Interventions for replacing missing teeth: different types of dental implants

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A substantive amendment to this systematic review was last made on 09 July 2002. Cochrane reviews are regularly checked and updated if necessary.

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 performances.

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

Search strategy: The Cochrane Oral Health Group Specialised Trials Register, The Cochrane Controlled Trials Register, MEDLINE and EMBASE were searched. Hand searching included several dental journals. Bibliographies of relevant clinical trials and review articles were checked for studies outside the handsearched journals. In addition, authors of all identified trials and fifty-five oral implant manufacturers were contacted to find unpublished or ongoing RCTs. Two extensive personal libraries (ME and AJ) were consulted. The last electronic search was conducted 8th May 2002.

Selection criteria: All randomised controlled trials of oral implants comparing implants with different materials, shapes and surface properties having a follow-up of at least one year.

Data collection and analysis: Data were independently extracted, in duplicate, by two reviewers (ME & HW). Authors were contacted for details of randomisation and withdrawals and a quality assessment was carried out. The Cochrane Oral Health Group's statistical guidelines were followed.

Main results: Thirty publications, representing 13 different RCTs, were identified. Five of these RCTs (seven publications), which reported results from a total of 326 patients, were suitable for inclusion in the review. Six implant systems were compared: Astra, Branemark, IMZ, ITI, Steri-Oss and Southern with a follow-up ranging from one to three years. All implants were made in commercially pure titanium and had different shapes and surface preparations. On a patient rather than per implant basis there were no statistically significant differences for failures and marginal bone level changes on intra-oral radiographs between various implant systems.

Reviewers' conclusions: There was no evidence that any of the implant systems evaluated was superior to the other. However, these findings are based on a few RCTs all having short follow-up periods and few participants. More RCTs should be conducted, with follow-up of at least five years

and including a sufficient number of patients, to detect a true difference if any exists. Such trials should be reported according to the CONSORT guidelines (http://www.consort-statement.org/).

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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 research, 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 1,300 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 differences in clinical performance among different implant types.

Objectives

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

Criteria for considering studies for this review

Types of studies

All randomised controlled clinical trials of oral implants for replacing missing teeth comparing different implant types.

Types of participants

Patients who have functionally loaded osseointegrated root-form oral implants and are followed up for at least one year. Patients subjected to bone grafting or guided tissue regeneration procedures and placement of implants in freshly extracted tooth sockets were excluded, as they are included in other Cochrane reviews (Coulthard 2002a; Coulthard 2002b).

Types of intervention

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

Types of outcome measures

- Implant mobility and removal of stable implants dictated by progressive marginal bone loss (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 bridge 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 fracture and other mechanical complications not allowing use of the implants (mechanical failures).
- Radiographic marginal bone level changes on intra-oral radiographs taken with a parallelling technique.

Search strategy for identification of studies

See: Collaborative Review Group search strategy

For the identification of studies included or considered for this review detailed search strategies were developed for each database searched. These were based on the search strategy developed for MEDLINE via OVID but revised appropriately for each database.

