Outcomes and Complication Rates of the Tooth-Implant–Supported Fixed Prosthesis: A Systematic Review and Meta-Analysis

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Purpose: To evaluate the implant and prosthetic outcomes and biologic and technical complications of tooth-implant–supported fixed dental prostheses (TISFDPs) in comparison with implant-supported fixed dental prostheses (ISFDPs).

Materials and Methods: A comprehensive electronic search was performed by two independent reviewers up to February 2019. A hand search in relevant dental journals was also performed. The search identified a total of 175 citations, and 160 were excluded. Of the remaining 15 articles, seven were included in the review.

Results: The implant failure rate was between 0% and 9% for the TISFDPs and between 0% and 13% for the ISFDPs, and the prosthesis failure rate was between 0% and 13% for the TISFDPs and between 0% and 17% for the ISFDPs; no significant differences were observed within 24 to 120 months of follow-up. Less peri-implant marginal bone loss was observed in the TISFDPs (MD: –0.29; 95% CI: –0.58, 0.00; P = .05), but the difference was marginally significant. Abutment tooth intrusion rate was 3%, while abutment tooth fracture rate was between 0% and 4%. No significant differences in the technical complications were observed, although the TISFDPs had higher failure rates in framework fracture and abutment/prosthesis screw loosening, while ISFDPs had a higher failure rate in porcelain fracture.

Conclusion: The TISFDPs could be an alternative treatment option to ISFDPs for the partially edentulous patient with both treatments achieving comparable implant, prosthetic, biologic, and technical outcomes. Int J Oral Maxillofac Implants 2020;35:685–699. doi: 10.11607/jomi.8091

Keywords: meta-analyses, systematic reviews, tooth-implant–supported fixed dental prostheses

The rehabilitation of the partially edentulous patient with implant-supported fixed dental prostheses (ISFDPs) has become a standard treatment option with long-term success and predictability. A survival rate of 95% over 5 years and 80% over 10 years of function is expected for ISFDPs.¹ The safe and predictable outcomes of implants in restoring partial edentulism with fixed prostheses have markedly reduced the indications for removable partial dentures. However, when anatomical, prosthodontic, or patient-related factors preclude the use of implants at both ends of the edentulous span, alternative approaches need to be considered. For example, the placement of single implants in the posterior area of distal extension situations to assist removable partial dentures has been reported with positive long-term outcomes.²⁻⁵ The alternative option of connecting natural teeth to implants to support tooth-implant fixed dental prostheses (TISFDPs) has also been described⁶,⁷ with variable outcomes.⁸ Traditionally, TISFDPs were considered a high-risk treatment option compared with tooth-supported or solely ISFDPs.⁹,¹⁰ The risk of failure in TISFDPs was thought to result from differences in the biomechanical behavior of implants and natural teeth under loading.¹¹ Implants are in direct functional contact with the surrounding bone,¹²,¹³ while natural teeth are suspended within the bone through viscoelastic periodontal ligaments.¹⁴ With this, a differential mobility of 5:1 between natural teeth and implants is thought to result in the TISFDPs being entirely implant borne.¹⁵,¹⁶ The difference in mobility between natural teeth and implants has been implicated in the increased incidence of biologic and mechanical/technical complications associated with TISFDPs.¹⁷ Among these, peri-implant marginal bone loss, periapical pathology, tooth intrusion, prosthetic screw loosening, and fracture of implants or prosthetic components were reported.⁹,¹⁸⁻²¹ Others attributed these complications to the type of connection used to splint the natural teeth to the implants, rather than to the TISFDP treatment itself.²,²²

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Historically, nonrigid connections were used to compensate for the differences in the resiliency between teeth and implants with the premise of improving treatment longevity. Implants with integrated flexible elements, mimicking the periodontal ligament, were also utilized, however, the clinical success of these mechanisms was limited. On the other hand, TISFDPs with rigid connections demonstrated more favorable outcomes and were recommended for application when treatment with TISFDPs is indicated, for example, in situations where anatomical limitations preclude the use of solely ISFDPs, where tooth and implant distribution is unfavorable, or when financial resources of patients are limited. Despite these recommendations, the clinical application of TISFDPs remained controversial. Over the past decades, several reviews of varied methodologies and designs addressing various aspects related to TISFDPs have been published. The majority of these reviews presented narrative accounts of a mixture of clinical, animal, and laboratory studies that lacked scientific rigidity in their selection. Others mainly focused on biomechanical aspects related to the type of connection and associated tooth intrusion phenomenon. Systematic reviews on treatment outcomes of TISFDPs of robust designs remain limited in the published literature. Hence, the aim of the present systematic review and meta-analysis was to evaluate the outcomes of TISFDPs in comparison to solely ISFDPs with respect to implant and prosthesis failure rates and the complications associated with their use.

**MATERIALS AND METHODS**

The present review was conducted in full adherence with the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and the Cochrane Collaboration. The review adopts the PICO index to answer a focused question:

- **P**: Population—partially edentulous patients who required fixed dental prostheses (FDPs)
- **I**: Intervention—TISFDPC
- **C**: Comparison—ISFDPO
- **O**: Outcomes—implant failure rate, abutment tooth failure rate, prosthesis failure rate, biologic complications, technical complications

**Types of Studies**

**Inclusion Criteria.** A study was deemed eligible if it was a randomized controlled trial (RCT), nonrandomized controlled clinical trial (CCT), or retrospective human study that compared TISFDPs with ISFDPs for oral rehabilitation treatment and reported on any of the following outcome measures: tooth and implant failure rate, prosthesis failure rate, peri-implant marginal bone level changes, and intrusion of abutment teeth for both groups with an observation period of not less than 24 months. No search restrictions were employed with regard to the language of the study.

**Exclusion Criteria.** Case series and case reports were excluded. Studies that lacked control groups or did not provide sufficient data were also excluded.

**Outcome Measures**

Outcome measures were as follows:

**Primary Outcomes:**
- Implant failure rate, abutment tooth failure rate, prosthesis failure rate.
- Implant failure rate is defined as the percentage of implants reported to be lost after placement.

