# Interventions for replacing missing teeth: different types of dental implants (Review)

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## TABLE OF CONTENTS

[Intervention Review]

# Interventions for replacing missing teeth: different types of dental implants

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## ABSTRACT

### Background

Dental implants are available in different materials, shapes and with different surface characteristics. In particular, numerous implant surface modifications have been developed for enhancing clinical performance.

### Objectives

To test the null hypothesis of no difference in clinical performance between various root-formed osseointegrated dental implant types.

### Search methods

We searched the Cochrane Oral Health Group's Trials Register, the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE and EMBASE. Handsearching included several dental journals. We checked the bibliographies of relevant clinical trials and review articles for studies outside the handsearched journals. We wrote to authors of the identified randomised controlled trials (RCTs), to more than 55 oral implant manufacturers; we used personal contacts and we asked on an internet discussion group in an attempt to identify unpublished or ongoing RCTs. No language restriction was applied. The last electronic search was conducted on 13 June 2007.

### Selection criteria

All RCTs of oral implants comparing osseointegrated implants with different materials, shapes and surface properties having a follow up of at least 1 year.

### Data collection and analysis

Screening of eligible studies, assessment of the methodological quality of the trials and data extraction were conducted in duplicate and independently by two review authors. Results were expressed as random-effects models using mean differences for continuous outcomes and risk ratios (RR) for dichotomous outcomes with 95% confidence intervals (CI).

**Main results**

Forty different RCTs were identified. Sixteen of these RCTs, reporting results from a total of 771 patients, were suitable for inclusion in the review. Eighteen different implant types were compared with a follow up ranging from 1 to 5 years. All implants were made in commercially pure titanium and had different shapes and surface preparations. On a 'per patient' rather than 'per implant' basis no significant differences were observed between various implant types for implant failures. There were statistically significant differences for perimplant bone level changes on intraoral radiographs in three comparisons in two trials. In one trial there was more bone loss only 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). In the other trial Southern implants displayed more bone loss at 5 years than Steri-Oss implants (mean difference -0.35 mm; 95% CI -0.70 to -0.01). However this difference disappeared in the meta-analysis. More implants with rough surfaces were affected by perimplantitis (RR 0.80; 95% CI 0.67 to 0.96) meaning that turned implant surfaces had a 20% reduction in risk of being affected by perimplantitis over a 3-year period.

**Authors' 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. These findings are based on a few RCTs, often at high risk of bias, with few participants and relatively short follow-up periods. More RCTs should be conducted, with follow up of at least 5 years including a sufficient number of patients to detect a true difference. Such trials should be reported according to the CONSORT recommendations (www.consort-statement.org/).

## PLAIN LANGUAGE SUMMARY

**Interventions for replacing missing teeth: different types of dental implants**

There is limited evidence showing that implants with relatively smooth surfaces are less prone to lose bone due to chronic infection (perimplantitis) than implants with rougher surfaces. On the other hand implants with a turned (smoother) surface might be at greater risk to fail early than implants with roughened surfaces. There is no evidence showing that any particular type of dental implant has superior long-term success.

Missing teeth can sometimes be replaced with dental implants into the jaw, as bone can grow around the implant. A crown, bridge or denture can then be attached to the implant. Many modifications have been developed to try to improve the long-term success rates of implants, and different types have been heavily marketed. More than 1300 types of dental implants are now available, in different materials, shapes, sizes, lengths and with different surface characteristics or coatings. However, the review found there is not enough evidence from trials to demonstrate superiority of any particular type of implant or implant system.

## BACKGROUND

Osseointegrated oral implants are available in different materials, body shapes, diameters, lengths, platforms, surface properties and coatings. In particular, the area of implant surface modifications and coatings has been subjected to aggressive marketing aimed at establishing the superiority of a given surface over the others. In implant dentistry, the word 'machined' has frequently been used as a description of a turned, milled or polished surface. However, a machined surface can be anything produced by a machine and surfaces produced with electro discharge, polish, ground, honed and sand blasting are all examples on machined surfaces (Stout 1990). 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 performance. 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 (Binon 2000). It is therefore important to know whether there are surface modifications, implant shapes or particular materials that can improve clinical results. This review looks at whether there are dif-

ferences in clinical performance among different implant types.

## OBJECTIVES

### 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 hypothesis 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 3 and 5 years in function.



## METHODS

### Criteria for considering studies for this review

#### Types of studies

All randomised controlled clinical trials (RCTs) of dental implants for replacing missing teeth comparing different implant types.

#### Types of participants

Patients who received osseointegrated root-formed dental implants and were followed up for at least 1 year with the implants functionally loaded.

#### Types of interventions

Implant treatment comparing dental implants for replacing missing teeth of different materials, shapes and/or surface properties.

#### Types of outcome measures

##### Primary outcomes

Implant failure defined as.

- Implant mobility and removal of stable implants dictated by progressive marginal bone loss or infection (biological failures). Biological failures were grouped as 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) prosthesis insertion, 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 outcomes

- Radiographic marginal bone level changes on intraoral radiographs taken with a paralleling technique.
- Occurrence of perimplantitis defined as implants affected by progressive marginal bone loss with signs of infection.

### Search methods for identification of studies

For the identification of studies 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 and was run with phases 1 and 2 of the Cochrane Sensitive Search Strategy for Randomised Controlled Trials (RCTs) as published in Appendix 5b.2 of the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6 (updated September 2006) and amended by the Cochrane Oral Health Group. *See* Appendix 1.

#### Searched databases

- The Cochrane Oral Health Group's Trials Register (to 13 June 2007).
- The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2007, Issue 2).
- MEDLINE (1966 to 13 June 2007).
- EMBASE (1980 to 13 June 2007).

The most recent electronic search was undertaken on 13 June 2007.

### Language

There were no language restrictions.

### Unpublished studies

We wrote to all the authors of the identified RCTs, we checked the bibliographies of all identified RCTs and relevant review articles, and we used personal contacts in an attempt to identify unpublished or ongoing RCTs. In the first version of this review we also wrote to more than 55 oral implant manufacturers and we requested information on trials through an Internet discussion group (implantology@yahoogroups.com), however we discontinued this due to poor yield.

### Handsearching

Details of the journals being handsearched by the Cochrane Oral Health Group's ongoing programme are given on the website: www.ohg.cochrane.org.

The following journals have been identified as being potentially important to be handsearched for this review: *British Journal of Oral and Maxillofacial Surgery*, *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *European Journal of Oral Implantology*, *Implant Dentistry*, *International Journal of Oral and Maxillofacial Implants*, *International Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *International Journal of Prosthodontics*, *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 review author up to the month in which the last electronic search was undertaken.

## Data collection and analysis

The titles and abstracts (when available) of all reports identified through the electronic searches were scanned independently by two review authors. For studies appearing to meet the inclusion criteria, or for which there were 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 review authors to establish whether the studies did meet the inclusion criteria or not. Disagreements were resolved by discussion. Where resolution was not possible, a third review author 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 'Characteristics of excluded studies' table, and the reasons for exclusion recorded.

### Quality assessment

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

Three main quality criteria were examined.

(1) Allocation concealment, recorded as:

(A) Adequate

(B) Unclear

(C) Inadequate, as described in the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6 (section 6.3).

Allocation concealment was considered adequate if it was centralised (e.g. allocation by a central office unaware of subject characteristics); pharmacy-controlled randomisation; prenumbered or coded identical containers which were administered serially to participants; on-site computer system combined with allocation kept in a locked unreadable computer file that can be accessed only after the characteristics of an enrolled patient have been entered; sequentially numbered, sealed, opaque envelopes; and other approaches similar to those listed above, along with the reassurance that the person who generated the allocation scheme did not administer it. Some schemes may be innovative and not fit any of the approaches above, but still provide adequate concealment. Approaches to allocation concealment which were considered clearly inadequate included any procedure that was entirely transparent before allocation, such as an open list of random numbers. Ideally the surgeon should have known the group allocation just before the treatment was delivered. Those articles or authors stating that allocation concealment procedures were implemented but did not provide details on how this was accomplished, were coded as 'unclear'.

(2) Treatment blind to outcome assessors, recorded as:

(A) Yes

(B) No

(C) Unclear

(D) Not possible.

(3) Completeness of follow up (is there a clear explanation for withdrawals and drop outs in each treatment group?) assessed as.

(A) No drop outs/yes. In the case that clear explanations for drop outs were given, a further subjective evaluation of the risk of bias assessing the reasons for the drop out was made.

(B) No.

After taking into account the additional information provided by the authors of the trials, studies were grouped into the following categories.

(A) Low risk of bias (plausible bias unlikely to seriously alter the results) if all criteria were met.

(B) 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 Handbook for Systematic Reviews of Interventions* 4.2.6 (section 6.7).

Further quality assessment was carried out to assess sample size calculations, definition of exclusion/inclusion criteria, and com-

parability of control and test groups at entry. The quality assessment criteria were pilot tested using several articles.

### Data extraction

Data were extracted by two review authors 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 review author 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.
Details of the outcomes reported, including method of assessment and time intervals.

### Data synthesis

For dichotomous outcomes, the estimates of effect of an intervention were expressed as risk ratios 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 implant.
Only if there were studies of similar comparisons reporting the same outcome measures was meta-analysis to be attempted. Risk ratios were combined for dichotomous data, and 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 (Elbourne 2002), using the generic inverse variance method in RevMan. The techniques described by Follmann (Follmann 1992) were used to estimate the standard error of the difference for split-mouth studies, where the appropriate data were not presented and could not be obtained.
The significance of any discrepancies in the estimates of the treatment effects from the different trials was to be assessed by means of Cochran's test for heterogeneity and the $I^2$ statistic, which describes the percentage total variation across studies that is due to heterogeneity rather than chance. Clinical heterogeneity was to be assessed by examining the types of participants and interventions for all outcomes in each study. It was planned to undertake sensitivity analyses to examine the effect of the study quality assessment on the overall estimates of effect. In addition, the effect of including unpublished literature on the review's findings was also to be examined, but there were insufficient trials to undertake this.

The following subgroup analyses were planned only for trials included to answer the primary hypothesis, however there were insufficient studies in the meta-analysis to undertake this.

(1) Whether implants were placed in mandibles or maxillae.
(2) Whether implants were placed in partially or fully edentulous jaws.
(3) Different number of placed implants (for instance overdentures supported by two versus overdentures supported by four implants).
(4) Whether the implants were immediately placed in tooth extraction sockets or not.
(5) Whether the implants were placed in anterior or posterior areas of the jaw.
(6) Whether the implants were placed in augmented (grafted or regenerated) bone or not.
(7) Whether the implants were placed with a submerged or non-submerged technique.
(8) Whether the implants were loaded at different times: immediate loading (up to 1 week) and conventional loading (3 months or more for mandibles and 6 months or more for maxillae).
(9) Different prosthetic designs (for instance overdentures versus screw-retained dentures or implant-supported bridges versus bridges supported by both implants and teeth).
(10) Whether the trial was supported by implant manufacturer(s) or not.

## RESULTS

### Description of studies

See: Characteristics of included studies; Characteristics of excluded studies; Characteristics of ongoing studies.
*See* Characteristics of included studies table.
*See* Characteristics of excluded studies table.

#### Characteristics of the trial setting and investigators

Of the 40 eligible trials (Friberg 1992; Gher 1994; Geertman 1996; Boerrigter 1997; Jones 1997; Kemppainen 1997; Truhlar 1997; Batenburg 1998; Karlsson 1998; Åstrand 1999; Reingewirtz 2000; van Steenberghe 2000; Khang 2001; Moberg 2001; Roccuzzo 2001; Tawse-Smith 2001; Gatti 2002; Geurs 2002; Heydenrijk 2002; Karabuda 2002; Mau 2002; Tawse-Smith 2002; Tomatis 2002; Åstrand 2002; Friberg 2003; Joly 2003; Mau 2003; Payne 2003; Rocci 2003; Testori 2003; Åstrand 2003; da Cunha 2004; Payne 2004; Wennström 2004; Fröberg 2006; Shin 2006; Du Preez 2007; Lang 2007; Schincaglia 2007; Stavropoulos 2007), 24 trials (Friberg 1992; Gher 1994; Geertman 1996; Boerrigter 1997; Jones 1997; Truhlar 1997; Karlsson 1998; Reingewirtz 2000; van Steenberghe 2000; Khang 2001; Roccuzzo 2001; Geurs 2002; Karabuda 2002; Mau 2002; Tomatis 2002; Joly 2003; Mau 2003; Rocci 2003; Testori 2003; Åstrand 2003; da Cunha

2004; Wennström 2004; Shin 2006; Du Preez 2007) were excluded due to problems with the data presented. Of the 16 included trials (Kemppainen 1997; Batenburg 1998; Åstrand 1999; Moberg 2001; Tawse-Smith 2001; Gatti 2002; Heydenrijk 2002; Tawse-Smith 2002; Åstrand 2002; Friberg 2003; Payne 2003; Payne 2004; Fröberg 2006; Lang 2007; Schincaglia 2007; Stavropoulos 2007), five were conducted in Sweden (Åstrand 1999; Moberg 2001; Åstrand 2002; Friberg 2003; Fröberg 2006), four in New Zealand (Tawse-Smith 2001; Tawse-Smith 2002; Payne 2003; Payne 2004), two in The Netherlands (Batenburg 1998; Heydenrijk 2002), two in Italy (Gatti 2002; Schincaglia 2007) one in Finland (Kemppainen 1997), one in Denmark (Stavropoulos 2007) and one was a multicentre European trial (Lang 2007). Twelve trials had a parallel group study design and four a split-mouth design (Åstrand 2002; Friberg 2003; Fröberg 2006; Schincaglia 2007). Twelve trials received support from industry (Kemppainen 1997; Batenburg 1998; Åstrand 1999; Tawse-Smith 2001; Tawse-Smith 2002; Åstrand 2002; Friberg 2003; Payne 2003; Payne 2004; Lang 2007; Schincaglia 2007; Stavropoulos 2007). All trials were conducted at university dental clinics or hospitals with three exceptions: two trials conducted in private practices (Gatti 2002; Fröberg 2006), and the multicentre trial (Lang 2007) in which a few centres were private practices. All studies included adults only.