The search strategy used a combination of controlled vocabulary and free text terms based on the following:
#1 randomized controlled trial.pt.
#2 controlled clinical trial.pt.
#3 randomized controlled trials.sh.
#4 random allocation.sh.
#5 double blind method.sh.
#6 single blind method.sh.
#7 latin square.ti,ab.
#8 crossover.ti,ab.
#9 (split adj (mouth or plot)).ti,ab.
#10 or/1-9
#11 (ANIMAL not HUMAN).sh.
#12 10 not 11
#13 clinical trial.pt.
#14 exp clinical trials/
#15 (clin$ adj25 trial$).ti,ab.
#16 ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).ti,ab.
#17 placebos.sh.
#18 placebo$.ti,ab.
#19 random$.ti,ab.
#20 research design.sh.
#21 or/13-20
#22 21 not 11
#23 22 not 12
#24 12 or 22
#25 exp Dental Implants/
#26 exp Dental Implantation/ or dental implantation.mp.
#27 exp Dental Prosthesis, Implant-Supported/
#28 ((osseointegrated adj implant$) and (dental or oral)).mp. [mp=title, abstract, registry number word, mesh subject heading]
#29 dental implant$.mp. [mp=title, abstract, registry number word, mesh subject heading]
#30 (implant$ adj5 dent$).mp. [mp=title, abstract, registry number word, mesh subject heading]
#31 dental-implant$.mp. [mp=title, abstract, registry number word, mesh subject heading]
#32 (((overdenture$ or crown$ or bridge$ or prosthesis or prostheses or restoration$) adj10 (Dental or oral)) and implant$).mp. [mp=title, abstract, registry number word, mesh subject heading]
#33 "implant supported dental prosthesis".mp. [mp=title, abstract, registry number word, mesh subject heading]
#34 ("blade implant$" and (dental or oral)).mp. [mp=title, abstract, registry number word, mesh subject heading]
#35 ((endosseous adj5 implant$) and (dental or oral)).mp. [mp=title, abstract, registry number word, mesh subject heading]

#36 ((dental or oral) adj5 implant$).mp. [mp=title, abstract, registry number word, mesh subject heading]
#37 25 or 26 or 27 or 28 or 29 or 30 or 32 or 33 or 34 or 35 or 36
#38 24 and 37

SEARCHED DATABASES

- Cochrane OHG Specialised Trials Register
- The Cochrane Controlled Trials Register: Cochrane Library issue 2, 2002
- MEDLINE 1966 - May 2002
- EMBASE 1974 - May 2002

The most recent electronic search was done on 8th May 2002.

The bibliographies of identified RCTs and review articles were checked for studies outside the handsearched journals. PubMed was independently searched using "related articles" feature. Personal references were also searched.

LANGUAGE
There were no language restrictions.

UNPUBLISHED STUDIES
Personal contacts were also used to identify ongoing or unpublished RCTs. Authors of the identified RCTs and fifty-five oral implant manufacturers were written to in an attempt to identify unpublished or ongoing studies.

HANDSEARCHING
Details of the journals being handsearched by the Oral Health Group's ongoing programme are given on the web site: http:\www.cochrane-oral.man.ac.uk
The following journals have been identified as being important to be handsearched for this review: British Journal of Oral and Maxillofacial Surgery, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, International Journal of Periodontics and Restorative Dentistry, International Journal of Prosthodontics, Journal of the American Dental Association, Journal of Biomedical Materials Research, Journal of Clinical Periodontology, Journal of Dental Research, Journal of Oral Implantology, Journal of Oral and Maxillofacial Surgery, Journal of Periodontology, Journal of Prosthetic Dentistry. Where these have not already been searched as part of the Cochrane Journal Handsearching Programme, the journals were handsearched by two of the reviewers (ME and AJ).

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

QUALITY ASSESSMENT
The quality assessment of the included trials was undertaken independently and in duplicate by two reviewers (ME, PC) as part of the data extraction process.
Three main quality criteria were examined:

1) Allocation concealment, recorded as:
(A) Adequate
(B) Unclear
(C) Inadequate
(D) Not used, as described in the Cochrane Reviewers' Handbook.

2) Treatment blind to patients and outcomes blind to 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) None
(B) Yes
(C) No

Further quality assessment was carried out to assess the definition of exclusion/inclusion criteria, adequate definition of success criteria and comparability of control and treatment groups at entry. The quality assessment criteria were pilot tested using several articles.

DATA EXTRACTION

Data were extracted by two reviewers (ME, HW) independently using specially designed data extraction forms. The data extraction forms were piloted on several papers and modified as required before use. Any disagreement was discussed and a third reviewer (PC) 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 relative risks together with 95% confidence intervals. For continuous outcomes, mean differences and standard deviations were used to summarise the data for each group.