**Secondary Outcomes:**
- Biologic complications—peri-implant marginal bone level changes, abutment tooth intrusion, abutment tooth fracture.
- Technical complications—implant abutment loosening/fracture, implant abutment/abutment screw/prosthesis screw loosening or fracture, framework fracture, porcelain veneer fracture.

**Literature Search Protocol**

The search protocol was conducted according to the recommendations made by Faggion and coworkers. Electronic databases, including MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials (CENTRAL), MetaRegister, ClinicalTrials.gov, and Grey literature in Europe (http://www.opengrey.eu), were utilized to search for trials up to February 7, 2019 (Table 1). Two authors (M.A. and N.A.) independently performed the search. The references of all eligible papers were scrutinized for additional article identification. A manual search of the last 5 years of relevant dental journals (Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Periodontics and Restorative Dentistry, International Journal of Prosthodontics, and Journal of Clinical Periodontology) was performed to complement the electronic database search.

**Selection of Studies**

Two reviewers (M.A. and N.A.) independently read the title, abstract, and keywords of the retrieved articles in duplicate to identify RCTs, CCTs, and retrospective studies. The full text of any potentially eligible study was
evaluated on the basis of the aforementioned eligibility criteria. When disagreements occurred, resolution was reached through open discussion between the two reviewers.

**Data Collection**

The data extraction process was independently executed by two reviewers (M.A. and N.A.). The collected study information included:

- **Study features**: first author, contact address, trial location, language of publication, year of publication, detailed study design (parallel group or split mouth), randomization method, study duration, allocation concealment, and blinding
- **Participants**: demographic features, eligibility criteria, number of participants in test and control groups, number and reasons for dropouts
- **Interventions**: the use of TISFDP
- **Comparison**: the use of ISFDP
- **Outcomes**: implant failure rate, abutment tooth failure rate, prosthesis failure rate, biologic and technical complications
- **Length of the observation period**

Any disagreements between reviewers were resolved by discussion to reach a consensus. Additional information was acquired by writing to corresponding authors of the included trials.

**Quality Assessment**

Two reviewers (M.A. and N.A.) independently used the Cochrane Collaboration’s Risk of Bias tool\(^*\) to evaluate the selected trials. The tool is based on seven items (sequence generation, allocation concealment, blinding of participants and investigators, blinding of outcome assessment, incomplete data outcome, selective outcome reporting, and potential sources of bias). The first section of the tool defines each item, while the second part sorts out studies into those having (1) low risk of bias if all the measures were judged at low risk of bias, (2) unclear risk of bias if one or more measures were judged at unclear risk of bias, or (3) high risk of bias if one or more measures were judged at high risk of bias.

**Data Synthesis**

Meta-analysis was carried out for studies recording similar outcome measures using a statistical software program (Review Manager [RevMan] Version 5.3, the Nordic Cochrane Centre, the Cochrane Collaboration). Dichotomous data such as abutment tooth and implant failure were expressed in risk ratio (RR) estimates and 95% confidence intervals (CIs). Continuous data such as peri-implant marginal bone levels were expressed in mean difference (MD) and 95% CIs. A fixed-effects model was initially used to pool the results, while a random-effects model was used when significant heterogeneity was present. In the presence of less than 10 studies, publication bias was not evaluated, as the power to identify publication bias is limited.\(^*\) Cochran’s test for heterogeneity and I\(^2\) statistic were used to examine heterogeneity across the selected studies.\(^*\) A significant heterogeneity is present when an I\(^2\) value of > 50 was detected. The unit of analysis was the abutment tooth/implant rather than the participant, as the outcomes may vary among the two treatment protocols.

**RESULTS**

**Description of Studies**

A total of 175 citations were retrieved from the initial search (Fig 1). After reviewing the titles and abstracts, 160 were excluded. The full texts of the remaining 15

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**Table 1  Databases and Search Terms**

<table>
<thead>
<tr>
<th>Databases and Search Terms</th>
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<tbody>
<tr>
<td><strong>Published studies</strong></td>
</tr>
<tr>
<td>PubMed</td>
</tr>
<tr>
<td>(1965–February 7, 2019)</td>
</tr>
<tr>
<td>(tooth implant support* OR implant support* OR prosthesis) AND (tooth implant connection OR connecting teeth to implants OR combined tooth implant support) AND (biological complication* OR technical complication* OR tooth intrusion OR tooth fracture OR prosthesis fracture OR screw loosening OR implant failure)</td>
</tr>
<tr>
<td><strong>EMBASE via Ovid</strong></td>
</tr>
<tr>
<td>(tooth implant support* OR implant support* OR prosthesis) AND (tooth implant connection OR connecting teeth to implants OR combined tooth implant support) AND (biological complication* OR technical complication* OR tooth intrusion OR tooth fracture OR prosthesis fracture OR screw loosening OR implant failure)</td>
</tr>
<tr>
<td><strong>Cochrane Central Register of Controlled Trials (CENTRAL) via Ovid</strong></td>
</tr>
<tr>
<td>(February 7, 2019)</td>
</tr>
<tr>
<td>((tooth implant supported OR implant supported) adj5 prosthesis).mp. AND ((biological or technical) adj5 complication$ OR implant adj5 failure).mp.</td>
</tr>
<tr>
<td><strong>Unpublished studies</strong></td>
</tr>
<tr>
<td>MetaRegister of controlled trials OpenGrey (<a href="http://www.opengrey.eu">www.opengrey.eu</a>) ClinicalTrials.gov</td>
</tr>
<tr>
<td>(February 7, 2019)</td>
</tr>
<tr>
<td>(tooth implant supported prosthesis OR implant supported prosthesis OR biological complications OR technical complications OR implant failure)</td>
</tr>
</tbody>
</table>
articles\textsuperscript{6,18,28,41–53} were scrutinized for eligibility. A total of eight studies\textsuperscript{6,28,41,45,47–49,52} fulfilled the inclusion criteria of the review. Because one study was published in two parts\textsuperscript{48,49}, only one reference\textsuperscript{49} was used throughout the present review. The hand search did not provide any further studies, and therefore, only seven studies were included in this review (Table 2). Of the seven included studies, two were conducted in Belgium\textsuperscript{45,49}, two in Sweden\textsuperscript{6,28}, one in Egypt\textsuperscript{47}, one in Germany\textsuperscript{52}, and one in Turkey\textsuperscript{41}.