### Characteristics of the interventions

Eighteen implant types with different modified surfaces were compared. Since we found discrepancies about the surface characteristics of the implants described in the reporting of two trials (Tawse-Smith 2001; Tawse-Smith 2002) and the manufacturer specification, it was decided to independently characterise the surface roughness of these implants.
(1) Astra® $TiO_2$-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 III type turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(6) Brånemark® Mark III TiUnite oxidized titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(7) Brånemark® Mark IV type (prototype) turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(8) Brånemark® Mark IV type turned titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(9) Brånemark® Mark IV TiUnite oxidized titanium grade one screws (Nobel Biocare AB, Göteborg, Sweden).
(10) IMZ® TPS (titanium plasma-sprayed) titanium grade two cylinders (Friedrichsfeld AG, Mannheim, Germany).
(11) ITI® TPS hollow titanium grade four screws and cylinders (Institut Straumann AG, Waldenburg, Switzerland).
(12) ITI® TPS solid titanium grade four cylindrical screws (Institut Straumann AG, Waldenburg, Switzerland).
(13) ITI® SLA solid sand-blasted large-grit acid-etched titanium grade four cylindrical screws (Institut Straumann AG, Waldenburg, Switzerland).
(14) ITI® SLA solid sand-blasted large-grit acid-etched titanium grade four tapered screws (Institut Straumann AG, Waldenburg, Switzerland).
(15) Southern® sand-blasted acid-etched titanium grade four screws (Southern Implants Irene, South Africa).
(16) Steri-Oss® HL series, 3.8 mm in diameter acid-etched titanium grade four screws (Steri-Oss, Yorba Linda, California, USA).
(17) 3i® full Osseotite sand-blasted acid-etched titanium grade four screws (Biomet 3i, Palm Beach Gardens, FL, USA).
(18) 3i® dual (turned surface in the coronal 2 mm portion) Osseotite sand-blasted acid-etched titanium grade four screws (Biomet 3i, Palm Beach Gardens, FL, USA).
In principle four types of surface modifications were analysed.
(1) Surface with a clear orientation of the irregularities due to the cutting procedure during turning (Brånemark turned implants).
(2) Surfaces without a domination direction (orientation) treated with techniques that remove material during manufacturing (Astra, ITI SLA, Steri-Oss, Southern implants, 3i).
(3) Surface without a dominating direction treated with a process that add material to the surface, plasma-spraying (IMZ TPS and ITI TPS implants).
(4) Oxidized surface without a dominating direction (Brånemark TiUnite implants).
Implants could be grouped according to their shape in four main categories: cylindrical screws (Brånemark, ITI SLA, some of the ITI TPS, Steri-Oss, Astra, Southern implants, 3i), hollow cylinders/screws (some of the ITI TPS implants), cylinders (IMZ implants), and tapered screws (ITI).
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, IMZ, 3i, and some ITI 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 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 one trial IMZ implants (Heydenrijk 2002) were used according to a one-stage protocol.

Implants were placed in edentulous mandibles (Batenburg 1998; Åstrand 1999; Moberg 2001; Tawse-Smith 2001; Gatti 2002; Heydenrijk 2002; Tawse-Smith 2002; Payne 2003; Fröberg 2006) and maxillae (Åstrand 1999; Payne 2004). Partially edentulous maxillae were treated in one trial (Åstrand 2002). Partially edentulous posterior mandibles were included in one trial (Schincaglia 2007). Implants placed in sinuses augmented with particulated bone from mandibular symphyses were evaluated in one trial (Stavropoulos 2007). Another study included fully and partially edentulous mandibles and maxillae, however, the majority were edentulous maxillae (Friberg 2003). Single implants were used in both maxillae and mandibles in two studies (Kemppainen 1997; Lang 2007), one of the latter trials included only immediate implants in fresh extraction sockets (Lang 2007) which could be augmented with Bio-Oss and bioresorbable barriers. In one trial (Payne 2004) 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 (Payne 2004) maxillary overdentures were attached to implants 12 weeks after implant placement. In another study (Tawse-Smith 2002) 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 (Payne 2003) whereas in another three trials implants were immediately loaded (Gatti 2002; Fröberg 2006; Schincaglia 2007).

Cross-arch fixed prostheses were retained by screws on four to six implants (Åstrand 1999; Moberg 2001; Friberg 2003; Fröberg 2006). Removable overdentures were retained by clip attachments to a bar supported by two (Batenburg 1998; Heydenrijk 2002) or four implants (Gatti 2002), or were retained by two (Tawse-Smith 2001; Tawse-Smith 2002; Payne 2003) or three (Payne 2004) ball attachments. Partial bridges were screw-retained on two to four implants (Åstrand 2002; Friberg 2003; Schincaglia 2007). Crowns were cemented on single implants (Kemppainen 1997; Lang 2007). Crowns and partial fixed bridges were cemented ( Stavropoulos 2007) and could not be removed to test implant stability.

### Characteristics of outcome measures

The main or primary outcomes (biological and mechanical failures) were recorded in all studies. The only exception was one trial (Stavropoulos 2007) where partial fixed restorations were cemented and could not be removed to assess implant stability.

The secondary outcomes (bone level measurements) were recorded in all trials. However, in two trials (Moberg 2001; Gatti 2002) perimplant 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 one trial the measurements of 78 implant surfaces out of 178 were missing, therefore the radiographic data were not used (Fröberg 2006). In another trial (Heydenrijk 2002) bone level assessment was calculated on a site basis and the authors were not able to supply the required data (patient basis). The 5-year data of another trial (Åstrand 1999) 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 (Åstrand 2002) could not be used since we did not have the standard deviation of the difference. Bone level changes data are not yet available for an ongoing study (Lang 2007).

### Study duration (including unpublished data kindly provided by the investigators)

1 year (Kemppainen 1997; Friberg 2003; Payne 2004; Lang 2007; Schincaglia 2007; Stavropoulos 2007). For one ongoing trial a 3-year follow up is expected (Lang 2007).
1 year and a half (Fröberg 2006).
2 years (Gatti 2002).
3 years (Moberg 2001; Åstrand 2002; Payne 2003).
5 years (Batenburg 1998; Åstrand 1999; Tawse-Smith 2001; Tawse-Smith 2002; Heydenrijk 2002).

## Risk of bias in included studies

The agreed quality of the included trials after having incorporated the information provided by the authors is summarised in 'Additional Table 1.' For each trial we assessed whether it was at low or high risk of bias. All studies were rated as at high risk of bias, with one exception (Lang 2007).

### Allocation concealment

Allocation was concealed in two trials (Lang 2007; Stavropoulos 2007). It was considered unclear for all other trials despite author clarifications, with five exceptions (Batenburg 1998; Gatti 2002; Åstrand 2002; Friberg 2003; Schincaglia 2007). According to the information provided by these authors, the randomisation procedure was not concealed to clinicians. No reply was obtained for three trials (Moberg 2001; Heydenrijk 2002; Fröberg 2006).

### 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 recognisable. However, in one trial an independent assessor was used (Schincaglia 2007), in another trial (Åstrand 1999) an independent assessor made the radiographic evaluations. In another trial

(Batenburg 1998) radiographs were read not in sequence per patient. In other four trials implant stability could have been measured by blinded assessors but this was not done (Kemppainen 1997; Gatti 2002; Friberg 2003; Stavropoulos 2007). Only in one study outcome assessors were masked (Lang 2007), for another trial no information was supplied (Fröberg 2006).

### Withdrawals

The reporting of withdrawals was adequate for all trials with two exceptions (Batenburg 1998; Payne 2004). However, authors supplied the missing information.

### Sample size

Only two studies undertook a priori sample size calculations ( Åstrand 1999; Schincaglia 2007). In one study (Åstrand 1999) the sample size was calculated to detect a true difference of 0.4 mm in marginal bone levels thought to be of clinical significance. Another study (Schincaglia 2007) calculated the sample size considering the implant as statistical unit but this is not correct. One multicentre study (Lang 2007) did not report any sample size calculation, but the sample it is believed to be sufficiently large (208 patients) to detect a statistically significant difference, if any.

### Inclusion/exclusion criteria

For more details *see* Characteristics of included studies table.

#### Main inclusion criteria

Edentulous mandibles of 8 to 15 mm of bone height (Payne 2003).
Edentulous mandibles of 13 to 15 mm of bone height (Tawse-Smith 2001; Tawse-Smith 2002).
Edentulous mandibles allowing placement of implants at least 9 mm long (Gatti 2002).
Edentulous mandibles (Moberg 2001; Fröberg 2006).
Severely resorbed edentulous mandibles (Batenburg 1998; Heydenrijk 2002).
Edentulous maxillae (Payne 2004).
Edentulous mandibles and maxillae not needing augmentation procedures (Åstrand 1999).
Partially edentulous jaw bone of at least 10 mm in height and 6 mm wide (Kemppainen 1997).
Partially edentulous maxillae not needing augmentation procedures (Åstrand 2002).
Bilateral partially edentulous posterior mandibles requiring at least two implants each (Schincaglia 2007).
Healed edentulous distal jaws (premolar/molar regions) of soft type bone quality (type III or IV according to Lekholm 1985 (Friberg 2003).
Partially edentulous augmented sinuses (preaugmentation bone height 2 to 9 mm) (Stavropoulos 2007).
Patients > 21 years needing an immediate postextractive implant in the aesthetic zone (premolar to premolar) between two adjacent teeth (Lang 2007).

#### Main exclusion criteria

Radiotherapy in the head and neck region (Kemppainen 1997; Batenburg 1998; Gatti 2002; Tawse-Smith 2001; Heydenrijk 2002; Tawse-Smith 2002; Åstrand 2002; Payne 2003).
Severe intermaxillary skeletal discrepancy (Gatti 2002).
Severe clenching and bruxism (Gatti 2002; Åstrand 2002).
Any history of bruxism (Tawse-Smith 2001; Tawse-Smith 2002; Payne 2003; Payne 2004).
Drug or alcohol abuse or both (Kemppainen 1997; Moberg 2001; Gatti 2002; Åstrand 2002).
Uncontrolled diabetes (Kemppainen 1997; Gatti 2002; Fröberg 2006).
Any evidence of previous and current smoking (Tawse-Smith 2001; Tawse-Smith 2002; Payne 2003; Payne 2004).
Smoking more than 10 cigarettes per day (Gatti 2002; Lang 2007).
Smoking more than 20 cigarettes per day (Åstrand 2002).
Current steroid treatment (Gatti 2002; Åstrand 2002).
Current chemotherapy treatment (Gatti 2002; Åstrand 2002).
Very soft bone (Tawse-Smith 2001; Tawse-Smith 2002; Payne 2003).
Grafted or regenerated bone (Friberg 2003; Payne 2004; Schincaglia 2007).
Extremely resorbed maxillae (Payne 2004).
Extraction sites < 4 months (Schincaglia 2007).
Insertion torque < 20 Ncm and implant stability quotient (ISQ) < 60 (Schincaglia 2007).
Different opposing occlusion bilaterally (Schincaglia 2007).
Presence of sinus pathology (Stavropoulos 2007).
Periodontal bone loss > 20% at the adjacent teeth (Lang 2007).
Full-mouth plaque and bleeding scores > 25% at baseline (Lang 2007).
Teeth to be replaced affected by periodontal disease (Lang 2007).
Presence of symptomatic periapical radiolucencies, acute abscesses or chronic sinus tracts at the implant site (Lang 2007).
Lack of primary implant stability (Lang 2007).
Less than 7 mm of mesio-distal space between the adjacent teeth (Lang 2007).
Less than 2 mm of keratinized mucosa (Lang 2007).

### 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 (Åstrand 1999), eight patients treated with Brånemark implants were scored as having type four bone quality (very soft bone) according to the Lekholm and Zarb classification (Lekholm 1985) versus one patient in the Astra group.

In another trial (Kemppainen 1997), 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 (Heydenrijk 2002).

## Effects of interventions

In total, 1854 implants (617 turned and 1237 implants with roughened surfaces) were originally placed in 771 patients (375 mandibles and 396 maxillae) in the 16 trials. During the follow-up period considered in this review (1, 3 and 5 years) there were 62 implant failures (two because of implant fracture in the same patient). Thirty-eight of the failed implants had a roughened surface and 24 had a turned surface. In particular, there were 42 early implant failures (25 implants had a roughened surface) and 20 late failures (13 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 1, 3 and 5 years are presented in 'Comparisons 1 to 3'.

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

Three trials were included in the following comparisons:

#### Brånemark Mark III implants: turned versus TiUnite oxide surface

One trial with a split-mouth design (Fröberg 2006) compared three Brånemark Mark III implants with turned surface versus three Brånemark Mark III with a TiUnite oxide surface supporting screw-retained metal-ceramic full bridges for 1 year. The implants were immediately loaded. Fifteen patients were included. No baseline differences for position, implant stability quotient, implant length appeared between the two groups. No withdrawals nor failures occurred during the study period and the risk ratio value was therefore inestimable (data not shown).

#### Brånemark Mark IV implants: turned versus TiUnite oxide surface

One trial with a split-mouth design (Schincaglia 2007) compared two or three Brånemark Mark IV implants with turned surface versus two Brånemark Mark IV with a TiUnite oxide surface supporting screw-retained metal-ceramic prostheses for 1 year. The implants were immediately loaded. Ten patients were included. No baseline differences for position, insertion torque values, implant length appeared between the two groups with the exception that two out of 10 bridges supported by the turned implants included three implants. No withdrawals. One implant with a turned surface failed 3 months after placement. Another turned implant displayed rotational mobility 1 month after placement, but was retightened and put out of occlusion. Two months later the implant was stable and was used to support the definitive restoration. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures (data not shown) and marginal bone level changes ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.7') of the different surfaces.

#### 3i implants: full versus dual Osseotite surface

One trial with a parallel group design (Stavropoulos 2007) compared one to three 3i implants in augmented sinus having full or dual (the coronal 2 mm were turned) Osseotite surfaces supporting cemented metal-ceramic prostheses for 1 year. Thirteen patients were included in each group. There did not appear to be any baseline differences for age, sex, smoking, bone height above the sinus and number of implants. No withdrawals. Four (three early failures) out of 17 full Osseotite implants and two (one early failure) out of 18 dual Osseotite implants failed. All failures occurred in different patients. We did not use data for implant failures in our calculation since the prosthesis could not be removed to evaluate the stability of individual implants. Considering the patient as the unit for the analysis, there was no statistically significant difference for marginal bone level changes ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.11') of the different surfaces.

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

Three trials were included in the following comparisons:

#### Brånemark Mark II type versus Brånemark conical transmucosal implants

One trial with a parallel group design (Gatti 2002) compared four Brånemark Mark II type screws with four Brånemark conical transmucosal screws supporting mandibular overdentures for 2 years. The implants were immediately loaded. Five patients were included in each 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 risk ratio value was therefore inestimable ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.3').

**Brånemark standard versus Brånemark Mark IV prototype implants**

One trial with a split-mouth design (Friberg 2003) 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. Eight withdrawals occurred (three due to death, two due to poor compliance and three patients wished to be excluded). Eight implants failed: five Mark II (three early failures) and three Mark IV (three early failures) in eight different patients. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.4') and marginal bone level changes ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.3') of the different implants after 1 year of function.