Clinical heterogeneity were to be assessed by examining the types of participants, interventions and outcomes in each study. Only if there were studies of similar comparisons reporting the same outcome measures was a meta-analysis to be attempted. Relative risks were to be combined for dichotomous data, and weighted mean differences for continuous data, using a random effects model. 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 any heterogeneity investigated.

It was planned to undertake sensitivity analyses to examine the effect of randomisation, allocation concealment and blind outcome 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, however there were insufficient studies to undertake this.

Description of studies

See: Tables of studies

See "Characteristics of included studies table".
See "Characteristics of excluded studies table".

CHARACTERISTICS OF THE TRIAL SETTING AND INVESTIGATORS

Of the 14 eligible trials (Friberg 1992; Geertman 1996; Boerrigter 1997; Jones 1997; Kemppainen 1997; Truhlar 1997; Batenburg 1998; Karlsson 1998; Åstrand 1999; van Steenberghe 2000; Khang 2001; Moberg 2001; Roccuzzo 2001; Tawse-Smith 2001), nine trials (Friberg 1992; Geertman 1996; Boerrigter 1997; Jones 1997; Truhlar 1997; Karlsson 1998; van Steenberghe 2000; Khang 2001; Roccuzzo 2001) were excluded due to problems with the data presented. Of the five included trials (Kemppainen 1997; Batenburg 1998; Åstrand 1999; Moberg 2001; Tawse-Smith 2001), two were conducted in Sweden (Åstrand 1999; Moberg 2001), one in Finland (Kemppainen 1997), one in New Zealand (Tawse-Smith 2001) and one in The Netherlands (Batenburg 1998). All five trials had a parallel group study design. Four trials received support from industry (Kemppainen 1997; Batenburg 1998; Åstrand 1999; Tawse-Smith 2001). Four trials were conducted at university dental clinics and one in a hospital (Åstrand 1999). All studies included adults.

CHARACTERISTICS OF THE INTERVENTIONS

Six different implant types where compared. Since the reviewers found discrepancies about the surface characteristics of the implants described in the reporting of one study (Tawse-Smith 2001) and the manufacturers' specification, it was decided to independently measure the surface roughness of each of the six implants. Some of the implants were already evaluated and the remainder were obtained directly from the trialists. The assessment was carried out by an expert in the field (AW) with an optical profilometer using a confocal design of its optics. Nine, 245 x 245µm areas on each fixture were measured. To be able to separate roughness from form and waviness, a Gaussian filter sized 50µm was used. Three parameters were used to describe the variation in height, spatial distribution and the increased surface area compared with a flat reference plane. Sa = average height deviation, Scx = average wavelength and Sdr = developed surface area.

1) Astra® (Astra Tech AB, Mölndal, Sweden) TIO blast titanium grade 3 screws. Sa=1.11µm, Scx=9.98µm, Sdr=31%. This surface demonstrates a homogenous structure. The irregularities are equally distributed over the surface.

2) Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark II type titanium grade 1 screws. Sa=0.68µm, Scx=8.09µm, Sdr=22%. A turned implant with visible marks from the cutting tool, an example of a surface with a clear orientation.

3) IMZ® (Friedrichsfeld AG, Mannheim, Germany) titaniummplasma-sprayed (TPS) titanium grade 2 cylinders. Sa=2.62µm, Scx=16.32µm, Sdr=78%. A rough, rather inhomogenous, structure and some small smooth parts were visible.

4) ITI® (Institut Straumann AG, Waldenburg, Switzerland) hollow TPS titanium grade 4 screws and cylinders. Sa=2.35µm, Scx=13.15µm, Sdr= 87%. A rough rather inhomogenous structure and some small smooth parts were visible.

5) Southern® (Southern Implants Irene, South Africa) sand-blasted acid-etched titanium grade 4 screws. Sa=1.43µm, Scx=12.18µm, Sdr= 50%.

