brånemark and 10 Southern implants). Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figure 1*) and marginal bone level changes between the implant systems after 1 year of function (*Figure 2*).

IMZ versus ITI implants

Two trials compared IMZ TPS cylinders with ITI TPS implants[11,23].

One trial[11] with a parallel group design compared two submerged IMZ TPS cylinders versus two non-submerged ITI TPS hollow screws supporting overdentures in edentulous mandibles for 5 years. Thirty patients were included in each group. No baseline differences for sex, mean edentulous period, mandibular bone quantity and height appeared between the two groups. Two patients from the ITI group died one prior to the 1-year examination and the other prior to the 3-year examination. At the 5-year examination one additional patient of the ITI group was sick and could not attend the examination. One IMZ implant failed prior to the abutment connection operation. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1, 3* and *5*). There was significantly more bone loss for IMZ at 1 year, with mean difference = 0.50 mm (95% CI 0.01 to 0.99) (*Figure 2*), however there were no significant differences in marginal bone level changes between the implant systems after 3 or 5 years of function (*Figures 4* and *6*).

One trial[23] with a parallel group design compared two non-submerged IMZ cylinders versus two non-submerged ITI solid screws supporting overdentures in edentulous mandibles for 1 year. Twenty patients were included in each group. It was unclear whether there were any baseline differences for the two groups. No withdrawal occurred during the study period. One IMZ implant failed (late failure). Considering the patient as the unit for the analysis, there was no statistically significant difference for failures between the implant systems after 1 year of function (*Figure 1*).

ITI versus Southern implants

One trial[31] with a parallel group design compared non-submerged ITI SLA screws with non-submerged Southern screws for the treatment of totally edentulous mandibles using two unsplinted implants supporting an overdenture for 3 year. The implants were early loaded 2 weeks after placement. Twelve patients were included in each group. The groups did not differ for age, number of years edentulous, number of previous dentures, bone quality and quantity. Three patients dropped out: two from the ITI group (death and lack of interest) and one from the Southern group (death) over the 3-year period. No implant failed and so we were unable to estimate the relative risk value, however considering the patient as the unit for the analysis, there was no statistically significant difference for marginal bone level changes between

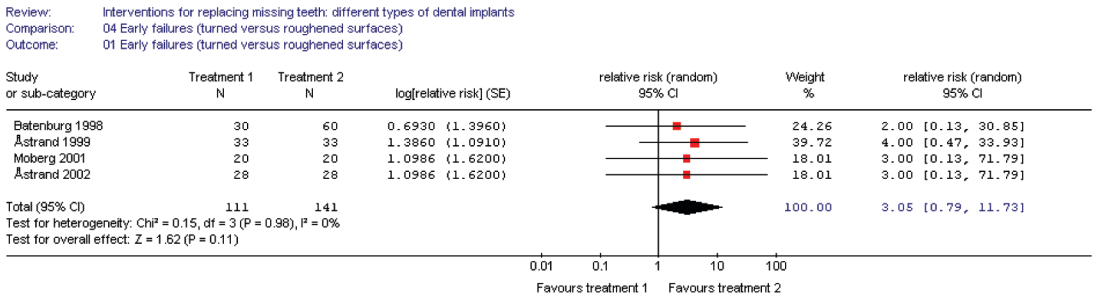

Figure 7. *Forest plot comparing early failures of implants with turned (machined) surfaces versus implants with roughened surfaces.*

the implant systems after 3 years of function (*Figures 2* and *4*).

Southern versus Steri-Oss implants

Two trials[19,26] with a parallel group design compared non-submerged Southern versus non-submerged Steri-Oss screws for the treatment of totally edentulous mandibles using two unsplinted implants supporting an overdenture. The design of the two trials was identical with the exception that in one trial the implants were conventionally loaded at 12 weeks[19], whereas in the other the implants were early loaded at 6 weeks[26]. In both articles Steri-Oss implants were described as having a turned surface, but after having analysed the surface of one implant, kindly provided by the authors, it was realised that the implant surface was chemically treated.