**ITI cylindrical versus ITI tapered**

One trial with a parallel group design (Lang 2007) compared single immediate postextractive ITI SLA implants of cylindrical versus tapered design for 1 year. One hundred and four patients were included in each group. There did not appear to be any baseline differences for age, sex, smokers, full mouth plaque and bleeding scores, and implant location. No withdrawals nor failures occurred during the study period and the risk ratio value was therefore inestimable ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.12').

**(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 (Åstrand 1999) 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 four bone quality (very soft bone) according to the Lekholm and Zarb classification (Lekholm 1985) 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 failure ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.1'; 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.1' and 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.1') nor for marginal bone level changes between the implant systems after 5 years of function ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.1' and 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.1').

**Astra versus ITI implants**

One trial (Kemppainen 1997) 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 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.2') and marginal bone level changes between the implant systems after 1 year of function ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.2').

**Brånemark versus IMZ implants**

One trial (Batenburg 1998) 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.6'; 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.3';

'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.2'). However there was significantly more bone loss for the IMZ implant group at 1 year with mean difference 0.60 mm (95% confidence interval (CI) 0.10 to 1.10), but no significant differences at years 3 and 5 ('Comparison 1', 'Outcome 1.2', Subcategory 1.2.5'; 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.2'; 'Comparison 3', 'Outcome 3.2', 'Subcategory 3.2.1').

**Brånemark versus ITI implants**

Three trials compared submerged Brånemark versus non-submerged ITI TPS implants (Batenburg 1998; Moberg 2001; Åstrand 2002).

One trial with a parallel group design (Batenburg 1998) 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.7'; 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.4'; 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.3') and marginal bone level changes ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.6'; 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.3'; 'Comparison 3', 'Outcome 3.2', 'Subcategory 3.2.2') between the implant systems after 5 years of function.

One trial with a parallel group design (Moberg 2001) 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.7' and 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.4').

A meta-analysis of the two above studies (Batenburg 1998; Moberg 2001) 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.7' and 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.4').

One split-mouth trial (Åstrand 2002) 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 five 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.5' and 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.4') after 3 years of function and for the marginal bone level changes between the implant systems after 1 year of function ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.4').

**Brånemark TiUnite versus Southern implants**

One trial (Payne 2004) 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 (five Brånemark and 10 Southern implants). Considering the patient as the unit for the analysis, there was no statistically significant difference for failures ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.8') and marginal bone level changes between the implant systems after 1 year of function ('Comparison 1', 'Outcomes 1.2', 'Subcategory 1.2.9').

**IMZ versus ITI implants**

Two trials compared IMZ TPS cylinders with ITI TPS implants (Batenburg 1998; Heydenrijk 2002).

One trial (Batenburg 1998) with a parallel group design compared two submerged IMZ TPS cylinders versus two non-sub-

merged 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.9'; 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.5'; 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.4'). There was significantly more bone loss for IMZ at 1 year, with mean difference = 0.50 mm (95% CI 0.01 to 0.99), however there were no significant differences in marginal bone level changes between the implant systems after 3 or 5 years of function ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.8'; 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.4'; 'Comparison 3', 'Outcome 3.2', 'Subcategory 3.2.3').

One trial (Heydenrijk 2002) with a parallel group design compared two non-submerged IMZ TPS cylinders versus two non-submerged ITI TPS solid screws supporting overdentures in edentulous mandibles for 5 years. Twenty patients were included in each group. It was unclear whether there were any baseline differences for the two groups. Two patients dropped out from ITI group (one died before the 3-year follow up and the other become ill after the 3-year follow up), and one from the IMZ group (moved abroad after the 3-year follow up). One IMZ implant failed (late failure). Radiographs were missing for two patients, one from each group. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures between the implant systems after 5 years of function ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.10'; 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.6'; 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.5').

### ITI versus Southern implants

One trial (Payne 2003 including unpublished data) 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 years. 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 risk ratio value, however considering the patient as the unit for the analysis, there was no statistically significant difference for marginal bone level changes between the implant systems after 3 years of function ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.8' and 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.5').

### Southern versus Steri-Oss implants

Two trials (Tawse-Smith 2001; Tawse-Smith 2002) 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 (Tawse-Smith 2001), whereas in the other the implants were early loaded at 6 weeks (Tawse-Smith 2002). 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 (Tawse-Smith 2001 and unpublished data) 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 four 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.13'; Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.8' and 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.6') and marginal bone level changes between the implant systems after 5 years of function ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.10'; 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.6' and 'Comparison 3', 'Outcome 3.2', 'Subcategory 3.2.4').

The other trial (Tawse-Smith 2002 and unpublished data) 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 four bone (Lekholm 1985) 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 ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.13'; Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.8' and 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.6'), 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) ('Comparison 3', 'Outcome 3.2', 'Subcategory 3.2.4'). Meta-analyses of the two above studies (Tawse-Smith 2001; Tawse-Smith 2002) were done. Considering the patient as the unit for the analysis, there was no statistically significant difference for failures ('Comparison 1', 'Outcome 1.1', 'Subcategory 1.1.11'; 'Comparison 2', 'Outcome 2.1', 'Subcategory 2.1.8' and 'Comparison 3', 'Outcome 3.1', 'Subcategory 3.1.6') and marginal bone level changes ('Comparison 1', 'Outcome 1.2', 'Subcategory 1.2.10'; 'Comparison 2', 'Outcome 2.2', 'Subcategory 2.2.6' and 'Comparison 3', 'Outcome 3.2', 'Subcategory 3.2.4') 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 'Comparison 4', 'Outcome 4.1'. Three trials were included (Batenburg 1998; Åstrand 1999; Moberg 2001). The data from four split-mouth trials (Åstrand 2002; Wennström 2004; Fröberg 2006; Schincaglia 2007) could not be included as we were unable to calculate the effect estimate for the paired data due to the zeros. All these trials with one exception in which no failures occurred (Fröberg 2006) showed one early implant failure of implants with a turned surface versus no failure for implants with roughened surfaces. 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, though trends clearly favoured implants with roughened surfaces.

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

A meta-analysis comparing the occurrence of perimplantitis between various implants with turned and roughened surfaces at 3 years is presented in 'Comparison 2', 'Outcome 2.3'. Three trials were included (Åstrand 1999; Moberg 2001; Åstrand 2002). 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 (risk ratio (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 (Batenburg 1998) 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 (Åstrand 1999) comparing the occurrence of perimplantitis between various implants with turned and roughened surfaces at 5 years and is presented in 'Comparison 3', 'Outcome 3.3'. 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 (Batenburg 1998) no data were presented and the author did not reply to our request for information.

## DISCUSSION

In order to properly compare 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 (test versus control group) whereas all the other parameters are identical. This was not done in the majority of the included randomised controlled trials (RCTs), as these trials compared implants with 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, early or immediate loading 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 three trials (Fröberg 2006; Schincaglia 2007; Stavropoulos 2007) testing different implant surfaces, though sample sizes were too small to possibly detect a statistically significant difference, if any, and three trials (Gatti 2002; Friberg 2003; Lang 2007) testing different designs of the Brånemark and ITI 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, in one trial (Gatti 2002), whereas for the other two trials (Friberg 2003; Lang 2007) it can be concluded that significant clinical differences among the tested different implant designs do not exist. No trial described implants made or coated with other materials.

In general, high success rates were reported for all implant systems. 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 (Batenburg 1998) there was more bone loss at 1 year for IMZ implants compared to Brånemark (mean difference 0.60 mm; 95% confidence interval (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 (Tawse-Smith 2002) 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 (Tawse-Smith 2001) 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 (Esposito 2001b). 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 (Moberg 2001; Åstrand 2002). Of particular interest is a split-mouth study (Åstrand 2002) 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 meta-analysis of three trials (Batenburg 1998; Åstrand 1999; Moberg 2001) evaluating whether implants with a turned surface are at higher risk of early implant failures indicated a clear trend towards more failures of implants with turned surfaces. The data of three additional split-mouth studies (Åstrand 2002; Wennström 2004; Schincaglia 2007) could not be used in the meta-analysis because both studies had one failure in the turned group and none in the roughened group. Because there was only one event in one group and none in the other group, we were unable to calculate risk ratios. A fourth excluded trial (Karlsson 1998) showed also two failures in the turned group versus none in the roughened surface group. All these data suggest that implants with a turned surface are at higher risk of early failures.

Another interesting observation is that all the implant fractures reported (five in total; two fractured implants in one patient in Åstrand 1999, and three fractured implants in three patients in Wennström 2004) occurred in a single implant system (Astra). It is possible that the early design of this implant with an internal connection had some structural weakness, which has been corrected when the problem became known to the manufacturer.

The most important observation is that no differences in failure rates were observed among various implant types. However, only two trials (Åstrand 1999; Schincaglia 2007) undertook a sample size calculation. Both trials were 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. However, 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 (Benn 1992). 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. The only exception was a multicentre trial (Lang 2007) in which tapered and a cylindrical-shaped ITI implants were evaluated. Since the sample size was quite large (104 patients in each group), it is possible to conclude that no apparent significant clinical differences were observed, therefore, clinicians can choose the implant design they prefer without a significant risk of compromising the final outcome.

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 (Tawse-Smith 2001; Tawse-Smith 2002) 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.

Only two trials appeared to use an adequate procedure for allocation concealment of the randomisation process (Lang 2007; Stavropoulos 2007). 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 (Schulz 1995a; Schulz 1995b). Due to this reason all trials but one (Lang 2007) 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 minimise detection bias were done: independent and masked outcome assessors were used in one multicentre trial (Lang 2007), an independent outcome assessor was used in one trial (Åstrand 1999), while in another trial the radiographic reading of bone levels was not done in sequence and not per patient (Batenburg 1998). Investigators should always consider using independent assessors or any other possible means when proper blinding is not possible to minimise detection bias. Due to the low number of trials included in the meta-analyses it was not possible to implement the planned sensitivity analysis to investigate to which extent the risk of bias might have influenced the results. This will be done in future updates as soon as sufficient number of trials having different quality scores will be available.

In another investigation, it was found that the design, analysis and reporting of RCTs on oral implants were generally poor ( Esposito 2001a). 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 (Tawse-Smith 2002) could support this suggestion.

Twelve of the 16 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.

# AUTHORS' CONCLUSIONS

## Implications for practice

Based on the available results of randomised controlled trials (RCTs), there is no evidence showing that any particular type of dental implant has superior long-term success. There is limited evidence showing that implants with relatively smooth (turned) surfaces are less prone to lose bone due to chronic infection (peri-implantitis) than implants with rougher surfaces. There is a tendency for implants with a turned surface to fail early more often than implants with roughened surfaces. There appears to be no clinical significant differences when using a cylindrical or tapered ITI immediate implant in postextractive sockets. No trial described implants made or coated with materials other than titanium. These conclusions are based on RCTs with relatively short follow-up periods, few patients and 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.

### Implications for research

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 minimise detection bias;

- a sufficient duration (5 years or more).

Such trials should be reported according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Moher 2001) (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 minimising the numerous confounding factors such as different implant shapes or clinical procedures.

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Schulz KF. Subverting randomization in controlled trials. *JAMA* 1995;**274**(18):1456–8.

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**Esposito 2003**
Esposito M, Worthington HV, Thomsen P, Coulthard P. Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database of Systematic Reviews* 2003, Issue 3. [Art. No.: CD003815. DOI: 10.1002/14651858.CD003815]

**Esposito 2005a**
Esposito M, Coulthard P, Thomsen P, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database of Systematic Reviews* 2005, Issue 1. [Art. No.: CD003815. DOI: 10.1002/14651858.CD003815.pub2]

**Esposito 2005b**
Esposito M, Coulthard P, Thomsen P, Worthington HV. The role of implant surface modifications, shape and material for the success of osseointegrated dental implants. A Cochrane systematic review. *The European Journal of Prosthodontics and Restorative Dentistry* 2005;**13**(1):15–31.

**Esposito 2005c**
Esposito M, Grusovin MG, Coulthard P, Thomsen P, Worthington HV. A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems: a systematic review of randomized controlled clinical trials. *The International Journal of Oral and Maxillofacial Implants* 2005;**20**(4):557–68.

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Esposito M, Grusovin MG, Coulthard P, Thomsen P, Worthington HV. A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems. A systematic review of randomized controlled clinical trials. *Implantologia* 2006;**4**:59–72.


* *Indicates the major publication for the study*

## CHARACTERISTICS OF STUDIES

### Characteristics of included studies *[ordered by study ID]*

**Batenburg 1998**

| | |
|---|---|
| Methods | 5-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. 2 withdrawals in the ITI group (death unrelated to treatment). At the 5-year examination 3 patients of the Brånemark group and 2 of the IMZ group were unable to attend due to sickness |
| Participants | Edentulous patients for at least 2 years with severely resorbed mandibles (class V-VI according to the classification of Cawood and Howell 1988). Patients subjected to radiotherapy in the head and neck region or preprosthetic surgery or previous oral implantology were excluded. Adults treated in the University Hospital of Groningen, The Netherlands. 90 enrolled (30 patients in each group) and results given for 88 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) submerged turned titanium screws versus ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged hollow titanium plasma-sprayed screws versus IMZ® (Friedrichsfeld AG, Mannheim, Germany) submerged titanium plasma-sprayed cylinders supporting overdentures on 2 implants connected with a bar |
| Outcomes | Periotest and tapping the implant with superstructures removed, sensibility of lip and chin, marginal bone level changes on standardised intraoral radiographs, plaque accumulation, calculus, bleeding on probing, mucosa score, probing pocket depth, mucosa recession, width of attached perimplant mucosa. 1-, 3- and 5-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | No | C - Inadequate |

**Friberg 2003**

| | |
|---|---|
| Methods | 1-year follow-up randomised, split-mouth study. Outcome assessors could only be partially blinded, but were not. 8 withdrawals (3 died, 2 had a poor compliance and 3 wished to be excluded) |
| Participants | Patients with totally or bilaterally edentulous jaws and with type bone quality 3 (soft bone) or 4 (very soft bone) according to the Lekholm and Zarb classification and healed extraction sockets. Patients subjected to bone augmentation procedures were excluded. Adults treated in 3 different specialist clinics/hospitals, Sweden. 44 enrolled and results given for 36 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) standard submerged turned titanium screws versus Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark IV prototype submerged turned titanium screws supporting fixed prostheses |

**Friberg 2003** (*Continued*)

| | |
|---|---|
| Outcomes | Insertion torque (Osseocare), wobbling during insertion, implant stability, resonance frequency with superstructures removed, sensibility of lip and chin, marginal bone level changes on standardised intraoral radiograph. 1-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | No | C - Inadequate |