6) Steri-Oss® (Steri-Oss, Yorba Linda, California, USA) HL series, 3.8 mm in diameter acid-etched titanium grade 4 screws. Sa=0.82µm, Scx=9.29µm, Sdr=26%.

In principle three types of surface modifications were analysed:
1) Surface with a clear orientation of the irregularities due to the cutting procedure during turning (Brånemark);
2) Surfaces without a domination direction (orientation), machined with techniques that remove material during manufacturing (Astra, Steri-Oss, Southern implants);

3) Surface without a dominating direction but machined with a process that add material to the surface, plasma-spraying (ITI and IMZ implants).

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

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 and IMZ implants were used according to a submerged (two-stage) procedure, i.e. implants were covered by the mucosa during the healing phase (three to six months in the mandible and six to seven months in the maxilla) and a second surgical intervention was necessary to connect the abutments (posts) to the implants. ITI, Southern and Steri-Oss implants were placed according to a non-submerged (one-stage) protocol, i.e. the abutments are directly connected to the implants, thus a second operation was avoided.

Implants were placed in edentulous mandibles (Åstrand 1999; Moberg 2001; Tawse-Smith 2001, Batenburg 1998) and maxillae (Åstrand 1999). Single implants were used in both maxillae and mandibles in one study (Kemppainen 1997).

In general, final prostheses were inserted four to eight months after implant placement in mandibles and seven to ten months in maxillae. However, in one study (Tawse-Smith 2001) mandibular overdentures were attached to the implants six to 12 weeks after implant placement. Cross-arch fixed prostheses were retained by screws on four to six implants (Åstrand 1999; Moberg 2001). Removable overdentures were retained by clip attachments to a bar supported by two implants (Batenburg 1998), or were retained by two ball attachments (Tawse-Smith 2001). Crowns were cemented on single implants (Kemppainen 1997).

CHARACTERISTICS OF OUTCOME MEASURES

Biological and mechanical failures as well as bone level measurements were recorded in all studies. However, in one trial (Moberg 2001) peri-implant bone level measurements were partly performed on panoramic radiographs and it was not included in the present analyses. In another trial (Batenburg 1998) insufficient data on the bone level assessment were presented and the authors were not able to supply the required data. All trials reported on implants functionally loaded for one year. One trial (Tawse-Smith 2001) included two years data and two trials presented three years data (Åstrand 1999; Moberg 2001)

Methodological quality

See: Table of included studies

ALLOCATION CONCEALMENT

The method of randomisation and allocation concealment was considered unclear for all trials despite author clarifications, with one exception (Batenburg 1998). According to the information provided by the authors, the randomisation procedure of this trial (Batenburg 1998) was not concealed. No reply was obtained for one trial (Moberg 2001).

BLINDING

It was not possible to blind the patients and outcome assessors to the interventions in all the included trials since in all cases the different shapes of implants and abutment were easily recognizable. However, in one trial (Åstrand 1999) an independent assessor made the radiographic evaluations.

WITHDRAWALS

The reporting of withdrawals was adequate for all trials with one exception (Batenburg 1998). However, an author of this study supplied the missing information.

SAMPLE SIZE

Only one study (Åstrand 1999) undertook an a priori calculation for the sample size to detect a true difference of 0.4 mm in marginal bone levels thought to be of clinical significance.

The percent agreement and kappa scores between the two raters were: 100%, 1.00 for allocation concealment and 60%, 0.38 for withdrawals.

Results

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- List of comparisons

In total, 957 implants (349 turned and 608 implants with roughened surfaces) were originally placed in 326 patients (238 mandibles and 88 maxillae) in the five trials. During the follow-up period considered in this review (one and three years) there were 25 implant failures (one due to implant fracture). Thirteen of the failed implants had a roughened surface and 12 had a turned surface. In particular, there were 18 early implant failures (ten implants had a roughened surface) and seven late failures (three implants had a roughened surface and one of these fractured). Peri-implantitis (advanced marginal bone loss with signs of infection such as suppuration) affected six implants (five implants had a roughened surface). Two implants were successfully treated, for two the outcome was uncertain and two implants failed.