Of the seven studies included in the present review, only one\textsuperscript{6} was RCT, five\textsuperscript{28,41,45,47,49} were CCTs, and one\textsuperscript{52} was retrospective. All the studies were conducted at a university setting. A split-mouth design was used in three trials\textsuperscript{6,28,45}. Information regarding the source of funding was missing in five studies\textsuperscript{6,41,45,47,49}, whereas one study\textsuperscript{52} was self-funded and only one declared receiving external funding\textsuperscript{28}.

Characteristics of Participants at Baseline
The baseline characteristics of patients in the included studies are described under the following criteria.

\textbf{Inclusion Criteria:}
\begin{itemize}
  \item Systemically healthy\textsuperscript{28,47}
  \item Absence of psychologic disorder\textsuperscript{47}
  \item Adequate oral home care\textsuperscript{47}
  \item Partial maxillary or mandibular edentulism of similar dimensions (≥ 5 mm wide and ≥ 12 mm high) that do not require bone grafting\textsuperscript{41}
  \item Partial maxillary or mandibular edentulism\textsuperscript{49,52}
  \item Partial mandibular edentulism\textsuperscript{47}
  \item Bilateral partial mandibular edentulism with maxillary complete denture\textsuperscript{5}
  \item Bilateral partial maxillary and mandibular edentulism\textsuperscript{45}
  \item Bilateral partial maxillary edentulism with sufficient bone volume\textsuperscript{28}
  \item Adequate maxillomandibular space of at least 5 mm\textsuperscript{47}
  \item Presence of opposing teeth or implants\textsuperscript{28,47}
  \item Abutment teeth with an optimal anatomical root-crown ratio of 2:3\textsuperscript{41}
\end{itemize}

\textbf{Exclusion Criteria:}
\begin{itemize}
  \item History of radiotherapy in the head and neck region\textsuperscript{28,47}
  \item Heavy smokers\textsuperscript{47} or smoking more than 20 cigarettes per day\textsuperscript{41}
  \item Alcoholic and/or drug abusers\textsuperscript{47}
  \item Parafunctional habits\textsuperscript{47}
  \item History of advanced periodontal disease\textsuperscript{41}
  \item History of endodontic treatment of most posterior teeth\textsuperscript{6}
  \item History of carious lesions or periodontal infections in the residual anterior maxillary dentition\textsuperscript{28}
  \item Previous use of removable partial prostheses and partial edentulism of more than 1 year\textsuperscript{41}
\end{itemize}

\textbf{Surgical and Prosthetic Techniques}
The implants were placed following either a one-stage\textsuperscript{6} or two-stage approach.\textsuperscript{28,41,45,49} The availability of sufficient bone volume was one of the prerequisites for placing the implants in only one study,\textsuperscript{41} whereas in one study,\textsuperscript{6} implants were placed even in the presence of heavily resorbed ridge. The remaining studies did not provide clear information on whether augmentation procedures were required prior to or at implant placement. The implant was placed approximately 11 mm distal to the abutment tooth,\textsuperscript{41} while the two implants were placed approximately 14 mm apart in the ISFDP group.\textsuperscript{41} Sleeping implants (implants left unconnected to prostheses) were placed in two studies\textsuperscript{6,28} and used to support FDPs when abutment teeth were not suitable. Prosthetic treatment started after 6 to 8 weeks of transmucosal healing,\textsuperscript{41} 3 to 6 months after implant placement,\textsuperscript{6,28,45,47,49} or up to 9 months after implant placement when simultaneous augmentation was required.\textsuperscript{52}
Implants were rigidly and nonrigidly connected to teeth. The remaining studies used only rigid connectors. Cement-retained rigid FDPs were fabricated, and posterior terminal implants were rigidly connected to abutment teeth. A precision attachment (McCollum T-attachment, Centres Metaux) was used in another study to provide rigid connection between the two parts of the TISFDP framework. The TISFDPs were also fitted with rigid custom-made titanium attachments or fabricated with telescopic crowns cemented to the abutment teeth with temporary cement and screw retained to the implants. In one study, the FDPs were made of one-piece framework of either metal or zirconia.

Abutment teeth, which were endodontically treated, were restored with posts and cores. The occlusal schemes were mutually protected, balanced occlusion, group function, or canine protected occlusion. In one study, the occlusal scheme was described as canine/incisor protected dynamic occlusion. The FDPs opposed natural dentition or complete maxillary dentures. The shortened dental arch concept was applied when the opposing dentition was shortened.

Characteristics of the Outcome Measures

**Primary Outcome Measures:**
- Implant failure rate
- Abutment tooth failure rate
- Prosthesis failure rate

**Secondary Outcome Measures:**
- Peri-implant marginal bone level changes
- Abutment tooth intrusion rate
- Abutment tooth fracture rate

**Technical complications—**
- FDP framework fracture rate
- FDP porcelain fracture rate
- Implant abutment/prosthesis screw loosening rate
- Implant abutment/prosthesis screw fracture rate

**Risk of Bias in Included Studies**
All the included studies were judged to be at high risk of bias (Table 3 and Fig 2).

**Allocation (Selection Bias)**
One study did not provide sufficient information on the method of randomization to enable a clear judgment and was hence considered under unclear risk of bias. Two studies showed clearly that randomization was not possible. The random sequence generation was not described in the remaining studies. None of the studies referred to allocation concealment and therefore were assessed at high risk of bias for this domain.

**Blinding (Performance Bias and Detection Bias)**
The choice between a TISFDP and ISFDP did not allow blinding of participants due to the nature of intervention. Nevertheless, blinding of the examiners toward recording some outcome measures was possible and might have reduced the risk of detection bias. Blinding was not reported in any study.