**Fröberg 2006**

| | |
|---|---|
| Methods | 1 year and a half follow-up randomised, split-mouth study. Unclear whether outcome assessors were blinded, but were not. No withdrawals |
| Participants | Patients with edentulous mandibles. Exclusion criteria were: systemic diseases resulting in increased risk of infection and impaired healing, serious cardiac diseases, deficient homeostasis and blood dyscrasias, anticoagulant medication, psychological diseases, uncontrolled acute infections. Adults treated in a private dental practice in Nässjö, Sweden. 15 enrolled and results given for 15 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark III TiUnite oxidized versus Mark III turned immediately loaded titanium screws supporting screw-retained cross-arch fixed bridges |
| Outcomes | Implant stability (resonance frequence analysis), marginal bone level changes on standardised intraoral radiographs, and marginal bleeding index |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | D - Not used |

**Gatti 2002**

| | |
|---|---|
| Methods | 2-year follow-up randomised, parallel group study. Outcome assessors could only be partially blinded, but were not. No withdrawals |
| Participants | Edentulous patients for at least 3 months with mandibles having a residual bone height in the interforaminal area adequate to harbour 4 implants at least 9 mm long. Exclusion criteria were: severe intermaxillary skeletal discrepancy, strong gagging reflex, severe clenching or bruxism, previous implant surgery in the interforaminal area, drug or alcohol abuse, moderate or heavy smoking (more than 10 cigarettes/day), radiotherapy in the head and neck region or treatment with antiblastic chemotherapeutics, chronic liver and renal disease, uncontrolled diabetes, haemophilia or other bleeding disorders or treatment with cumarin, |

**Gatti 2002** (*Continued*)

| | |
|---|---|
| | metabolic bone disorders, immunocompromised conditions including human immunodeficiency virus, current steroid treatment, current pregnancy, general contraindications for surgical procedures, physical or psychiatric handicaps that could interfere with good oral hygiene, presence of mucosal disease such as lichen planus. Adults treated in a private dental practice in Milan, Italy. 10 enrolled (5 patients in each group) and results given for 10 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark II type non-submerged turned titanium screws versus Brånemark® (Nobel Biocare AB, Göteborg, Sweden) conical transmucosal screws used without abutments supporting overdentures on 4 implants connected with a bar and immediately loaded |
| Outcomes | Implant stability, marginal bone level changes on intraoral radiographs taken with a paralleling technique and on intraoral panoramic radiographs, plaque accumulation, gingival index, probing pocket depth. 1- and 3-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | No | C - Inadequate |

**Heydenrijk 2002**

| | |
|---|---|
| Methods | 5-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. 3 withdrawals: 2 from the ITI goup for death (year 3) and illness (year 4) and 1 from the IMZ group for moving (year 4) |
| Participants | Edentulous patients for at least 2 years with severely resorbed mandibles (class V-VI according to the classification of Cawood and Howell 1988). Patients subjected to radiotherapy in the head and neck region or preprosthetic surgery or previous oral implantology were excluded. Adults treated in the University Hospital of Groningen, The Netherlands. 40 enrolled (20 patients in each group) and results given for 37 |
| Interventions | IMZ® (Friedrichsfeld AG, Mannheim, Germany) non-submerged titanium plasma-sprayed cylinders versus ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged solid titanium plasma-sprayed screws supporting overdentures on 2 implants connected with a bar |
| Outcomes | Periotest, marginal bone level changes on standardised intraoral radiographs, plaque accumulation, bleeding index, calculus, mucosa score, probing pocket depth, microbiological sampling. 5-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Kemppainen 1997**

| | |
|---|---|
| Methods | 1-year follow-up randomised, parallel group study. Outcome assessors could only be partially blinded, but were not. No withdrawals |
| Participants | Partially edentulous patients for at least 6 months needing single-tooth replacement and having at least 10 mm of bone height and 6 mm of bucco-lingual and mesio-distal bone width, mostly in the anterior region of the maxilla. Patients with uncontrolled diabetes, radiation therapy in the orofacial region, drug and alcohol abuse and psychological problems were excluded. Mainly young adults treated in the University Dental Clinic of Helsinki, Finland. 82 enrolled (37 patients received Astra implants and 45 the ITI implants) and results given for 82 |
| Interventions | Astra® (Astra Tech AB, Mölndal, Sweden) TiO2-blasted submerged titanium screws versus ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged hollow titanium plasma-sprayed screws and cylinders for single tooth replacement |
| Outcomes | Implant stability, marginal bone level changes on standardised intraoral radiographs, plaque accumulation, gingival index, probing pocket depth. 1-year data used |
| Notes | ITI hollow screws were only placed in the mandibles. |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Lang 2007**

| | |
|---|---|
| Methods | 1-year follow-up randomised, parallel group study. Outcome assessors were blinded. No withdrawals |
| Participants | Patients > 21 years needing an immediate postextractive implant in the aesthetic zone (premolar to premolar) between two adjacent teeth. Exclusion criteria were: generic contraindication to oral surgery, smoking more than 10 cigarettes per day, periodontal bone loss > 20% at the adjacent teeth, full-mouth plaque and bleeding scores > 25% at baseline, teeth to be replaced affected by periodontal disease, presence of symptomatic periapical radiolucencies, acute abscesses or chronic sinus tracts at the implant site, lack of primary implant stability, less than 7 mm of mesio-distal space between the adjacent teeth, less than 2 mm of keratinised mucosa. Adults treated at 9 different European centres. 208 enrolled (104 patients in each group) and results given for 208 |
| Interventions | ITI® (Institut Straumann AG, Waldenburg, Switzerland) submerged sand-blasted large-grit acid-etched (SLA) solid titanium screws: cylindrical versus tapered shape. Sites were augmented with granules of deproteinized bovine bone mineral (BioOss Spongiosa) and resorbable barriers (BioGide) if there was a residual gap defect of at least 0.5 mm between the bone and the implant, exposed SLA surface in a supracrestal location, and a buccal bony plate less than 1 mm |
| Outcomes | Implant stability (resonance frequence analysis), complications, marginal bone level changes on standardised intraoral radiographs, patient evaluation of the surgical procedure, operator and assistant evaluation of the surgical procedure |

**Lang 2007** (*Continued*)

| | | |
|---|---|---|
| Notes | | |
| ***Risk of bias*** | | |
| **Item** | **Authors' judgement** | **Description** |
| Allocation concealment? | Unclear | D - Not used |

**Moberg 2001**

| | |
|---|---|
| Methods | 3-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. 4 withdrawals: 2 in the Branemark group (1 died and 1 did not attend the radiographic examination) and 2 died in the ITI group |
| Participants | Edentulous mandibles. General and/or local contraindications such as systemic medical conditions, drug abuse or local jaw pathology. Adults treated in the University Dental Clinic of the Karolinska Institute, Huddinge, Sweden. 40 enrolled (20 patients in each group) and results given for 36 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark II type submerged turned titanium screws versus ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged hollow titanium plasma-sprayed screws supporting fixed bridges |
| Outcomes | Periotest and tapping the implant with superstructures removed at 3 years, marginal bone level changes on intraoral and panoramic radiographs, plaque accumulation, marginal bleeding, probing pocket depths, tightness of screws, sensory changes, treatment time, patient satisfaction, mechanical and biological complications, perimplant infections with bone loss. 1- and 3-year data used |
| Notes | At the 3-year examination, 2 ITI implants were undergoing treatment for perimplantitis and their fate was unknown at the time of reporting |
| ***Risk of bias*** | |

| **Item** | **Authors' judgement** | **Description** |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Payne 2003**

| | |
|---|---|
| Methods | 3-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. 3 withdrawals: 2 in the ITI group (death and lack of interest) and 1 in the Southern group (death) |
| Participants | Patients aged 55-80 years with edentulous mandibles having 8 to 15 mm of residual anterior bone height. Exclusion criteria were patients with type bone IV quality (very soft bone) according to the Lekholm and Zarb classification detected at implant insertion (none), previously bone-grafted or irradiated jaws, history of bruxism, any evidence of current or previous smoking and any systemic diseases likely to compromise implant surgery. Adults treated in the School of Dentistry, University of Otago, Dunedin, New Zealand. 24 enrolled (12 patients in each group) and results given for 23 |

**Payne 2003** (*Continued*)

| | |
|---|---|
| Interventions | ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged sand-blasted large-grit acid-etched (SLA) solid titanium screws versus Southern® (Southern Implants Ltd, Irene, South Africa) non-submerged sand-blasted acid-etched titanium screws supporting overdentures on 2 implants early loaded at 2 weeks |
| Outcomes | Resonance frequency analysis, marginal bone level changes on standardised intraoral radiographs, bridge survival, plaque accumulation, modified gingival index, probing pocket depth, width of the keratinised mucosa, recession, prosthetic maintenance events. 1- and 3-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Payne 2004**

| | |
|---|---|
| Methods | 1-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. 2 withdrawals: 1 in the Brånemark group (1 of the study implants could not be placed) and 1 in the Southern group (death) |
| Participants | Patients aged 55-80 years with edentulous maxillae opposing overdentures supported by 2 implants. Exclusion criteria were maxillae with a shape type E (extremely resorbed) according to the Lekholm and Zarb classification on radiographs, previously bone-grafted maxillae, history of bruxism, any evidence of current or previous smoking and any systemic disease likely to compromise implant surgery. Adults treated in the School of Dentistry, University of Otago, Dunedin, New Zealand. 40 enrolled (20 patients in each group) and results given for 38 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) TiUnite non-submerged oxidized titanium screws of 3.3 mm diameter versus Southern® (Southern Implants Ltd, Irene, South Africa) non-submerged sand-blasted acid-etched titanium screws 3.25 mm diameter supporting maxillary overdentures on 3 unsplinted implants early loaded at 12 weeks. 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 |
| Outcomes | Stability test, marginal bone level changes on standardised intraoral radiographs, resonance frequency values. 1-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|

**Payne 2004** (*Continued*)

| | | |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Schincaglia 2007**

| | |
|---|---|
| Methods | 1-year follow-up randomised, split-mouth study. Outcome assessors were blinded to radiograghic assessement. No withdrawals |
| Participants | Patients with bilateral distal partial edentulous mandibles allowing the placement of at least 2 8.5 mm long implants. Exclusion criteria were need of augmentation procedures, extraction sites healing < 4 months, different type of opposing bilateral occlusion, implants inserted with a torque < 20 Ncm or with an implant stability quotient < 60. Adults treated in the School of Dentistry, University of Bologna, Italy. 10 patients enrolled and results given for 10 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark IV TiUnite oxidized versus Mark IV turned immediately loaded titanium screws supporting screw-retained partial fixed bridges |
| Outcomes | Resonance frequency analysis, marginal bone level changes on intraoral radiographs, bridge survival. 1-year data used |
| Notes | |

***Risk of bias***

| **Item** | **Authors' judgement** | **Description** |
|---|---|---|
| Allocation concealment? | No | C - Inadequate |

**Stavropoulos 2007**

| | |
|---|---|
| Methods | 1-year follow-up randomised, parallel group study. Outcome assessors could only be partially blinded, but were not. No withdrawals |
| Participants | Partially edentulous patients needing sinus lift with bone height above the sinus between 2 to 9 mm. Exclusion criteria were presence or history of sinus pathology. Adults treated in the University of Aarhus, Denmark. 26 patients enrolled and results given for 26 |
| Interventions | 3i® (Biomet 3i, Palm Beach Gardens, FL, USA) full Osseotite sand-blasted acid-etched versus dual Osseotite sand-blasted acid-etched titanium screw in augmented sinus with bone form the mental symphisis supporting cemented crowns/partial bridges |
| Outcomes | Implant survival, marginal bone level changes on standardised intraoral radiographs, bridge survival, bleeding on probing, probing pocket depths, recessions. 1-year data used |
| Notes | |

***Risk of bias***

**Stavropoulos 2007** (*Continued*)

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Yes | A - Adequate |

**Tawse-Smith 2001**

| | |
|---|---|
| Methods | 5-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. 2 withdrawals at 5 years: 1 from the Steri-Oss (patient requested to be excluded) and 1 from the Southern group (death) |
| Participants | Edentulous mandibles having 13 to 15 mm of residual anterior bone height. Exclusion criteria were patients with type bone four quality (very soft bone) according to the Lekholm and Zarb classification detected at implant insertion (none), previously bone-grafted or irradiated jaws, history of bruxism, any evidence of current or previous smoking and any systemic disease likely to compromise implant surgery. Adults treated in the School of Dentistry, University of Otago, Dunedin, New Zealand. 12 enrolled (12 patients in each group) and results given for 24 |
| Interventions | Steri-Oss® (Steri-Oss, Yorba Linda, California, USA) non-submerged acid-etched titanium screws HL series, 3.8 mm in diameter versus Southern® (Southern Implants Ltd, Irene, South Africa) non-submerged sand-blasted acid-etched titanium screws supporting mandibular overdentures on 2 implants conventionally loaded at 12 weeks |
| Outcomes | Periotest, marginal bone level changes on standardised intraoral radiographs, overdenture survival, plaque accumulation, modified sulcus bleeding index, probing pocket depth, width of the keratinised mucosa. 1-, 3- and 5-year data used |
| Notes | |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Tawse-Smith 2002**

| | |
|---|---|
| Methods | 5-year follow-up randomised, parallel group study. Outcome assessors could not be blinded. No withdrawals at 5 years |
| Participants | Edentulous mandibles having 13 to 15 mm of residual anterior bone height. Exclusion criteria were patients with type bone four quality (very soft bone) according to the Lekholm and Zarb classification detected at implant insertion (none), previously bone-grafted or irradiated jaws, history of bruxism, any evidence of current or previous smoking and any systemic disease likely to compromise implant surgery. Adults treated in the School of Dentistry, University of Otago, Dunedin, New Zealand. 24 enrolled (12 patients in each group) and results given for 24 |

**Tawse-Smith 2002** (*Continued*)

| | |
|---|---|
| Interventions | Steri-Oss® (Steri-Oss, Yorba Linda, California, USA) non-submerged acid-etched titanium screws HL series, 3.8 mm in diameter versus Southern® (Southern Implants Ltd, Irene, South Africa) non-submerged sand-blasted acid-etched titanium screws supporting mandibular overdentures on 2 implants early loaded at 6 weeks |
| Outcomes | Periotest, marginal bone level changes on standardised intraoral radiographs, bridge survival, plaque accumulation, modified sulcus bleeding index, probing pocket depth, width of the keratinised mucosa. 1-, 3- and 5-year data used |
| Notes | Most of the failed implants were placed by a surgeon who placed only Steri-Oss implants |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Åstrand 1999**

| | |
|---|---|
| Methods | 5-year follow-up randomised, parallel group study. Patients and outcome assessor could not be blinded, but an independent assessor was used. 2 withdrawals in the Astra group after year 3 due to patient death |
| Participants | Edentulous patients. 2 patients were excluded at the implant installation since they did not meet the inclusion criteria (insufficient bone volume with need of bone graft or guided tissue regeneration). Adults treated in the University Hospital of Linkoping, Sweden. 68 enrolled (34 patients in each group) and results given for 66 |
| Interventions | Astra® (Astra Tech AB, Mölndal, Sweden) TiO2 blasted submerged titanium screws versus Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark II type submerged turned titanium screws supporting fixed bridges |
| Outcomes | Pain from implant region, implant stability tested with superstructure removed, bridge survival, marginal bone level changes on standardised intraoral radiographs, plaque accumulation, bleeding on probing, operation time, mechanical complications, perimplant infections with bone loss (perimplantitis), presence or absence of attached perimplant mucosa. 1-, 3- and 5-year data used |
| Notes | 8 patients in the Branemark group were scored at implant insertion as having type four bone quality (very soft bone) according to the Lekholm and Zarb classification versus 1 patient in the ITI group |