No meta-analysis could be attempted as although different studies sometimes compared the same pair of implant types, they were confounded by other factors, for example one study considered overdentures and another fixed bridges. Another example was early loading and conventional loading. Implant failures and marginal bone level changes at one and three years are presented in Metaview comparisons 01 to 02.

ASTRA VERSUS BRÅNEMARK IMPLANTS

One trial (Åstrand 1999) with a parallel design compared submerged Astra versus submerged Brånemark screws in totally edentulous patients for three years. Thirty-three fully edentulous patients (17 maxillas 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. No withdrawals occurred during the study period. 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 per cent power in mandibles.

Nine Brånemark implants failed in five patients (one patient lost five implants and the bridge) versus two Astra implant failures in two patients (one failure was due to implant fracture between one- and three-year follow-ups) (comparison 02, outcome 01). Two additional Astra implants were successfully treated for peri-implantitis (suppuration combined with advanced bone loss).

At the patient level there was no statistically significant difference for failures and marginal bone level changes between the implant systems after three years of function (comparison 01, outcomes 01 and 02; comparison 02, outcomes 01,02).

ASTRA VERSUS ITI IMPLANTS

One trial (Kemppainen 1997) with a parallel design compared submerged Astra versus non-submerged ITI hollow cylinders and screws for single tooth replacement for one 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; eighteen 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) (comparison 01, outcome 01). All ITI implants were successful.

At the patient level there was no statistically significant difference for failures and marginal bone level changes between the implant systems after one year of function.

BRÅNEMARK VERSUS IMZ IMPLANTS

One trial (Batenburg 1998) with a parallel design compared two submerged Brånemark versus two IMZ submerged implants supporting overdentures in edentulous mandibles for one year. Thirty patients were included in each group. It was unclear whether there were any baseline differences for the two groups. Two patients dropped-out prior to the one-year examination (one in the Brånemark and one in the IMZ group). One Brånemark and one IMZ implant failed prior to the abutment connection operation (comparison 01, outcome 01).

At the patient level there was no statistically significant difference for failures between the implant systems after one year of function.

BRÅNEMARK VERSUS ITI IMPLANTS

Two trials (Batenburg 1998; Moberg 2001) with a parallel design compared submerged Brånemark versus non-submerged ITI hollow screws in totally edentulous mandibles.

One trial (Batenburg 1998) compared two implants supporting overdentures for one year. Thirty patients were included in each group. It was unclear whether there were any baseline differences for the two groups. One patient of the Brånemark group dropped-out prior to the one-year examination. One Brånemark implant failed prior to the abutment connection operation (comparison 01, outcome 01).

At the patient level there was no statistically significant difference for failures between the implant systems after one year of function.

One trial (Moberg 2001) compared implants supporting a fixed bridge for three 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 three-year examination (one in the Brånemark and two in the ITI group). One patient with Brånemark implants did not attend the three-year radiographic examination. Two Brånemark implants failed (one early failure and one for peri-implantitis between year one and two) (comparison 02, outcome 01). One ITI implant failed for peri-implantitis at two years. However, two additional ITI implants were found to be affected by peri-implantitis at the three-year examination and were under treatment. Their outcome was unknown at the time of reporting.

At the patient level there was no statistically significant difference for failures between the implant systems after three years of function.

IMZ VERSUS ITI IMPLANTS

One trial (Batenburg 1998) with a parallel design compared two submerged IMZ cylinders versus two non-submerged ITI hollow screws supporting overdentures in edentulous mandibles for one year. Thirty patients were included in each group. It was unclear whether there were any baseline differences for the two groups. One patient in the IMZ group dropped-out prior to the one-year examination. One IMZ implant failed prior to the abutment connection operation (comparison 01, outcome 01).