**Incomplete Outcome Data (Attrition Bias)**
Withdrawals occurred in two studies. In one study, three participants were excluded due to death (two participants) and refusal of one participant to attend the follow-up. Two participants were excluded in another study due to death and failure to attend the 2-year follow-up. No withdrawals were reported in the other studies.

**Selective Reporting (Reporting Bias)**
All studies were judged to be at low risk of reporting bias.

**Other Potential Sources of Bias**
One study was self-funded, and another study was partly funded by the implant manufacturer. The source of funding was not specified in the remaining studies.

**Outcomes and Pooled Estimates**
In total, 494 participants with 649 FDPs were included in the review, of which 299 were TISFDPs. In one trial, the use of implant-supported cantilever FDPs were reported, but only data related to TISFDP and ISFDP groups were included in the quantitative analysis.

**Primary Outcomes**

**Implant Failure Rate.** The rate of implant failure was reported in all included studies. The failure rate for the TISFDPs ranged from 0% to 9%, while that for the ISFDPs ranged from 0% to 13%. The overall meta-analysis found no significant difference between TISFDPs and ISFDPs in the rate of implant failure (RR: 2.06; 95% CI: 0.55, 7.80; P = .29; Fig 3a). Moderate heterogeneity was noted (Chi² = 4.82; df = 3; P = .19; I² = 38%).

**Abutment Tooth Failure Rate.** The rate of abutment tooth failure was reported in all included studies. The rate of abutment tooth failure was 2% in one study and 4% in two studies. None of the abutment teeth failed in the remaining four trials.

**Prosthesis Failure Rate.** The rate of prosthesis failure was reported in all included studies. For TISFDPs, the prosthesis failure rate ranged from 0% to...
### Table 2  Characteristics of the Included Studies

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Study design</td>
<td>CCT (parallel-group)</td>
<td>RCT (split-mouth)</td>
<td>CCT (split-mouth)</td>
</tr>
<tr>
<td>Location</td>
<td>Hacettepe University, Ankara, Turkey</td>
<td>Umea University, Sweden</td>
<td>Catholic University Leuven, Belgium</td>
</tr>
<tr>
<td>No. of FDPs</td>
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<td>ISFDP: 34</td>
<td>ISFDP: 15</td>
</tr>
<tr>
<td>No. of implants</td>
<td>TISFDP: 34</td>
<td>ISFDP: 30</td>
<td>ISFDP: 30</td>
</tr>
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<td>Age (y)</td>
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<td>57.7</td>
<td>49.5 (37 to 65)</td>
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<td>Methods of assessment</td>
<td>Periapical radiograph</td>
<td>Periapical radiograph</td>
<td>Periapical radiograph</td>
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<tr>
<td>Implant system</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Implant diameter (mm)</td>
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<tr>
<td>Implant length (mm)</td>
<td>10</td>
<td>7–13</td>
<td>7–18</td>
</tr>
<tr>
<td>Implant location</td>
<td>Mandibular and maxillary arches</td>
<td>Mandibular arch</td>
<td>Mandibular and maxillary arches</td>
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<td>Connector type</td>
<td>Rigid</td>
<td>Rigid</td>
<td>Rigid and nonrigid</td>
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<td>Mutually protected occlusion or Group function</td>
<td>Balanced occlusion</td>
<td>Equal contact in maximal occlusion Canine guidance or group function during excursions</td>
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<tr>
<td>Peri-implant marginal bone level changes (mm) at 24 mo</td>
<td>TISFDP: 0.285 ± 0.329</td>
<td>ISFDP: 0.3 ± 0.1**</td>
<td>NR</td>
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<tr>
<td>Abutment tooth intrusion rate, n (%)</td>
<td>0 (0)</td>
<td>NR</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Abutment tooth fracture rate, n (%)</td>
<td>0 (0)</td>
<td>NR</td>
<td>0 (0)</td>
</tr>
<tr>
<td>FDP framework fracture rate, n (%)</td>
<td>TISFDP: NR</td>
<td>ISFDP: NR</td>
<td>0 (0)</td>
</tr>
<tr>
<td>FDP porcelain fracture rate, n (%)</td>
<td>TISFDP: 0 (0)</td>
<td>ISFDP: 3 (20)</td>
<td>0 (0)</td>
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<tr>
<td>Implant abutment/prosthesis screw loosening rate, n (%)</td>
<td>TISFDP: 3 (13)</td>
<td>ISFDP: 2 (4)</td>
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<tr>
<td>Implant abutment/prosthesis screw fracture rate, n (%)</td>
<td>TISFDP: 0 (0)</td>
<td>ISFDP: 0 (0)</td>
<td>0 (0)</td>
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<td>Abutment tooth failure rate, n (%)</td>
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<td>0 (0)</td>
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<td>Implant failure rate, n (%)</td>
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<td>ISFDP: 6 (13)</td>
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<td>Prostheses failure rate, n (%)</td>
<td>TISFDP: 1 (3)</td>
<td>ISFDP: 0 (0)</td>
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<tr>
<td>Observation time (mo)</td>
<td>26 (mean)</td>
<td>120</td>
<td>78 (mean)</td>
</tr>
</tbody>
</table>

RCT = randomized controlled trial; CCT = controlled clinical trial; RCT = retrospective; TISFDP = tooth-implant–supported fixed dental prosthesis; ISFDP = implant-supported fixed dental prosthesis; NR = not reported.

*Information obtained from the authors.
†Sleeping implants were not counted.
‡Dynamic occlusion, using connectors.
§Straumann System, Nobel Biocare.
¶Brånemark Mark II, Nobel Biocare.
*Tapered screw vent implant, Zimmer Biomet Dental.
**Obtained from the 2-year follow-up study (Gunne et al, 1992).