***Risk of bias***

| Item | Authors' judgement | Description |
|---|---|---|
| Allocation concealment? | Unclear | B - Unclear |

**Åstrand 2002**

| | |
|---|---|
| Methods | 3-year follow-up randomised, split-mouth study. Outcome assessors could not be blinded. 2 patients died before the 3-year follow up |
| Participants | Patients aged 20-75 years with partially edentulous maxillae. Exclusion criteria were: known leukocyte disfunction, uncontrolled endocryne disorders, psychotic disorders, heavy smoking habits (more than 20 cigarettes/day), alcohol or drug abuse, current steroid or chemotherapy treatments, local irradiation therapy, insufficient bone volume with need of bone graft or guided tissue regeneration, heavy bruxism, current periodontitis, less than 6 months healing after tooth extraction. Adults treated in 5 different dental clinics, Sweden. 28 enrolled and results given for 26 |
| Interventions | Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark II type submerged turned titanium screws versus ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged solid titanium plasma-sprayed screws supporting maxillary fixed partial bridges |
| Outcomes | Pain from implant region, bridge survival, marginal bone level changes on standardised intraoral radiographs, plaque accumulation, bleeding on probing, mechanical complications, hyperplasia of the perimplant mucosa, perimplant infections with bone loss (perimplantitis). 1-year data used |
| Notes | Implant stability not recorded. Data on implant failures may be underestimated and were therefore not included in the statistical calculations |

***Risk of bias***

| **Item** | **Authors' judgement** | **Description** |
|---|---|---|
| Allocation concealment? | No | C - Inadequate |

## Characteristics of excluded studies *[ordered by study ID]*

| Study | Reason for exclusion |
|---|---|
| Boerrigter 1997 | Number of enrolled patients unclear. No reply to letter. |
| da Cunha 2004 | Only data at implant placement but no data after 1 year in function |
| Du Preez 2007 | Quasi-random trial. |
| Friberg 1992 | Study classified as not RCT after author's reply. |
| Geertman 1996 | Data of 2 different RCTs were combined. Asked for separate data. No reply to letter |
| Geurs 2002 | Unclear which implant type(s) failed and number of drop outs. Author's reply failed to clarify the issue |
| Gher 1994 | Problems with design and analysis. The unit of randomisation was both the patient and the implant and it was not possible to use the data without further information from authors. The authors did not reply to our |

(*Continued*)

| | |
|---|---|
| | letter |
| Joly 2003 | Follow up less than 1 year. |
| Jones 1997 | Study classified as not RCT. No reply to letter. |
| Karabuda 2002 | Study classified as not RCT after author's reply. |
| Karlsson 1998 | Not all patients were participating in a split-mouth study. Author's reply failed to clarify the issue |
| Khang 2001 | Sort of 'split-mouth' study with unequal number of implants randomly allocated to each patient. Author had not time to reanalyse data |
| Mau 2002 | 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. Unclear follow-up periods. We were unable to extract any meaningful data. No reply to letter |
| Mau 2003 | 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 |
| Reingewirtz 2000 | Study classified as not RCT since only one Calcitek implant was compared with 23 Microdent. Not written to authors |
| Rocci 2003 | Not RCT but quasi-random trial with alternate assignment. |
| Roccuzzo 2001 | 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 |
| Shin 2006 | Number of enrolled patients unclear. No reply to letter. |
| Testori 2003 | Problem as implant types: Osseotite and Osseotite NT were confounded with early and immediate loading |
| Tomatis 2002 | Study classified as not RCT after author's reply. |
| Truhlar 1997 | Due to the extreme complexity of the study design we were unable to extract any meaningful data. No reply to letter |
| van Steenberghe 2000 | 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 |
| Wennström 2004 | Implant stability not assessed with removed prosthesis, radiographic data presented in a way we could not use. No reply to letter. Data on early implant failures could have been used, unfortunately there was only a single failure and being a split-mouth study we were unable to calculate the effect estimate for the paired data due to the zero |
| Åstrand 2003 | Parallel group study in which patients in the test group received Brånemark Mark IV implants in bone quality type 3 and 4 and Brånemark Mark II or standard implants in bone quality type 1 and 2. Patients in the control group received Brånemark standard or Mark 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 |

(*Continued*)

| | |
|---|---|
| | who was unable to provide data in the appropriate form |

RCT = randomised controlled trial

## Characteristics of ongoing studies *[ordered by study ID]*

**Cannizzaro**

| | |
|---|---|
| Trial name or title | Immediately loaded hydroxyapatite coated versus rough titanium implants placed with a flapless procedure for partial edentulism: a double-blinded, randomised clinical trial |
| Methods | |
| Participants | |
| Interventions | |
| Outcomes | |
| Starting date | |
| Contact information | Cannizzaro G, Leone M, Esposito M |
| Notes | |

## DATA AND ANALYSES

### Comparison 1. All comparisons at 1 year

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Implant failure | 13 | | risk ratio (Random, 95% CI) | Subtotals only |
| 1.1 Astra TiO2-blasted versus Brånemark turned titanium screws (different implant systems) | 1 | 66 | risk ratio (Random, 95% CI) | 0.25 [0.03, 2.12] |
| 1.2 Astra TiO2- blasted versus ITI TPS hollow titanium screws and cylinders (different implant systems) | 1 | 82 | risk ratio (Random, 95% CI) | 3.63 [0.15, 88.57] |
| 1.3 Brånemark turned titanium screws: standard versus conical (different implant shapes) | 1 | 10 | risk ratio (Random, 95% CI) | Not estimable |
| 1.4 Brånemark turned titanium screws: standard versus Mark IV prototype (different implant shapes) | 1 | 76 | risk ratio (Random, 95% CI) | 1.67 [0.41, 6.83] |
| 1.5 Brånemark Mark II versus ITI TPS solid screws (different implant systems) | 1 | 56 | risk ratio (Random, 95% CI) | 1.04 [0.91, 1.18] |
| 1.6 Brånemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | 1 | 60 | risk ratio (Random, 95% CI) | 1.0 [0.06, 15.55] |
| 1.7 Brånemark turned versus ITI TPS hollow titanium screws (different implant systems) | 2 | 99 | risk ratio (Random, 95% CI) | 2.95 [0.31, 28.24] |
| 1.8 Brånemark TiUnite versus Southern blasted/etched titanium screws (different implant systems) | 1 | 38 | risk ratio (Random, 95% CI) | 0.57 [0.20, 1.63] |
| 1.9 IMZ TPS cylinders versus ITI TPS hollow titanium screws (different implant systems) | 1 | 59 | risk ratio (Random, 95% CI) | 2.90 [0.12, 69.40] |
| 1.10 IMZ TPS cylinders versus ITI TPS titanium screws (different implant systems) | 1 | 40 | risk ratio (Random, 95% CI) | 3.00 [0.13, 71.79] |
| 1.11 ITI SLA versus Southern blasted/etched titanium screws (different implant systems) | 1 | 23 | risk ratio (Random, 95% CI) | Not estimable |

| | | | | |
|---|---|---|---|---|
| 1.12 ITI SLA cylindrical versus ITI SLA tapered screws (different implant shapes) | 1 | 208 | risk ratio (Random, 95% CI) | Not estimable |
| 1.13 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | 2 | 48 | risk ratio (Random, 95% CI) | 6.25 [0.77, 50.72] |
| 2 Bone levels | 10 | | mean difference (Random, 95% CI) | Subtotals only |
| 2.1 Astra TiO2-blasted versus Brånemark turned titanium screws (different implant systems) | 1 | 65 | mean difference (Random, 95% CI) | -0.09 [-0.33, 0.15] |
| 2.2 Astra TiO2-blasted versus ITI TPS hollow titanium screws and cylinders (different implant systems) | 1 | 82 | mean difference (Random, 95% CI) | 0.02 [-0.02, 0.06] |
| 2.3 Brånemark turned titanium screws: standard versus Mark IV prototype (different implant shapes) | 1 | 56 | mean difference (Random, 95% CI) | 0.02 [-2.31, 2.35] |
| 2.4 Brånemark Mark II versus ITI TPS solid screws (different implant systems) | 1 | 56 | mean difference (Random, 95% CI) | 0.05 [-0.20, 0.30] |
| 2.5 Brånemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | 1 | 59 | mean difference (Random, 95% CI) | -0.6 [-1.10, -0.10] |
| 2.6 Brånemark turned versus ITI TPS hollow titanium screws (different implant systems) | 1 | 58 | mean difference (Random, 95% CI) | -0.1 [-0.44, 0.24] |
| 2.7 Brånemark Mark IV turned screws versus Brånemark Mark IV TiUnite screws (different implant surfaces) | 1 | 20 | mean difference (Random, 95% CI) | 0.11 [-0.38, 0.60] |
| 2.8 IMZ TPS cylinders versus ITI TPS hollow titanium screws (different implant systems) | 1 | 59 | mean difference (Random, 95% CI) | 0.5 [0.01, 0.99] |
| 2.9 ITI SLA versus Southern blasted/etched titanium screws (different implant systems) | 1 | 23 | mean difference (Random, 95% CI) | -0.03 [-0.18, 0.12] |
| 2.10 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | 2 | 42 | mean difference (Random, 95% CI) | -0.05 [-0.20, 0.10] |
| 2.11 3i full Osseotite versus 3i dual Osseotite (different implant surfaces) | 1 | 20 | mean difference (Random, 95% CI) | -0.04 [-0.71, 0.63] |

**Comparison 2. All comparisons at 3 years**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Implant failure | 8 | | risk ratio (Random, 95% CI) | Subtotals only |
| 1.1 Astra TiO2-blasted versus Branemark turned titanium implants (different implant systems) | 1 | 66 | risk ratio (Random, 95% CI) | 0.40 [0.08, 1.92] |
| 1.2 Brånemark Mark II versus ITI TPS solid screws (different implant systems) | 1 | 52 | risk ratio (Random, 95% CI) | 1.0 [0.86, 1.16] |
| 1.3 Brånemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | 1 | 59 | risk ratio (Random, 95% CI) | 1.03 [0.07, 16.02] |
| 1.4 Brånemark turned versus ITI TPS hollow titanium screws (different implant systems) | 2 | 93 | risk ratio (Random, 95% CI) | 2.19 [0.34, 14.26] |
| 1.5 IMZ TPS cylinders versus ITI TPS hollow titanium screws (different implant systems) | 1 | 58 | risk ratio (Random, 95% CI) | 2.81 [0.12, 68.58] |
| 1.6 IMZ TPS cylinders versus ITI TPS titanium screws (different implant systems) | 1 | 39 | risk ratio (Random, 95% CI) | 2.86 [0.12, 65.76] |
| 1.7 ITI SLA versus Southern blasted/etched titanium screws (different implant systems) | 1 | 21 | risk ratio (Random, 95% CI) | Not estimable |
| 1.8 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | 2 | 47 | risk ratio (Random, 95% CI) | 6.78 [0.85, 54.08] |
| 2 Bone levels | 5 | | mean difference (Random, 95% CI) | Subtotals only |
| 2.1 Astra TiO2-blasted versus Brånemark turned titanium screws (different implant systems) | 1 | 65 | mean difference (Random, 95% CI) | -0.06 [-0.40, 0.28] |
| 2.2 Brånemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | 1 | 56 | mean difference (Random, 95% CI) | -0.4 [-1.05, 0.25] |
| 2.3 Brånemark turned versus ITI TPS hollow titanium screws (different implant systems) | 1 | 57 | mean difference (Random, 95% CI) | -0.1 [-0.54, 0.34] |
| 2.4 IMZ TPS cylinders versus ITI TPS titanium screws (different implant systems) | 1 | 57 | mean difference (Random, 95% CI) | 0.3 [-0.32, 0.92] |

| | | | | |
|---|---|---|---|---|
| 2.5 ITI SLA versus Southern blasted/etched titanium screws (different implant systems) | 1 | 21 | mean difference (Random, 95% CI) | 0.05 [-0.16, 0.26] |
| 2.6 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | 2 | 41 | mean difference (Random, 95% CI) | -0.17 [-0.41, 0.06] |
| 3 Perimplantitis (turned versus roughened surfaces) | 3 | 155 | risk ratio (Random, 95% CI) | 0.80 [0.67, 0.96] |

**Comparison 3. All comparisons at 5 years**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Implant failure | 5 | | risk ratio (Random, 95% CI) | Subtotals only |
| 1.1 Astra TiO2-blasted versus Brånemark turned titanium screws (different implant systems) | 1 | 64 | risk ratio (Random, 95% CI) | 0.43 [0.09, 2.05] |
| 1.2 Brånemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | 1 | 57 | risk ratio (Random, 95% CI) | 1.11 [0.07, 16.59] |
| 1.3 Brånemark turned versus ITI TPS hollow titanium screws (different implant systems) | 1 | 54 | risk ratio (Random, 95% CI) | 3.00 [0.13, 70.40] |
| 1.4 IMZ TPS cylinders versus ITI TPS hollow titanium screws (different implant systems) | 1 | 57 | risk ratio (Random, 95% CI) | 2.71 [0.12, 63.59] |
| 1.5 IMZ TPS cylinders versus ITI TPS titanium screws (different implant systems) | 1 | 37 | risk ratio (Random, 95% CI) | 2.86 [0.12, 65.76] |
| 1.6 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | 2 | 46 | risk ratio (Random, 95% CI) | 6.21 [0.80, 48.43] |
| 2 Bone levels | 3 | | mean difference (Random, 95% CI) | Subtotals only |
| 2.1 Brånemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | 1 | 56 | mean difference (Random, 95% CI) | -0.7 [-1.45, 0.05] |
| 2.2 Brånemark turned versus ITI TPS hollow titanium screws (different implant systems) | 1 | 53 | mean difference (Random, 95% CI) | -0.2 [-0.66, 0.26] |

| | | | | |
|---|---|---|---|---|
| 2.3 IMZ TPS cylinders versus ITI TPS titanium screws (different implant systems) | 1 | 57 | mean difference (Random, 95% CI) | 0.5 [-0.25, 1.25] |
| 2.4 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | 2 | 40 | mean difference (Random, 95% CI) | -0.20 [-0.50, 0.10] |
| 3 Perimplantitis (turned versus roughened surfaces) | 1 | | risk ratio (Random, 95% CI) | Totals not selected |
| 3.1 Astra TiO2-blasted versus Brånemark turned titanium screws (different implant systems) | 1 | | risk ratio (Random, 95% CI) | Not estimable |