One trial[19] with a parallel group design included 12 subjects in each of the two groups followed up to 5 years (conventional loading at 12 weeks). Patients having type 4 bone were to be excluded, but none was found. There were no baseline differences in bone quality and quantity between the two groups. Two drop-outs occurred over a 5-year period: one in the Steri-Oss group (patient request) and one in the Southern group (death). One patient in the Steri-Oss group had an early implant failure. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1, 3* and *5*) and marginal bone level changes between the implant systems after 5 years of function (*Figures 2, 4 and 6*).

The other trial[26] with a parallel group design included 12 subjects in each group followed up to 5 years (early loading at 6 weeks). This study also presented data at 2 years of the previous trial (conventional loading at 12 weeks). Patients having type 4 bone[37] were to be excluded, but none was found. There were no baseline differences in bone quality and quantity between the two groups. No drop outs occurred over a 5-year period. Five patients in the Steri-Oss group had seven early failures. No implant was lost in the Southern group. Most of the failed implants were placed by one surgeon who only placed some Steri-Oss implants. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1, 3* and *5*), however there was a statistically significant difference in mean marginal bone level changes between the implant systems after 5 years of function, with the Southern group having more bone loss than Steri-Oss mean difference –0.35 mm (95% CI –0.70 to –0.01) (*Figure 6*).

Meta-analyses of the two above studies[19,26] were done. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (*Figures 1, 3* and *5*) and marginal bone level changes (*Figures 2, 4* and *6*) between the implant systems after 5 years of function.

Secondary hypotheses

(1) Early failures between turned and roughened surfaces

A meta-analysis comparing early implant failures between various implants with turned and roughened surfaces is presented in *Figure 7*. Four trials were included[11,13,17,20]. Although one was a split-mouth study,[20] this has been calculated as a parallel group study as we were unable to calculate the effect estimate for the paired data due to the zero. As the overall estimate is not significant, we do not feel that this would have changed the results substantially. Considering the patient as the unit for the analysis, there was no statistically significant difference for early failures between the implants with turned and roughened surfaces.

(2) Perimplantitis between turned and roughened surfaces at 3 years

A meta-analysis comparing the occurrence of peri-implantitis between various implants with turned and roughened surfaces at 3 years is presented in *Figure 8*. Three trials were included[13,17,20]. Considering the patient as the unit for the analysis, there was a borderline statistically significant difference for the occurrence of perimplantitis between the implants with turned and roughened surfaces. More implants with rough surfaces were affected by perimplantitis (RR 0.80; 95% CI 0.67 to 0.96). Implants with turned surfaces had a 20% reduction in risk of being affected by perimplantitis. For another trial[11] no data were presented and the author did not reply to our request of information.

(3) Perimplantitis between turned and roughened surfaces at 5 years

Only one trial was available[13] comparing the occurrence of perimplantitis between various implants with turned and roughened surfaces at 5 years and is presented in *Figure 9*. Considering the patient as the unit for the analysis, there was no statistically significant difference for the occurrence of perimplantitis between the implants with turned and roughened surfaces. For another trial[11] no data were presented and the author did not reply to our request of information.