At the patient level there was no statistically significant difference for failures between the implant systems after one year of function.

STERI-OSS VERSUS SOUTHERN IMPLANTS

One trial (Tawse-Smith 2001) with a parallel 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 for two years. This trial comprised two additional groups for each implant system (12 subjects in each group): a control group where mandibular implants where loaded at 12 weeks and a test group where implants were loaded early at six weeks. The role of different loading strategies is discussed in another Cochrane review (Esposito 2002). Patients having type four bone were to be excluded, but none was found. There were no baseline differences in bone quality and quality between the four groups. However, the Steri-Oss and Southern implants, in conventionally loaded groups, were longer than those in the early loaded groups. In the 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 realized that the implant surface was chemically treated. The following information was based on the results at one-year follow-up. No drop out occurred at one year. One patient in the Steri-Oss conventionally loaded group (12 weeks) had an early implant failure, whereas five patients in the Steri-Oss early loaded group (six weeks) had seven early failures (comparison 01, outcome 01).

No implants were lost in the Southern groups. Most of the failed implants were placed by one surgeon who only placed some Steri-Oss implants.
At the patient level there was no statistically significant difference for failures and marginal bone level changes between the implant systems after one year of function (comparison 01, outcomes 01 and 02).

Discussion

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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 any of the RCTs we included, 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). Therefore, the present systematic review actually presents data of comparisons between different implant systems and not of specific implant characteristics.

In general, high success rates were reported for all implant systems. No statistically significant differences were found when root-formed titanium implants with different surface characteristics and shapes were compared. No trial described implants made or coated with other materials. Only one trial (Åstrand 1999) undertook a sample size calculation for detecting a true difference in marginal bone levels of 0.4 mm, considered to be of clinical significance. However, it can be debated whether a 0.4 mm difference bears any clinical significance. Also 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). 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, if any. In other words, it cannot be dismissed that a difference in effectiveness between various modified surfaces, materials and shapes does exist.

Whilst it was not the aim of this review to evaluate comparisons between submerged and non-submerged implants, it was noted that three trials (Kemppainen 1997; Moberg 2001; Batenburg 1998) failed to demonstrate any difference in success rates or marginal bone loss when comparing implants with different surfaces used in a submerged or non-submerged fashion. The great majority of the implants placed in a non-submerged mode were in mandibles, where success rates are usually higher (Esposito 1998). However, if these findings are substantiated by more robust RCTs, it will be possible to reduce patient discomfort and treatment costs by using a non-submerged technique. The issue of submerged and non-submerged implants is part of another Cochrane review (Coulthard 2002b).

It was judged to be premature to make any meta-analytic comparisons with respect to clinical effectiveness of oral implants with various degrees of surface roughness grouping different implant systems having similar degrees of surface roughness. This was due to the limited number of patients and short follow-up periods presently available. However, such comparisons will be attempted when additional data become available.

None of the trial authors characterized 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 one trial (Tawse-Smith 2001) 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 characterize 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.

The randomisation and concealment of allocation procedures were considered to be unclear for all, but one trial (Batenburg 1998) despite clarifications by authors of four trials (Kemppainen 1997; Batenburg 1998; Åstrand 1999; Tawse-Smith 2001). These aspects of trial designing and reporting need to be improved since it has been

shown that RCTs where randomisation and allocation concealment procedures were inadequately conducted tended to overestimate treatment effects (Schultz 1995a; Schultz 1995b).

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

Four of the five included trials reported that they were commercially funded, and we did not confirm this in the fifth study. It is possible that there could be publication bias in this area, however, these studies would probably not have taken place unless there was commercial funding. Ideally independent studies should be conducted.