13%, and for the ISFDPs, the range was between 0% and 17%. The overall meta-analysis found no significant difference between TISFDPs and ISFDPs in the rate of prosthesis failure (RR: 2.22; 95% CI: 0.57, 8.62; P = .25; Fig 3b). Heterogeneity was noted (Chi² = 8.82; df = 4; P = .07; I² = 55%).
### Table 2

<table>
<thead>
<tr>
<th>Study</th>
<th>CCT (split-mouth)</th>
<th>CCT (parallel-group)</th>
<th>CCT (parallel-group)</th>
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<td>Tanta University, Egypt</td>
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<td>University of Heidelberg, Germany</td>
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<td></td>
<td>52</td>
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<td>69$^a$</td>
<td>20</td>
<td>329</td>
<td>189$^a$</td>
</tr>
<tr>
<td></td>
<td>67 (49–84)</td>
<td>25 to 50</td>
<td>TISFD$^b$: 51.8 (20 to 79)</td>
<td>ISFD$^b$: 52.3 (22 to 78)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>ISFDP: 78 (mean)</td>
<td>61.2 (21 to 83)</td>
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<td>Periapical radiograph</td>
<td></td>
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<td>NR</td>
<td>8–14</td>
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<td>Maxillary arch</td>
<td>Rigid</td>
<td>Rigid</td>
<td>Rigid and nonrigid</td>
<td>FDPs made in one piece without using connectors</td>
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<tr>
<td></td>
<td>NR</td>
<td>Canine guidance</td>
<td>Equal contact in maximal occlusion</td>
<td>Canine / incisor protected dynamic occlusion</td>
</tr>
<tr>
<td></td>
<td>0.09 ± 0.52</td>
<td>0.73 ± 0.060</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>0.42 ± 0.55</td>
<td>0.71 ± 0.067</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td>1 (4)</td>
<td>NR</td>
<td>3 (2)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td>NR</td>
<td>NR</td>
<td>2 (1)</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>NR</td>
<td>NR</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td>NR</td>
<td>NR</td>
<td>1 (0)</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Peri-implant marginal bone level changes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biologic Complications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abutment tooth intrusion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Secondary Outcomes**

### Biologic Complications

#### Peri-implant marginal bone level changes

The overall meta-analysis, which included the four studies,$^{28,41,47}$ showed less peri-implant marginal bone loss around TISFD$^b$Ps (MD: $-0.29$; 95% CI: $-0.58$, $0.00$; $P = .05$; Fig 4a), and the difference was marginally significant. Substantial heterogeneity was detected ($\chi^2 = 94.75$; df $= 3$; $P < .0001$; $I^2 = 97\%$).

#### Abutment tooth intrusion

Abutment tooth intrusion in TISFD$^b$Ps was reported in six studies.$^{28,41,45,47,49,52}$ Of these, tooth intrusion was observed only in one study$^{45}$ with a rate of 3%.

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Abutment tooth fracture

Four studies\(^{28,41,45,49}\) reported on the abutment tooth fracture rate in TISFDPs. No incident of abutment tooth fracture was observed in two studies,\(^{41,45}\) while in the other two, the rate was 1%\(^{49}\) and 4%\(^{28}\).

**Technical Complications.** The overall meta-analysis of three studies\(^{45,49,52}\) showed that TISFDPs had a higher framework fracture rate than ISFDPs (RR: 7.00; 95% CI: 0.36, 134.27; \(P = .20\)) (Fig 4b). In contrast, the rate of porcelain fracture, which was observed in three studies,\(^{41,45,52}\) was higher in the ISFDP group compared with the TISFDP group (RR: 0.33; 95% CI: 0.03, 3.52; \(P = .36\)) (Fig 4c). The differences in framework and porcelain fractures between the two groups, however, were not statistically significant.

The rate of implant abutment/prosthesis screw loosening was recorded in six studies.\(^{6,28,41,45,47,52}\) TISFDPs had a higher rate of implant abutment/prosthesis screw loosening compared with ISFDPs. The pooled estimates did not show any significant difference between TISFDPs and ISFDPs (RR: 2.79; 95% CI: 0.92, 8.46; \(P = .07\)) (Fig 4d). No significant heterogeneity was noticed (Chi\(^2\) = 0.49; df = 3; \(P = .92\); I\(^2\) = 0%). The rate of implant abutment/prosthesis screw fracture was reported in six studies.\(^{28,41,45,47,49,52}\) The overall meta-analysis

---

**Table 3  Assessment of Risk of Bias of the Included Studies**

<table>
<thead>
<tr>
<th>Study</th>
<th>Random sequence generation (selection bias)</th>
<th>Allocation concealment (selection bias)</th>
<th>Blinding of outcome assessment (detection bias)</th>
<th>Incomplete outcome data (attrition bias)</th>
<th>Selective reporting (reporting bias)</th>
<th>Other bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akça and Cehreli, 2008(^{41})</td>
<td>High risk</td>
<td>Unclear risk</td>
<td>High risk</td>
<td>Low risk</td>
<td>Low risk</td>
<td>None detected</td>
</tr>
<tr>
<td>Gunne et al, 1999(^{6})</td>
<td>No information</td>
<td>Uninformed</td>
<td>High risk</td>
<td>All outcomes appear to be detected</td>
<td>All outcomes appear to be detected</td>
<td>None detected</td>
</tr>
<tr>
<td>Hosny et al, 2000(^{45})</td>
<td>Unclear risk</td>
<td>High risk</td>
<td>High risk</td>
<td>Low risk</td>
<td>Low risk</td>
<td>None detected</td>
</tr>
<tr>
<td>Lindh et al, 2001(^{28})</td>
<td>High risk</td>
<td>High risk</td>
<td>High risk</td>
<td>Low risk</td>
<td>Low risk</td>
<td>None detected</td>
</tr>
<tr>
<td>Mostafa et al, 2015(^{49})</td>
<td>High risk</td>
<td>High risk</td>
<td>High risk</td>
<td>Low risk</td>
<td>Low risk</td>
<td>None detected</td>
</tr>
<tr>
<td>Naert et al, 2001(^{44,49})</td>
<td>High risk</td>
<td>High risk</td>
<td>High risk</td>
<td>Low risk</td>
<td>Low risk</td>
<td>None detected</td>
</tr>
<tr>
<td>Rammelsberg et al, 2013(^{52})</td>
<td>High risk</td>
<td>High risk</td>
<td>High risk</td>
<td>Low risk</td>
<td>Low risk</td>
<td>None detected</td>
</tr>
</tbody>
</table>

**Fig 2  Risk of bias graph.**
Alsabeeha/Atieh

found no significant difference between the TISFDPs and ISFDPs in the rate of implant abutment/prosthesis screw fracture (RR: 1.20; 95% CI: 0.30, 4.80; \( P = .80 \); Fig 4e). No heterogeneity was noted (Chi2 = 0.12, df = 1; I2 = 0%).