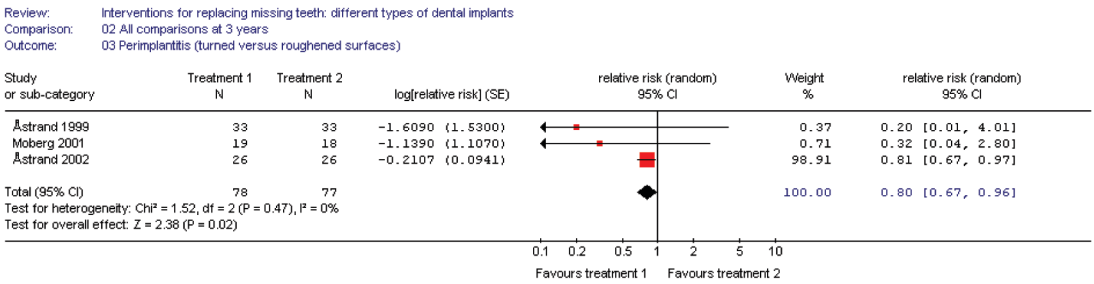

Figure 8. *Forest plot comparing the occurrence of perimplantitis defined as progressive marginal bone loss associated with sign of infection of implants with turned (machined) surfaces versus implants with roughened surfaces at 3 years.*

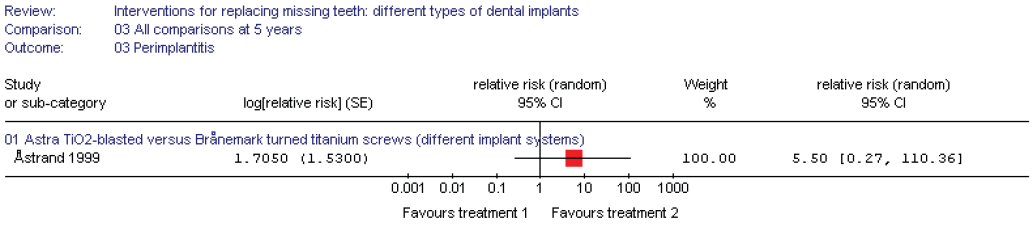

Figure 9. *Forest plot comparing the occurrence of perimplantitis defined as progressive marginal bone loss associated with sign of infection of implants with turned (machined) surfaces versus implants with roughened surfaces at 5 years.*

DISCUSSION

It is important to know whether there are implants systems or specific implant characteristics associated with increased success rates, primarily for the patient's benefit. In order to properly compare the efficacy of various implant systems properly well conducted long-term RCTs are needed. The present systematic review confirms the current knowledge that high success rates up to 5 years of loading can be achieved for all the evaluated implant systems.

In order to properly evaluate the effect of different implant characteristics, the ideal trial should be designed in a way that only the characteristic of interest (i.e. surface roughness or implant shape or implant material) is different whereas all the other parameters are identical. This was not done in the majority of the included RCTs, as these trials compared implants having a combination of different surface characteristics, shapes, dimensions, different purity of titanium and these were placed according to different surgical protocols (submerged versus non-submerged, immediately or early loaded, etc.). Therefore, the present systematic review mainly presents data of comparisons between different implant systems and not of specific implant characteristics. The only exceptions were two trials[21,28] testing different design of the Brånemark implants, having different shapes but similar surface properties and material. However, the number of patients included may have not been sufficient to detect a statistically significant difference, if any. No trial described implants made or coated with other materials.

A few statistically significant differences were found when different implant systems with different surface characteristics and shapes were compared using the patient rather than the implants as the unit of the statistical analyses. In one trial[11] there was more bone loss at 1 year for IMZ implants compared to Brånemark (mean difference 0.60 mm; 95% CI 0.01 to 1.10) and to ITI implants (mean difference 0.50 mm; 95% CI 0.01 to 0.99). However, these differences disappeared at years 3 and 5. Another RCT[26] showed a statistically significant difference after 5 years for marginal bone level changes. However, this difference disappeared when combining the results of this trial with another trial having similar characteristics[19] in a meta-analysis. The fact that only a few patients were included and that the difference in bone levels was actually due to apparent bone gain and not bone loss may indicate that this statistically significant difference could be a spurious finding. Therefore we have to be very careful when drawing conclusions from this observation. These observed statistically significant differences in marginal bone levels seem not to indicate important clinically differences, since no differences in implant failures were observed so far over a 5-year period.