**Comparison 4. Early failures (turned versus roughened surfaces)**

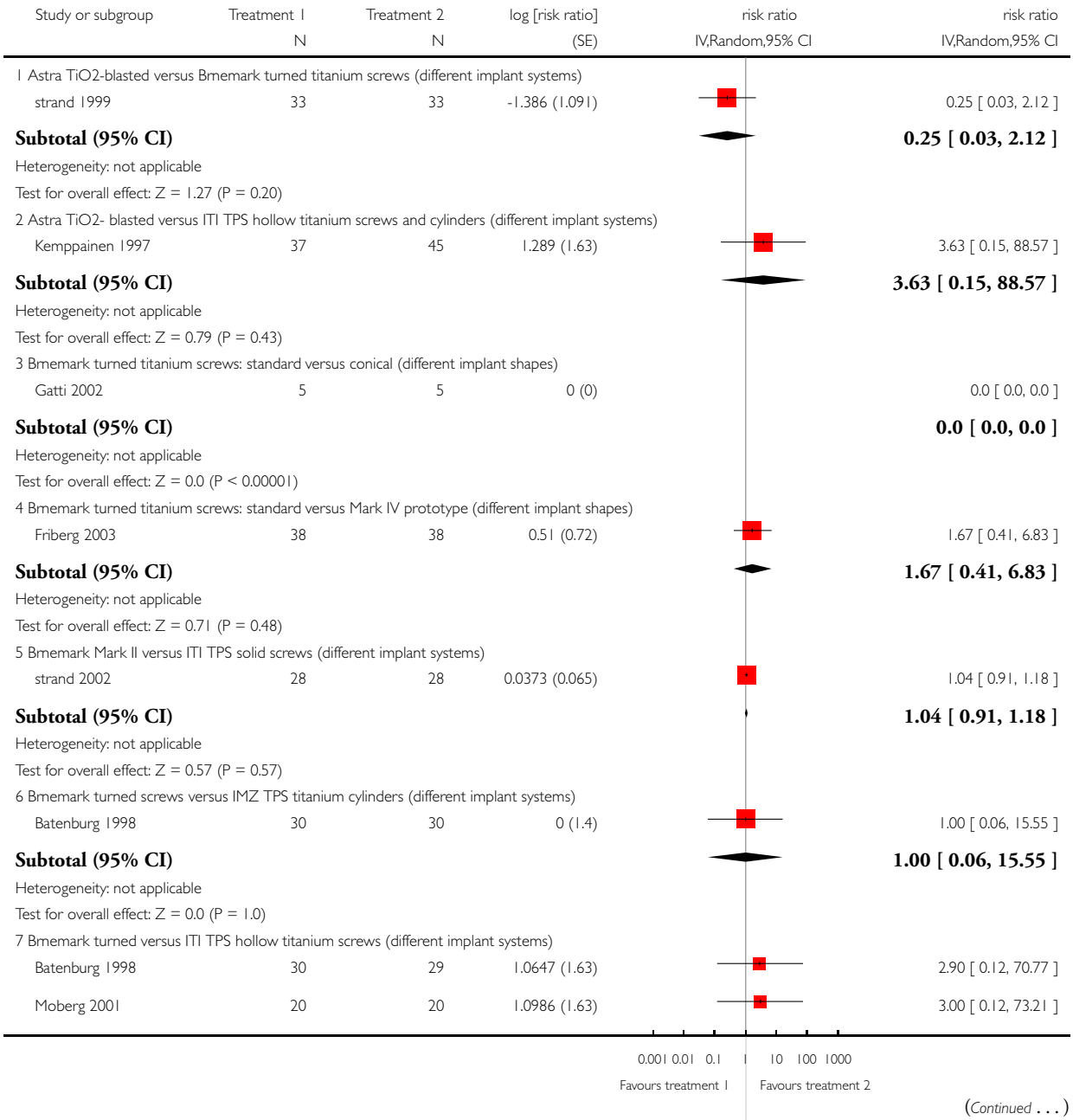
| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Early failures (turned versus roughened surfaces) | 3 | 196 | risk ratio (Random, 95% CI) | 3.06 [0.69, 13.55] |

## Analysis 1.1. Comparison 1 All comparisons at 1 year, Outcome 1 Implant failure.

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 1 All comparisons at 1 year

Outcome: 1 Implant failure

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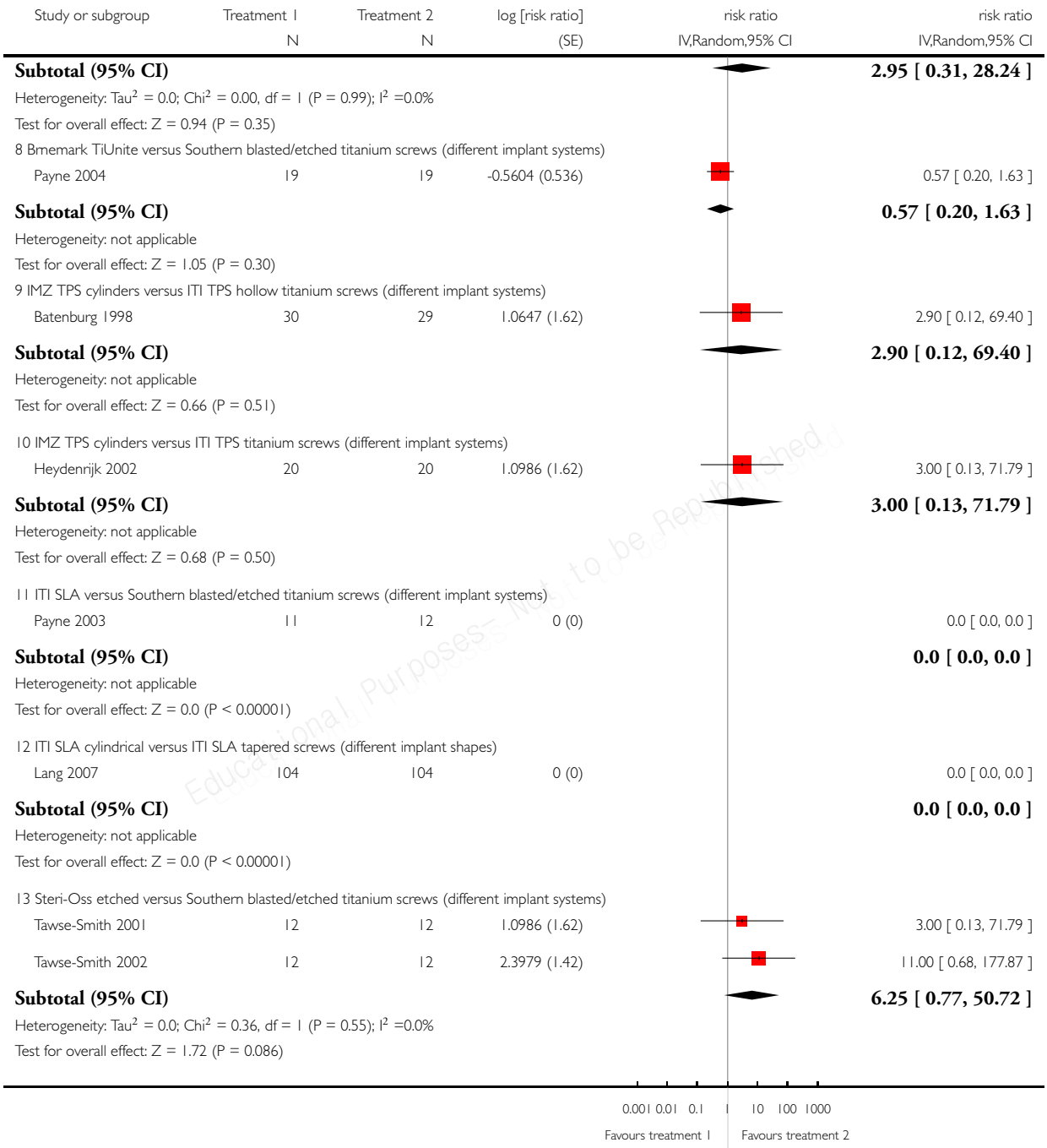
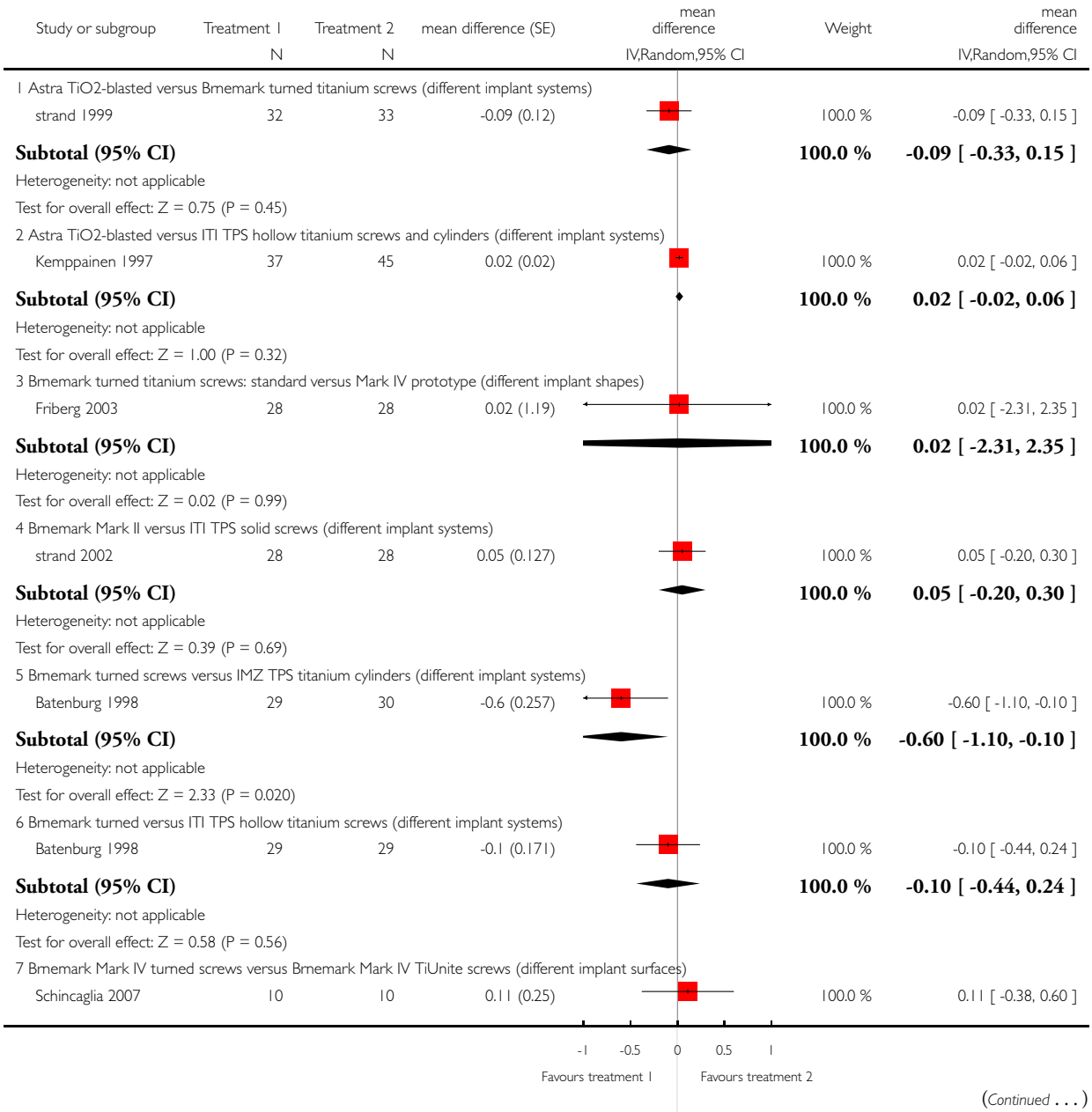


## Analysis 1.2. Comparison 1 All comparisons at 1 year, Outcome 2 Bone levels.

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 1 All comparisons at 1 year