**DISCUSSION**

**Summary of the Main Findings**

The overall implant failure rate in this review was between 0% and 13% over 24 to 120 months of follow-up. The meta-analysis did not reveal any significant differences in the implant failure rates between TISFDPs and ISFDPs (0% to 9% for TISFDPs; 0% to 13% for ISFDPs). The highest failure rate for implants in both treatments was reported in the study by Gunne et al.\(^6\) This study was an RCT of a split-mouth design with the longest observation period of 120 months. It included a total of 69 implants placed in 23 patients with Kennedy Class I mandibles opposing maxillary complete dentures. All failed implants (eight in total: three in the TISFDPs and six in the ISFDPs) occurred during the first 2 years with one implant failing prior to functional loading. The authors considered the TISDP a predictable treatment option comparable to the ISDP. On the other hand, the study by Lindh et al.\(^28\) reported 4% and 3% implant failure rates for TISFDPs and ISFDPs, respectively, over an observation period of 24 months. These rates included one implant failure in the TISDP group and two in the ISDP group. In contrast to the study by Gunne et al.\(^6\), the implants and reconstruction were placed exclusively in the mandible, the intervention in the study by Lindh et al.\(^28\) was performed mainly in the posterior maxillae of 26 patients. In the remaining six studies, no implant failure in both treatment groups was reported in three studies,\(^41,45,47\) while in the remaining three,\(^28,49,52\) the overall implant failure rate was between 0.3% and 3%. In a large patient cohort, Naert et al.\(^49\) conducted a CCT with two parallel treatment groups (a test group with TISFDPs and a control with ISFDPs) of 123 patients each and a total of 663 implants. The mean follow-up period

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### Table 1: Comparison of Primary Outcomes

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>TISDP</th>
<th>ISDP</th>
<th>M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akca and Cehreli, 2008</td>
<td>0</td>
<td>34</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Gunne et al, 1999</td>
<td>2</td>
<td>23</td>
<td>0.67 [0.15, 3.05]</td>
</tr>
<tr>
<td>Hosny et al, 2000</td>
<td>0</td>
<td>30</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Lindh et al, 2001</td>
<td>1</td>
<td>26</td>
<td>1.33 [0.13, 14.02]</td>
</tr>
<tr>
<td>Mostafa et al, 2015</td>
<td>0</td>
<td>10</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Naert et al, 2001</td>
<td>10</td>
<td>339</td>
<td>9.71 [1.25, 75.39]</td>
</tr>
<tr>
<td>Rammelsberg et al, 2013</td>
<td>1</td>
<td>52</td>
<td>3.63 [0.23, 57.13]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>114</td>
<td>731</td>
<td>2.06 [0.55, 7.80]</td>
</tr>
</tbody>
</table>

**DISCUSSION**

**Summary of the Main Findings**

The overall implant failure rate in this review was between 0% and 13% over 24 to 120 months of follow-up. The meta-analysis did not reveal any significant differences in the implant failure rates between TISFDPs and ISFDPs (0% to 9% for TISFDPs; 0% to 13% for ISFDPs). The highest failure rate for implants in both treatments was reported in the study by Gunne et al.\(^6\) This study was an RCT of a split-mouth design with the longest observation period of 120 months. It included a total of 69 implants placed in 23 patients with Kennedy Class I mandibles opposing maxillary complete dentures. All failed implants (eight in total: three in the TISFDPs and six in the ISFDPs) occurred during the first 2 years with one implant failing prior to functional loading. The authors considered the TISDP a predictable treatment option comparable to the ISDP. On the other hand, the study by Lindh et al.\(^28\) reported 4% and 3% implant failure rates for TISFDPs and ISFDPs, respectively, over an observation period of 24 months. These rates included one implant failure in the TISDP group and two in the ISDP group. In contrast to the study by Gunne et al.\(^6\), the implants and reconstruction were placed exclusively in the mandible, the intervention in the study by Lindh et al.\(^28\) was performed mainly in the posterior maxillae of 26 patients. In the remaining six studies, no implant failure in both treatment groups was reported in three studies,\(^41,45,47\) while in the remaining three,\(^28,49,52\) the overall implant failure rate was between 0.3% and 3%. In a large patient cohort, Naert et al.\(^49\) conducted a CCT with two parallel treatment groups (a test group with TISFDPs and a control with ISFDPs) of 123 patients each and a total of 663 implants. The mean follow-up period

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of the trial was 78 months, and findings were published in two parts. A total of 10 implants failed in the TISFDP group, while only one implant in the ISFDP group failed. Implant failures occurred between 4 and 11 years of function, in contrast to the study of Gunne et al., where failures were observed in the first 2 years. It should be noted that in the study of Naert et al., implants that failed prior to or at the time of abutment connection were not included in the survival analysis. The authors concluded that while both treatments have shown comparable implant outcomes, a greater tendency toward higher implant failure over time is expected with TISFDPs.

The overall rate of abutment tooth failure in this review ranged from 0% to 4%. The highest failure rate of 4% was reported in two studies, Gunne et al. and Lindh et al., where one abutment tooth fractured and one failed due to mobility. It should be noted that in the study of Lindh et al., 56% of teeth used as abutments were endodontically treated teeth fitted with posts and cores, while in the study of Gunne et al., endodontically treated teeth were not used as abutments. A further 2% abutment tooth failure was reported in the study of Naert et al., where five out of 313 abutment teeth failed (two because of fracture; three extracted due to caries or periodontitis).