Reviewers' conclusions

Implications for practice

Based on the available results of RCTs, there is no reliable evidence supporting the superiority of one type of implant surface, material or shape over the other for root-formed osseointegrated implants. No trial described implants made or coated with other materials than titanium. The comparison of implant systems placed following a submerged or non-submerged technique was not the aim of the present review (Coulthard 2002b). However, no statistically significant differences were observed between the two procedures. These conclusions are based on a few RCTs with relatively short follow-up periods and few patients. So we basically 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

In order to understand if there is any surface modification or material able to significantly improve the effectiveness of oral implants more well designed long-term RCTs are needed. It is recommended that such trials include a sufficient number of patients to detect a true difference, if any, and that they are of sufficient duration (five years or more). Such trials should be reported according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Moher 2001) (http://www.consort-statement.org/). Ideally, these trials should investigate only one aspect, such as the role of various degrees of surface roughness or the role of calcium-phosphate coatings, thus minimizing the numerous confounding factors such as different implant shapes or clinical procedures.

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Potential conflict of interest

None known.

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** indicates the major publication for the study*

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Cover sheet

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Interventions for replacing missing teeth: different types of dental implants

Reviewer(s)	Esposito M, Coulthard P, Worthington HV, Jokstad A, Wennerberg A
Contribution of Reviewer(s)	Conceiving, designing and coordinating the review (ME) Developing search strategy and undertaking searches (ME, AJ, PC) Screening search results and retrieved papers against inclusion criteria (ME, PC) Appraising quality and abstracting data from papers (ME, HW) Writing to authors for additional information (HW, ME) Data management for the review and entering data into RevMan (HW, ME) Analysis and interpretation of data (ME) Analysis of the surface implant characteristics (AW) Writing the review (ME) Providing general advice on the review (PC, HW, AJ, AW) Performing previous work that was the foundation of current study (ME, AJ, HW, PC)
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Date new studies sought but none found	Information not supplied by reviewer
Date new studies found but not yet included/excluded	Information not supplied by reviewer
Date new studies found and included/excluded	Information not supplied by reviewer
Date reviewers' conclusions section amended	Information not supplied by reviewer
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Synopsis

No strong evidence to show that any particular type of dental implant has superior longterm success rates.

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 longterm success rates of implants, and different types have been heavily marketed. More than 1,300 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.

Tables & Graphs

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- Table of ongoing studies

List of comparisons

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Fig 01 ALL COMPARISONS AT ONE YEAR

01.01.00 Implant failure
01.02.00 Bone levels

Fig 02 ALL COMPARISONS AT THREE YEARS

02.01.00 Implant failure
02.02.00 Bone levels

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Additional tables are not available for this review

Table of included studies

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Study	Methods	Participants	Interventions	Outcomes	Notes	Allocation concealment
Batenburg 1998	One-year follow-up randomised, parallel group study. Patients and outcome	Edentulous patients for at least 2 years with severely resorbed mandibles (class V-VI according to the Cawood and	Brånemark® (Nobel Biocare AB, Göteborg, Sweden) submerged turned titanium screws versus ITI® (Institut	Periotest and tapping the implant with superstructures removed, sensibility of lip and chin,		D

	assessor could not be blinded. Two withdrawals: one in the IMZ group (moved) and one in the ITI group (death unrelated to treatment).	Howell, 1988, classification). 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.	Straumann AG, Waldenburg, Switzerland) non-submerged hollow titanium plasma-sprayed screws versus IMZ® (Friedrichsfeld AG, Mannheim, Germany) submerged titanium plasma-sprayed supporting overdentures on 2 implants connected with a bar.	marginal bone level changes on standardized intra-oral radiographs, plaque accumulation, calculus, bleeding on probing, mucosa score, probing pocket depth, mucosa recession, width of attached peri-implant mucosa. One year data used.		
Kemppainen 1997	One-year follow-up randomised, parallel group study. Patients and outcome assessor could not be blinded. No withdrawals.	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 arterior region of the maxilla. 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.	Astra® (Astra Tech AB, Mölndal, Sweden) TiO2blast submerged titanium screws versus ITI® (Institut Straumann AG, Waldenburg, Switzerland) non-submerged hollow titanium plasma-sprayed screws and cylinders for single tooth replacement.	Implant stability, marginal bone level changes on standardized intra-oral radiographs, plaque accumulation, gingival index, probing pocket depth. One year data used.	ITI hollow screws were only placed in the mandibles.	B
Moberg 2001	Three-year follow-up	Edentulous mandibles.	Brånemark® (Nobel Biocare	Periotest and tapping the	At the 3-year examination, 2	B