The assessment of radiographic bone level changes around implants is a secondary or surrogate outcome measure and is commonly used. A surrogate outcome can be defined as a measure of the disease process. Surrogate outcome measures cannot be recommended as primary parameters to evaluate effectiveness of oral implants, however they may be useful diagnostic tools for the early detection of potential problems, allowing early treatment to preserve healthy conditions[2]. Primary or true outcomes such as implant failures are often rare and distant events, whereas, surrogate endpoints are in general sensitive predictors for the true outcomes. The problem of using mean marginal bone level assessments is that a severe marginal bone loss affecting few implants is diluted by the averaging process. In addition, once an implant has failed, its values are removed from the calculations, suddenly improving the bone level measurements. These limitations of the mean marginal bone level measurements may delay an early detection of a statistically significant difference. One possible way to overcome this problem is to dichotomise the bone level measurements, establishing an arbitrary threshold level of severe bone loss (for instance 5 mm), and to count how many patients had at least one implant affected by such severe bone

loss. Implants that failed because of progressive bone loss should remain in the calculations.

Of clinical interest is the meta-analytic finding of the occurrence of statistically more perimplantitis requiring additional interventions around implants with roughened surfaces when compared with implants with turned surfaces over a 3-year period. In other words there is a 20% less risk of having perimplantitis around implants with a turned surface. This observation deserves some critical and objective reasoning. On one hand, the occurrence of more perimplantitis did not result in higher failure rates, on the other hand we do not have sufficient information on what happens over longer follow-up periods and sample sizes were very small. It may also be that implants with various degree of surface roughness do not behave in the same way. The majority of perimplantitis occurred around implants with TPS surfaces[17,20]. Of particular interest is a split-mouth study[20] including 26 patients in which perimplantitis affected seven implants in five patients, all having a TPS surface and none of the contralateral implants with a turned surface. The implants with the TPS surface of this brand are no longer commercially available. The authors also informed us that they will not consider evaluating the implants at longer follow ups since the implants are no longer on the market. However this commonly used approach will preclude us from having important information, and could explain why we have to be very careful when assessing the published literature, since we actually might not have access to important unpublished information (usually with negative findings). This statistically significant difference may therefore bear important consequences, the first being that implants with various degrees of surface roughness may not behave in the same way, but some may provide better results than others and this finding may have relevant clinical consequences. Clinicians and patients should also consider whether it is easier to handle an early failure, before the prosthetic phase, or a late failure after implant(s) have been restored into function for few years.

The most important observation is that no differences in failure rates were observed among various implant types. However, only one trial[13] undertook a sample size calculation and this was powered for detecting a true difference in marginal bone levels of 0.4 mm, considered to be of clinical significance, and not for implant failures. It can be debated whether a 0.4 mm difference bears any clinical significance, taking into consideration that it is very difficult to achieve valid bone loss measurements of less than 0.2 mm even in an in vitro situation[38]. As implant failures are rare events, thousands of patients may be needed in order to detect statistically significant differences. Thus, the number of patients included in the few available trials was likely to be too low and follow-up periods too short to detect a significant difference in failure rates, if any. In other words, it cannot be dismissed that a difference in effectiveness between various modified surfaces, materials and shapes does exist.

None of the trial authors characterised the implant surfaces themselves. This is understandable since they relied on the information provided by the manufacturers or published in other studies. However, after having analysed the surface of some implants we realised that the surface description of the Steri-Oss implants reported in two trials[19,26] did not correspond to what we actually found. In fact, the surface was acid-etched and not turned as described in the articles. Such a finding was indeed unexpected. In experimental research it is recommended that authors characterise in detail the surface properties of their implants. We feel that the same recommendation could be given for clinical trials where the implant characteristics could be described in detail and possibly independently verified.