Outcome: 2 Bone levels

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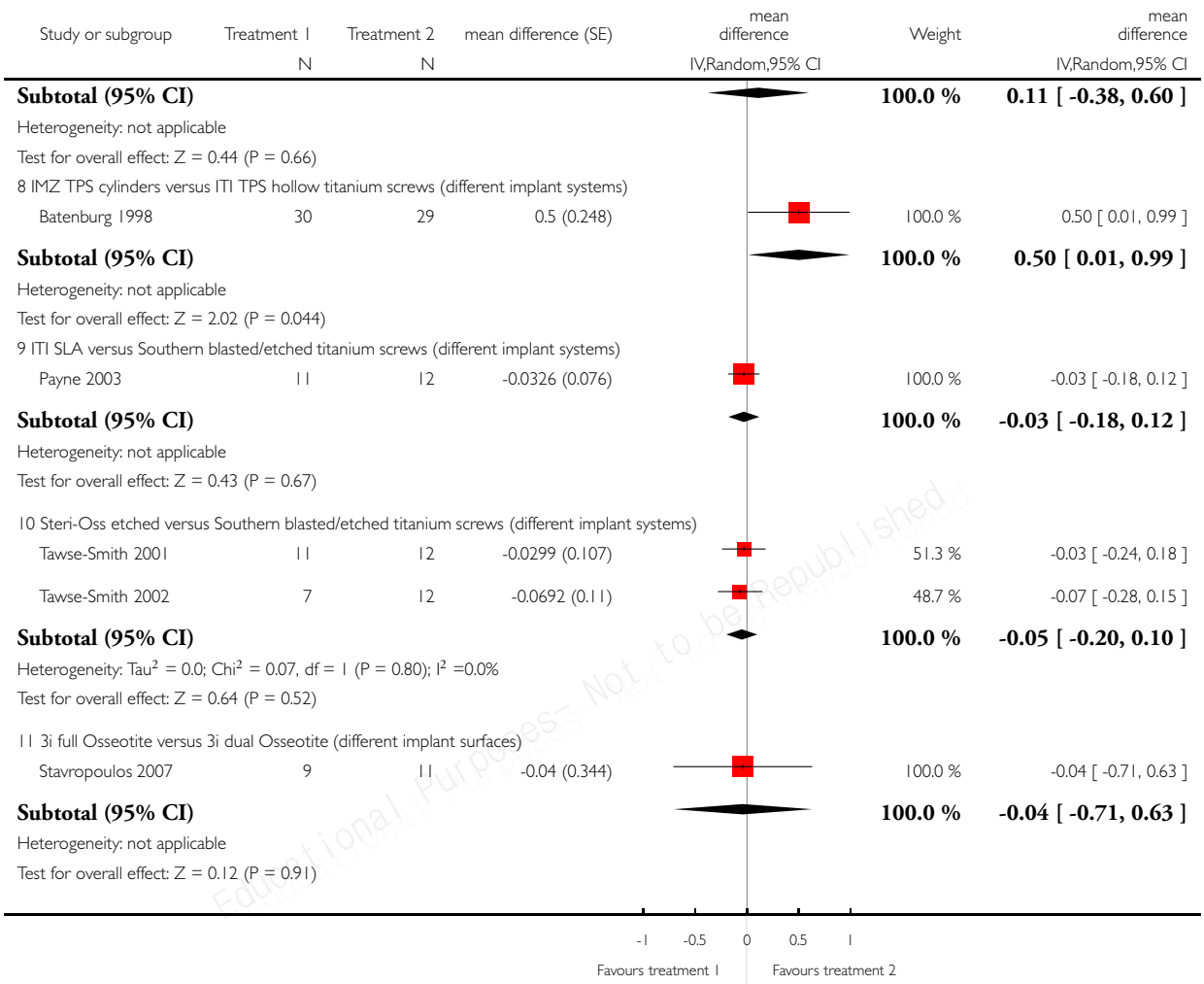
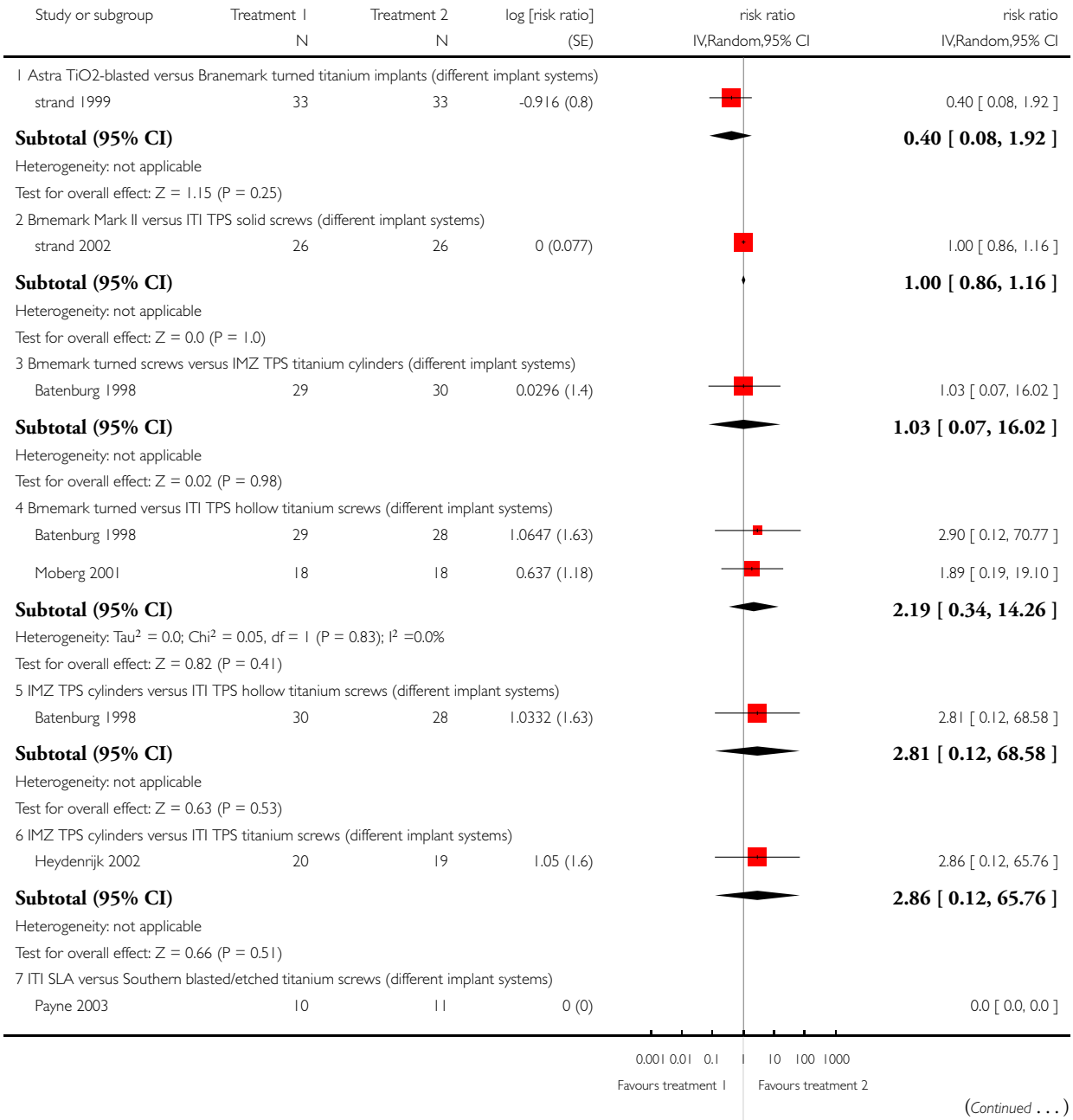


## Analysis 2.1. Comparison 2 All comparisons at 3 years, Outcome 1 Implant failure.

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 2 All comparisons at 3 years

Outcome: 1 Implant failure

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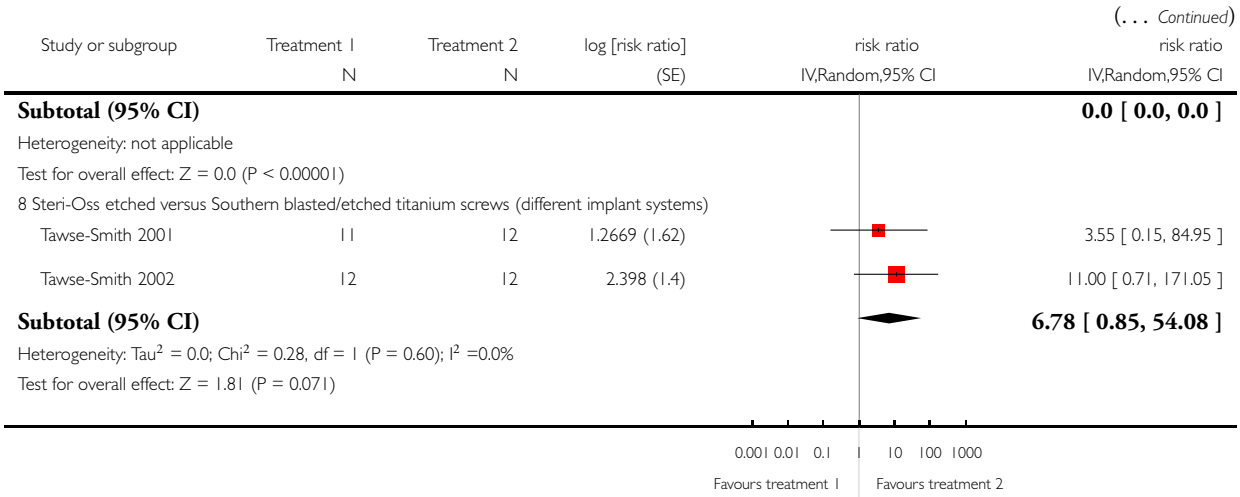


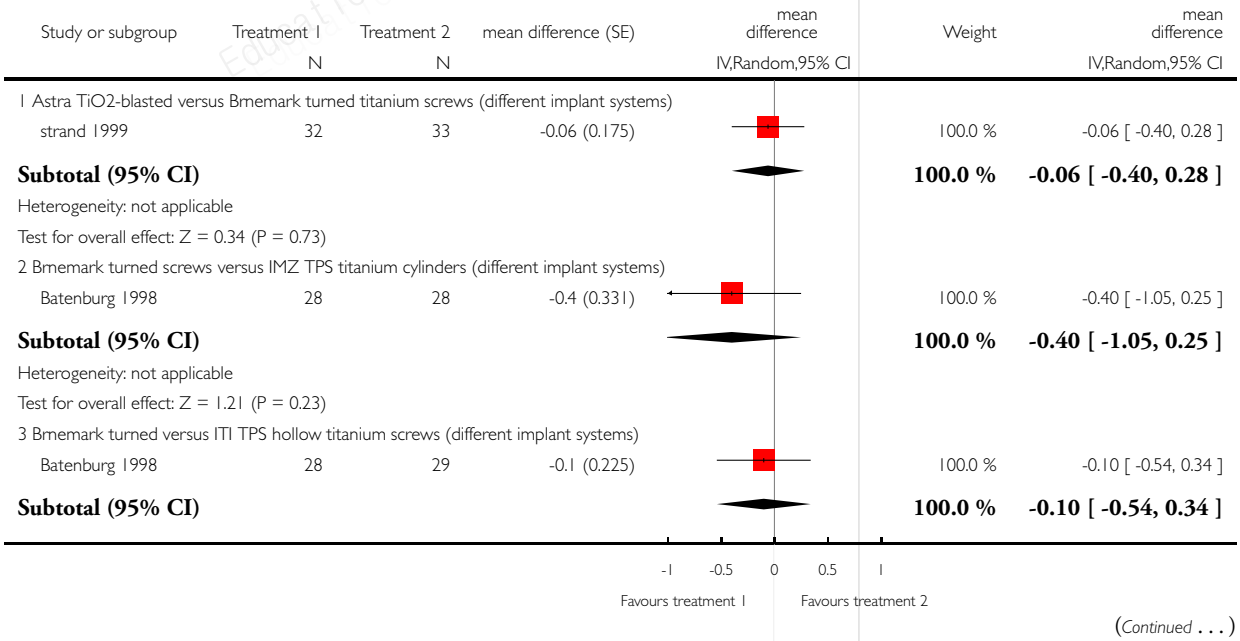



### Analysis 2.2. Comparison 2 All comparisons at 3 years, Outcome 2 Bone levels.

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 2 All comparisons at 3 years

Outcome: 2 Bone levels

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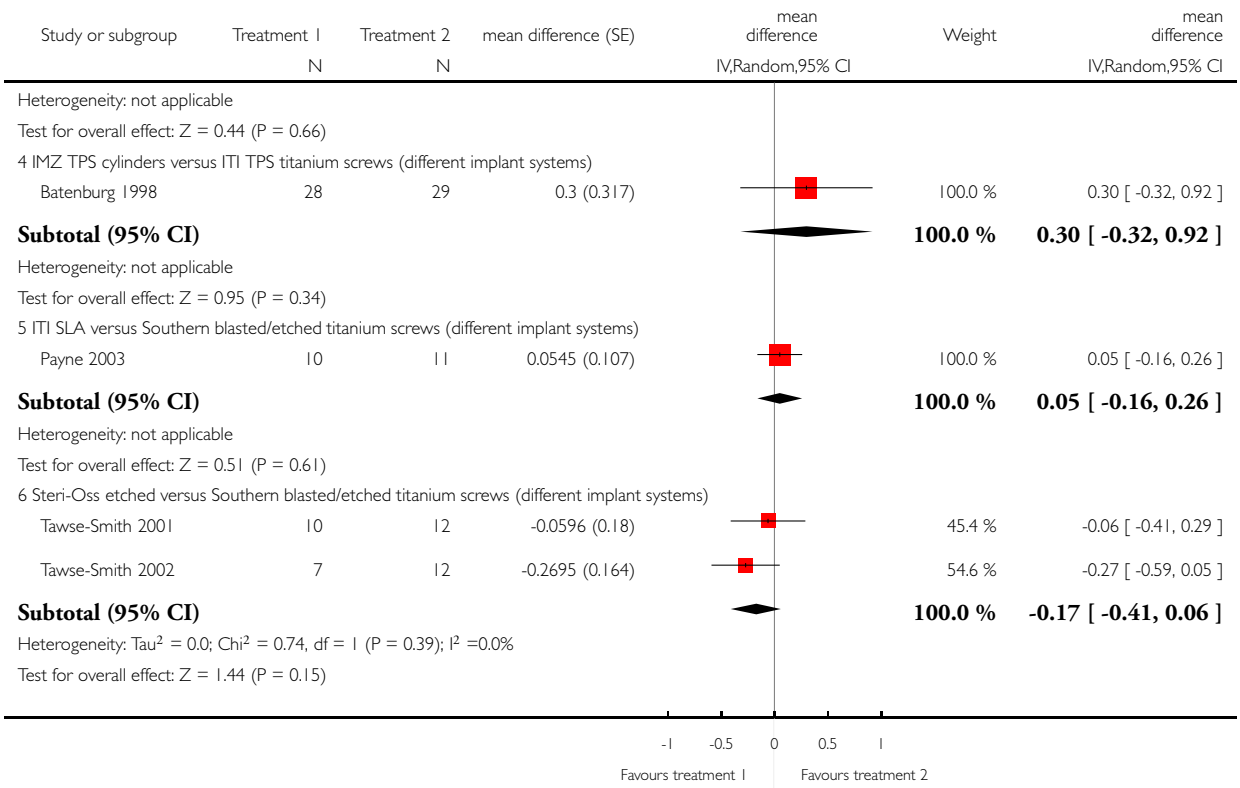


### Analysis 2.3. Comparison 2 All comparisons at 3 years, Outcome 3 Perimplantitis (turned versus roughened surfaces).

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 2 All comparisons at 3 years

Outcome: 3 Perimplantitis (turned versus roughened surfaces)

| Study or subgroup | Turned N | Roughened N | log [risk ratio] (SE) | risk ratio IV,Random,95% CI | Weight | risk ratio IV,Random,95% CI |
|---|---|---|---|---|---|---|
| Moberg 2001 | 19 | 18 | -1.139 (1.107) | | 0.7 % | 0.32 [ 0.04, 2.80 ] |
| strand 1999 | 33 | 33 | -1.609 (1.53) | | 0.4 % | 0.20 [ 0.01, 4.01 ] |
| strand 2002 | 26 | 26 | -0.2107 (0.0941) | | 98.9 % | 0.81 [ 0.67, 0.97 ] |
| **Total (95% CI)** | | | | | **100.0 %** | **0.80 [ 0.67, 0.96 ]** |

Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.52$, df = 2 (P = 0.47); $I^2 = 0.0\%$