The overall prosthesis failure rate in the present review was between 0% and 13% for the TISFDPs and between 0% and 17% for the ISFDPs during a follow-up period of 24 to 120 months. The meta-analysis did not reveal any significant differences in the prosthesis failure rate between TISFDPs and ISFDPs. In two studies, the prosthesis failure rate was between 0% and 13% for the TISFDPs and between 0% and 17% for the ISFDPs (Table 4).

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>TISFDP</th>
<th>ISFDP</th>
<th>Mean difference</th>
<th>Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
<td></td>
</tr>
<tr>
<td>Akca and Cehreli, 2008</td>
<td>–0.189</td>
<td>0.523</td>
<td>34</td>
<td>0.285</td>
</tr>
<tr>
<td>Gunne et al, 1999</td>
<td>0.3</td>
<td>0.1</td>
<td>20</td>
<td>0.7</td>
</tr>
<tr>
<td>Lindh et al, 2001</td>
<td>0.09</td>
<td>0.52</td>
<td>26</td>
<td>0.42</td>
</tr>
<tr>
<td>Mostafa et al, 2015</td>
<td>0.73</td>
<td>0.06</td>
<td>10</td>
<td>0.71</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>90</td>
<td>154</td>
<td>100.0%</td>
<td>–0.29</td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.08; Chi² = 94.75, df = 3 (P < .00001); I² = 97%
Test for overall effect: Z = 1.95 (P = .05)
IV = inverse variance; CI = confidence interval; z = z test

Figs 4a to 4c Comparison: Tooth-implant–supported fixed dental prosthesis (TISFDP) versus implant-supported fixed dental prosthesis (ISFDP). Secondary outcomes: (a) peri-implant marginal bone level changes (mm), (b) fixed dental prosthesis framework fracture rate, (c) fixed dental prosthesis porcelain fracture rate.
no prosthesis failed in both treatment groups during an observation period of 24 to 78 months. The highest prosthesis failure rate for the TISFDPs and ISFDPs of 13% and 17%, respectively, was observed in the study of Gunne et al.\(^6\) In that study, three out of the 23 loaded ISFDPs failed due to loss of two implants and one abutment tooth, while four out of the 23 ISFDPs were lost within the first 24 months of function subsequent to the loss of supporting implants. Apparently, the small sample size of 23 prostheses in each group has resulted in such high failure rates. This is in comparison to the study by Naert et al.\(^{49}\) of a larger sample of 140 TISFDPs, of which 11% or 15 prostheses failed due to loss of supporting implants (10 prostheses), abutment teeth loss (two prostheses), and an additional three due to framework fracture. In the ISFDP group, only one prosthesis failed due to loss of one supporting implant. Similar prosthesis failure rates for TISFDPs and ISFDPs of 8% were reported in the study by Lindh et al.\(^{28}\) where two prostheses in each group failed due to loss of one implant and one abutment tooth in the TISFDPs and two implants in the ISFDPs. In the two studies of Akça and Cehreli\(^{41}\) and Rammelsberg et al.\(^{52}\) the reported TISFDP failure rate was 3% and 4%, respectively. Akça and Cehreli\(^{41}\) reported that one prosthesis out of the 34 TISFDPs placed had to be remade, as the abutment tooth required endodontic treatment, while none of the 15 ISFDPs failed during the study period of 26 months. On the other hand, of the total 48 TISFDPs used in the study of Rammelsberg et al.\(^{52}\) two failed because of loss of implants compared with one failure in the ISFDPs resulting from extensive ceramic chipping.

Considering the peri-implant marginal bone level changes around implants in TISFDPs and ISFDPs, the meta-analysis, which was based on four studies in the present review, showed a marginally significant difference in favor of TISFDPs but with significant heterogeneity. In three studies, the bone loss was observed in both treatment groups. On the other hand, the study of Akça and Cehreli\(^{41}\) demonstrated a gain of 0.189 mm in the TISFDPs compared with a marginal bone loss of 0.285 mm in the ISFDPs. The marginal bone level measurements in the four studies were all recorded at the 24-month recall interval. It has been previously
suggested, based on in vitro studies, that unfavorable load distribution between teeth and implants in TISFDPs could result in excessive peri-implant bone loss leading to failure of osseointegration. Others have shown no such adverse effect when a rigid connection is used to connect natural teeth to implants. Contrary to this, Naert et al reported more marginal bone loss in the rigidly connected compared with the nonrigidly connected TISFDPs or even the ISFDPs. The data from the study of Naert et al, however, was not included in the meta-analysis of bone level changes because the measurements were recorded at different exposure time points (baseline to 6 months and 6 months to 15 years). No other systematic reviews presented details on marginal bone loss around implants supporting TISFDPs, precluding possible comparisons. The marginal bone loss values reported in this review after 24 months of loading, however, remain within the accepted criteria for implant success.

Abutment tooth intrusion and abutment tooth fracture are biologic complications commonly associated with TISFDP treatment. Abutment tooth intrusion, in particular, has been the subject of considerable debate in the literature. Several theories have been postulated to explain this phenomenon and its impact on TISFDP treatment outcomes. The differential vertical mobility between implants and natural teeth of 1:5 was thought to result in the TISFDPs being entirely implant supported over time. The unfavorable load distribution between teeth and implants, however, seems to be dependent on the type of attachment used to connect the implants to abutment teeth. Previous systematic reviews of clinical studies on TISFDPs demonstrated a trend toward abutment tooth intrusion in nonrigidly connected TISFDPs. For example, an intrusion rate of 5.2% and 8.2% in abutment teeth with nonrigid connections was reported in the studies of Lang et al and Tsoukosoglou et al, respectively, in the study of Mamalis et al, where 66% of nonrigidly connected TISFDPs were intruded compared with 44% rigidly connected prostheses. Similarly, in the present review, 3% of the total 34 nonrigidly connected TISFDPs in one study suffered from abutment tooth intrusion. No other incident of abutment tooth intrusion was observed in the remaining studies of the present review, including one where both rigid and nonrigid connections were used. On the other hand, the rate of abutment tooth fracture, based on four studies, ranged from 0% to 4%. In the study by Lindh et al, one abutment tooth out of 26 teeth supporting TISFDPs fractured during the 24-month observation period. In addition, Naert et al reported the fracture of two abutment teeth in two patients out of the total study cohort of 123. No incident of abutment tooth fracture was reported in the study of Hosny et al, where 18 TISFDPs were followed under function for 78 months. An attempt to draw comparisons with other systematic reviews was not possible due to lack of specific details on abutment tooth fracture in these reviews.