	randomised, parallel group study. Patients and outcome assessor could not be blinded. Four withdrawals: 2 in the Branemark group (one died and one did not attend the radiographic examination) and 2 died in the ITI group.	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.	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.	implant with superstructures removed at 3 years, marginal bone level changes on intra-oral and panoramic radiographs, plaque accumulation, marginal bleeding, probing pocket depths, tightness of screws, sensory changes, treatment time, patient satisfaction, mechanical and biological complications, peri-implant infections with bone loss. One and 3-year data used.	ITI implants were undergoing treatment for peri-implantitis and their fate was unknown at the time of reporting.	
Tawse-Smith 2001	Two-year follow-up randomised, parallel group study. Patients and outcome assessor could not be blinded. No withdrawals at one year.	Edentulous mandibles having 13 to 15 mm of residual anterior bone height. Exclusion criteria were patients with type bone 4 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 systematic	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 overdentures	Periotest, marginal bone level changes on standardized intra-oral radiographs, bridge survival, plaque accumulation, modified sulcus bleeding index, probing pocket depth, width of the keratinised mucosa. One year data used.	Steri-Oss and Southern implants in the conventionally loaded groups seemed to be longer than the implants placed in the early loaded groups. Most of the failed implants were placed by a surgeon who placed only Steri-Oss implants.	B

		diseases likely to compromise implant surgery. Adults treated in the University Dental Clinic of the University of Otago, Dunedin, New Zealand. 48 enrolled (12 patients in each of the four groups) and results given for 48.	on 2 implants conventionally loaded at 12 weeks or early loaded at 6 weeks.			
Åstrand 1999	Three-year follow-up randomised, parallel group study. Patients and outcome assessor could not be blinded. No withdrawals.	Edentulous patients. Two 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.	Astra® (Astra Tech AB, Mölndal, Sweden) TiO2blast submerged titanium screws versus Brånemark® (Nobel Biocare AB, Göteborg, Sweden) Mark II type submerged turned titanium screws supporting fixed bridges.	Pain from implant region, implant stability tested with superstructure removed, bridge survival, marginal bone level changes on standardized intra-oral radiographs, plaque accumulation, bleeding on probing, operation time, mechanical complications, peri-implant infections with bone loss, presence or absence of attached peri-implant mucosa. One and 3-year data used.	8 patients in the Branemark group were scored at implant insertion as having type 4 bone quality (very soft bone) according to the Lekholm and Zarb classification versus 1 patient in the ITI group.	B

Table of excluded studies Top of document Previous table

Study	Reason for exclusion
Boerrigter 1997	Number of enrolled patients unclear. No reply to letter.
Friberg	Study classified as not RCT after author's reply .

1992	
Geertman 1996	Data of two different RCTs were combined. Asked for separate data. No reply to letter.
Jones 1997	Study classified as not RCT. No reply to letter.
Karlsson 1998	Not all patients were participating in a split-mouth study. Author reply failed to clarify the issue.
Khang 2001	Sort of "split-mouth" study with unequal number of implant randomly allocated to each patient.
Roccuzzo 2001	Problem as time of implant loading is confounded with implant type. Mobile implants not considered failures.
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.

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A table of ongoing studies is not available for this review