Test for overall effect: Z = 2.38 (P = 0.017)



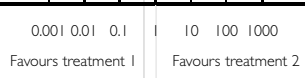

### Analysis 3.1. Comparison 3 All comparisons at 5 years, Outcome 1 Implant failure.

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 3 All comparisons at 5 years

Outcome: 1 Implant failure

| Study or subgroup | Treatment 1 N | Treatment 2 N | log [risk ratio] (SE) | risk ratio IV,Random,95% CI | Weight | risk ratio IV,Random,95% CI |
|---|---|---|---|---|---|---|
| 1 Astra TiO2-blasted versus Bmemark turned titanium screws (different implant systems) | | | | | | |
| strand 1999 | 31 | 33 | -0.844 (0.798) | | 100.0 % | 0.43 [ 0.09, 2.05 ] |
| **Subtotal (95% CI)** | | | | | **100.0 %** | **0.43 [ 0.09, 2.05 ]** |
| Heterogeneity: not applicable | | | | | | |
| Test for overall effect: Z = 1.06 (P = 0.29) | | | | | | |
| 2 Bmemark turned screws versus IMZ TPS titanium cylinders (different implant systems) | | | | | | |
| Batenburg 1998 | 27 | 30 | 0.104 (1.38) | | 100.0 % | 1.11 [ 0.07, 16.59 ] |
| **Subtotal (95% CI)** | | | | | **100.0 %** | **1.11 [ 0.07, 16.59 ]** |
| Heterogeneity: not applicable | | | | | | |
| Test for overall effect: Z = 0.08 (P = 0.94) | | | | | | |

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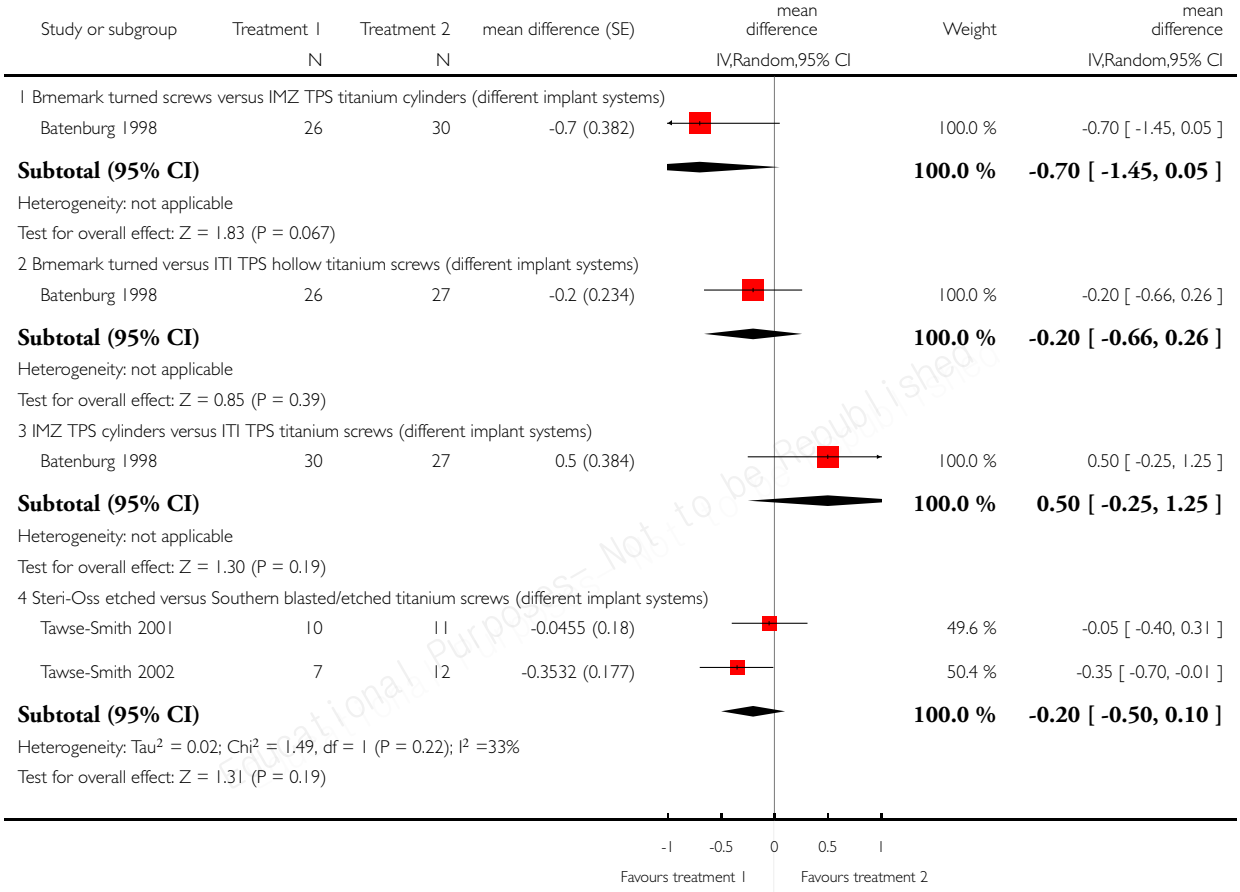
| Study or subgroup | Treatment 1 N | Treatment 2 N | log [risk ratio] (SE) | risk ratio IV,Random,95% CI | Weight | risk ratio IV,Random,95% CI |
|---|---|---|---|---|---|---|
| 3 Bmemark turned versus ITI TPS hollow titanium screws (different implant systems) | | | | | | |
| Batenburg 1998 | 27 | 27 | 1.0986 (1.61) | | 100.0 % | 3.00 [ 0.13, 70.40 ] |
| **Subtotal (95% CI)** | | | | | **100.0 %** | **3.00 [ 0.13, 70.40 ]** |
| Heterogeneity: not applicable | | | | | | |
| Test for overall effect: Z = 0.68 (P = 0.50) | | | | | | |
| 4 IMZ TPS cylinders versus ITI TPS hollow titanium screws (different implant systems) | | | | | | |
| Batenburg 1998 | 30 | 27 | 0.9969 (1.61) | | 100.0 % | 2.71 [ 0.12, 63.59 ] |
| **Subtotal (95% CI)** | | | | | **100.0 %** | **2.71 [ 0.12, 63.59 ]** |
| Heterogeneity: not applicable | | | | | | |
| Test for overall effect: Z = 0.62 (P = 0.54) | | | | | | |
| 5 IMZ TPS cylinders versus ITI TPS titanium screws (different implant systems) | | | | | | |
| Heydenrijk 2002 | 19 | 18 | 1.05 (1.6) | | 100.0 % | 2.86 [ 0.12, 65.76 ] |
| **Subtotal (95% CI)** | | | | | **100.0 %** | **2.86 [ 0.12, 65.76 ]** |
| Heterogeneity: not applicable | | | | | | |
| Test for overall effect: Z = 0.66 (P = 0.51) | | | | | | |
| 6 Steri-Oss etched versus Southern blasted/etched titanium screws (different implant systems) | | | | | | |
| Tawse-Smith 2001 | 11 | 11 | 1.0986 (1.58) | | 44.0 % | 3.00 [ 0.14, 66.38 ] |
| Tawse-Smith 2002 | 12 | 12 | 2.398 (1.4) | | 56.0 % | 11.00 [ 0.71, 171.05 ] |
| **Subtotal (95% CI)** | | | | | **100.0 %** | **6.21 [ 0.80, 48.43 ]** |
| Heterogeneity: $Tau^2$ = 0.0; $Chi^2$ = 0.38, df = 1 (P = 0.54); $I^2$ =0.0% | | | | | | |
| Test for overall effect: Z = 1.74 (P = 0.081) | | | | | | |

### Analysis 3.2. Comparison 3 All comparisons at 5 years, Outcome 2 Bone levels.

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 3 All comparisons at 5 years

Outcome: 2 Bone levels

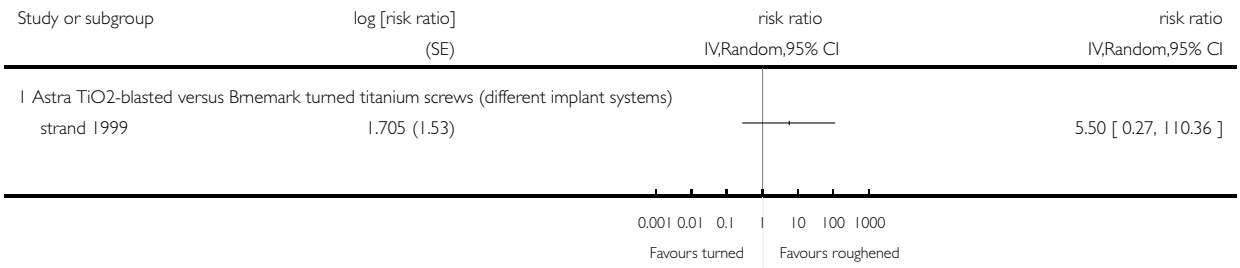


### Analysis 3.3. Comparison 3 All comparisons at 5 years, Outcome 3 Perimplantitis (turned versus roughened surfaces).

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 3 All comparisons at 5 years

Outcome: 3 Perimplantitis (turned versus roughened surfaces)

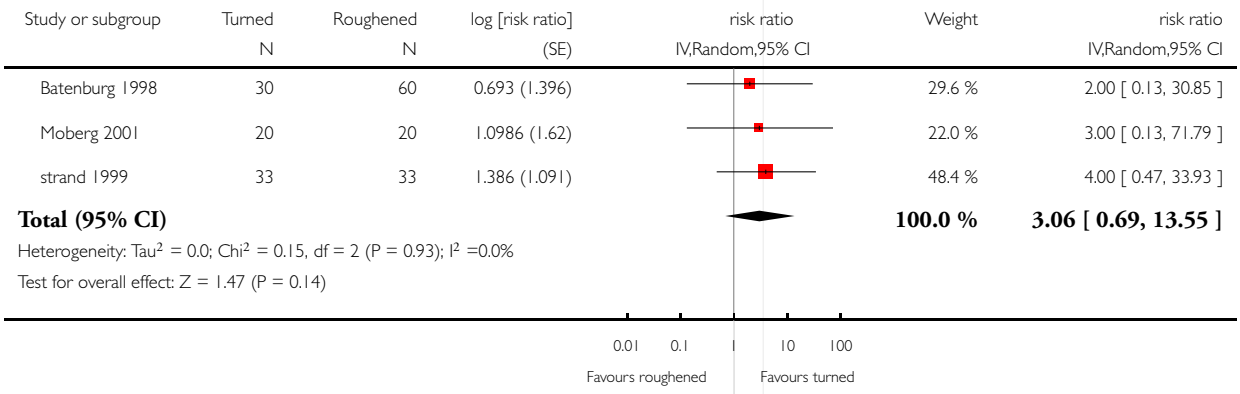



### Analysis 4.1. Comparison 4 Early failures (turned versus roughened surfaces), Outcome 1 Early failures (turned versus roughened surfaces).

Review: Interventions for replacing missing teeth: different types of dental implants

Comparison: 4 Early failures (turned versus roughened surfaces)

Outcome: 1 Early failures (turned versus roughened surfaces)



## ADDITIONAL TABLES

**Table 1. Results of quality assessment after correspondence with authors**

| Study ID | Allocation | Blinding of assessor | Withdrawals | Risk of bias |
|---|---|---|---|---|
| Kemppainen 1997 | Unclear | Not possible in part | Yes | High |
| Batenburg 1998 | Inadequate | Not possible but radiograph mixed | Yes | High |
| Åstrand 1999 | Unclear | Not possible but independent assessor | Yes | High |
| Moberg 2001 | Unclear | Not possible | Yes | High |
| Tawse-Smith 2001 | Unclear | Not possible | Yes | High |
| Åstrand 2002 | Inadequate | Not possible | Yes | High |
| Gatti 2002 | Inadequate | Not possible in part | Yes | High |
| Heydenrijk 2002 | Unclear | Not possible | Yes | High |
| Tawse-Smith 2002 | Unclear | Not possible | Yes | High |
| Payne 2003 | Unclear | Not possible | Yes | High |
| Friberg 2003 | Inadequate | Not possible in part | Yes | High |
| Payne 2004 | Unclear | Not possible | Yes | High |
| Schincaglia 2007 | Inadequate | Partly | Yes | High |
| Stavropoulos 2007 | Adequate | No | Yes | High |
| Lang 2007 | Adequate | Yes | Yes | Low |
| Fröberg 2006 | Unclear | Unclear | Yes | High |

# APPENDICES

## Appendix 1. MEDLINE (OVID) search strategy

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

# WHAT'S NEW

Last assessed as up-to-date: 9 August 2007.

| Date | Event | Description |
|---|---|---|
| 13 June 2008 | Amended | Converted to new review format. |

# HISTORY

Protocol first published: Issue 3, 2002

Review first published: Issue 4, 2002

| Date | Event | Description |
|---|---|---|
| 10 August 2007 | New citation required and conclusions have changed | Substantive amendment. This update of the review includes four new additional included and three new excluded randomised controlled trials. The follow up of one previously included study has been prolonged to 5 years. The quality assessment section has been simplified. Minor changes to the conclusions |

## CONTRIBUTIONS OF AUTHORS

Conceiving, designing and co-ordinating the review (Marco Esposito (ME)).

Developing search strategy and undertaking searches (ME, Paul Coulthard (PC)).

Screening search results and retrieved papers against inclusion criteria (ME, PC, Lawrence Murray-Curtis (LMC)).

Appraising quality (ME, PC, LMC).

Extracting data from papers (ME, Helen Worthington (HW), LMC).

Writing to authors for additional information (ME, HW).

Data management for the review and entering data into RevMan (HW, ME).

Analysis and interpretation of data (ME, HW).

Writing the review (ME).

Providing general advice on the review (PC, HW, Maria Gabriella Grusovin (MG)).

Performing previous work that was the foundation of current study (ME, HW, PC).

## DECLARATIONS OF INTEREST

Marco Esposito is working as independent methodological consultant for various implant related projects for some of the companies whose implants were used both in the included and excluded trials.

## SOURCES OF SUPPORT


### Internal sources

- School of Dentistry, The University of Manchester, UK.

### External sources

- The Swedish Medical Research Council (9495), Sweden.
- The Hjalmar Svennson Foundation, Sweden.
- The PPP Foundation, UK.
- The Jubileumsfonden (The Sahlgrenska Academy at Goteborg University), Sweden.


## INDEX TERMS

## Medical Subject Headings (MeSH)

*Dental Implantation, Endosseous; *Dental Implants; Jaw, Edentulous [*rehabilitation]; Jaw, Edentulous, Partially [rehabilitation]; Randomized Controlled Trials as Topic

## MeSH check words

Humans