We considered the concealment of allocation procedure of the randomisation process adequate for only two trials[31,35]. These trials were initiated after the first version of this review was published, so the authors, who were contacted, implemented an allocation concealment procedure to minimize selection bias in their trial. This aspect of trial designing and reporting needs to be improved since it has been shown that RCTs where allocation concealment procedures were inadequately conducted tended to overestimate treatment effects[39,40]. Due to this reason all but two trials were judged to be at high risk of bias in our validity assessment. While it is always possible to conceal the allocation to the treatment group, it is not always possible to blind patients, treatment providers and outcomes assessors. This is particularly true in the type of trials that we have assessed, where the different shape of the implants or the prosthetic components in many but not all instances precluded a proper blinding. However, some attempts to minimize detection bias were done: an independent outcome assessor was used in one trial[13], while in another trial the radiographic reading of bone levels was not done in sequence and not per patient[11]. Investigators should always consider using independent assessors or any other possible means when proper blinding is not possible to minimize detection bias.

In another investigation, it was found that the design, analysis and reporting of RCTs on oral implants were generally poor[41]. This supports the finding that so many trials had to be excluded from the present review. Investigators should design studies carefully deciding on either a parallel group or a split-mouth design on outset, not combining the two designs in one study. Split-mouth studies should ideally have equal numbers of implants in each group placed per patient. The analysis of these studies should be a 'paired' analysis, taking the pairing of the implants within patients into account. Another sometimes related problem is that both split-mouth and parallel group studies are analysed at the level of the implant, not taking the clustering of the implants within a patient into account. The design and analysis of these studies is frequently complex and it is recommended that statisticians are involved in the initial planning stages and protocol writing for these studies.

The generalisation of the results of the included trials to ordinary clinical conditions should be considered with extreme caution. In general, treatments were administered by experienced clinicians and the follow-up regimens were strict. It is unlikely that dentists with non comparable experience could match similar positive results. The observation that the inclusion of a less trained surgeon might have influenced the result of one trial[26] could support this suggestion.

Nine of the 12 included trials reported that they were commercially funded. It is possible that there could be bias in this area, on the other hand, these studies would probably not have taken place unless there was commercial funding. Ideally independent studies should be conducted.

CONCLUSIONS

Based on the available results of RCTs, there is limited evidence showing that implants with relatively smooth (turned) surfaces are less prone to lose bone due to chronic infection (perimplantitis) than implants with rougher surfaces. On the other hand, there is no evidence showing that any particular type of dental implant has superior long-term success. No trial described implants made or coated with materials other than titanium. These conclusions are based on a few RCTs with relatively short follow-up periods, few patients and often at high risk of bias. So we do not know if there are implant characteristics or an implant system that is superior to others due to the scarcity of reliable scientific research. In order to understand if there is any surface modification or material able to significantly improve the effectiveness of oral implants more well-designed long-term RCTs are needed. It is recommended that such trials include:

- a sufficient number of patients to disclose a true difference, if any;
- a proper group allocation concealment;
- independent outcome assessors when blinding is not possible to minimize detection bias;
- a sufficient duration (5 years or more).

Such trials should be reported according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines[42] (http://www.consort-statement.org/). Ideally, these trials should investigate only one aspect, such as the role of various degrees of surface roughness or the role of calcium-phosphate coatings, thus minimizing the numerous confounding factors such as different implant shapes or clinical procedures.

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This invited review is based on a Cochrane systematic review entitled "Interventions for replacing missing teeth: different types of dental implants" published in The Cochrane Library (see www.CochraneLibrary.net for information). Cochrane systematic reviews are regularly updated to include new research, and in response to comments and criticisms from readers. If you wish to comment on this review, please send your comments to Marco Esposito. The Cochrane Library should be consulted for the most recent version of the review. The results of a Cochrane Review can be interpreted differently, depending on people's perspectives and circumstances. Please consider the conclusions presented carefully. They are the opinions of the review authors, and are not necessarily shared by the Cochrane Collaboration.

Conflict-of-interest statement: Marco Esposito, Paul Coulthard and Peter Thomsen had received benefits from commercial parties related directly or indirectly to the subject matter of this article.

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