Several technical complications related to implant components and prosthetic superstructures were analyzed in the present review. Implant abutment/prosthesis screw loosening was reported in six studies. The rate was between 0% and 13% for the TISFDPs and 0% to 4% for the ISFDPs, with no significant differences observed. The highest rate of abutment screw loosening was reported in the study by Gunne et al, where three gold screws required retightening in the TISFDPs compared with two in the ISFDPs. Another four incidents were reported in the study by Lindh et al (two in each treatment group), and another two in the study of Mostafa et al (both in the TISFDPs). Abutment/prosthesis screw fracture was minimal in this review, with overall rates falling between 0% and 4%. The meta-analysis, based on six studies, did not detect any significant differences between TISFDPs and ISFDPs in this aspect. The highest number of abutment screw fractures was reported in the study of Naert et al with a total of five incidents (three in the TISFDPs and two in the ISFDPs). On the other hand, four fractures (one in the TISFDPs and three in the ISFDPs) were reported in the study of Lindh et al. No abutment screw fractures in TISFDPs or ISFDPs were reported in the remaining four studies. No explanations were offered for the occurrence of abutment screw loosening or fracture, and whether it is material related or due to improper prosthetic design is mere speculation. These complications are in accordance with findings from other systematic reviews where similar incidences were collectively reported for TISFDPs and ISFDPs.

Of all the technical complications presented in this review, porcelain fracture demonstrated the highest rate in both TISFDPs and ISFDPs, with 15% and 19%, respectively, in the study by Rammelsberg et al, where in 7 out of 48 TISFDPs and 17 out of 91 ISFDPs suffered from porcelain fracture. The authors attributed the high rate of porcelain fracture to prostheses being posteriorly located and to the male sex, where chewing demands are considerably higher. In another study, three, or 9%, of TISFDPs had porcelain fracture, while none was observed in the ISFDPs. In the study by Hosny et al, on the other hand, no porcelain fracture in either group was observed. Although higher incidence of porcelain fracture in this review was observed in the ISFDPs compared with TISFDPs, the meta-analysis did not reveal any significant differences. The findings on porcelain fracture reported in the present review confirm those previously reported in other systematic reviews, taking into consideration the evolution of veneering materials over the years from acrylic to porcelain and zirconia. Framework fracture was a rare occurrence
in the present review and limited to TISFDPs, where three out of 123 patients (2%) had framework fracture compared with none in the ISFDPs. In the other two studies where information on framework fracture was provided, no incidences were observed. Similar to other technical complications, the meta-analysis of framework fracture did not reveal any significant differences between TISFDPs and ISFDPs. No reports on framework fracture in either TISFDPs or ISFDPs were presented in other systematic reviews for comparison.

**Overall Completeness and Applicability of Evidence**

The inclusion of only seven studies may have overestimated or underestimated the intervention effect, as each analysis comprised a limited number of implants and prostheses. In addition, substantial heterogeneity was noted despite the stringent selection criteria employed in this review. It is also acknowledged that implants are not independent units and that data analysis based on abutment tooth/implant rather than the participant may underestimate the outcomes and complications associated with TISFDPs and ISFDPs. The criteria used to select the studies were, however, more rigorous, compared with previous systematic reviews, where all studies had control groups and studies that lacked sufficient information to compare between TISFDPs and ISFDPs were excluded. The lack of significant differences between the treatment groups in this review may indicate the reliability of both interventions. Also, although the quantitative analysis may still limit general applicability to clinical practice, the findings support the consideration of TISFDPs as an alternative treatment option for the partially edentulous patient.

The present review highlights the need for more well-designed RCTs reporting on surgical, prosthetic, and patient-based outcomes of TISFDPs and ISFDPs following the Consolidated Standards of Reporting Trials (CONSORT) statement (www.consort-statement.org). Such trials will improve the methodologic quality of reporting and significantly enhance the existing body of evidence on the use of TISFDPs.

**Quality of Evidence**

The only RCT included in this review failed to provide a clear description of the randomization method and allocation concealment. Other trials were not randomized, and therefore, all the trials were judged to be at high risk of bias. In addition, the assessment of the outcomes was not blinded, which may be viewed as an additional source of bias. Blinding of participants and clinicians may not be possible and was not considered in the quality assessment of the included studies. Significant heterogeneity was also detected in the quantitative analysis of implant failure rate and peri-implant marginal bone level changes.

**Agreements and Disagreements with Other Reviews**

There are limited reviews of clinical studies comparing TISFDPs with ISFDPs that were published in accordance with accepted guidelines for reporting systematic reviews. In the reviews by Lang et al and Mamaalis et al, the authors adopted a similar methodology in the selection of studies and data analysis. These reviews, however, extracted data from studies with different implant reconstructions, including single-crown restorations and fixed and removable implant-supported prostheses. On the other hand, the present review by Tsaousoglou et al focused mainly on the influence of biomechanical aspects of connection type (rigid or nonrigid) on the implant and prosthesis outcomes. In contrast to the present review, no corresponding control groups of ISFDPs were strictly required in the included studies of these reviews to allow objective outcome comparisons. In addition, the present review attempted an exhaustive search with no language restrictions through published and grey literature in the search for outcome comparisons.

**CONCLUSIONS**

Within the limitations of this review, the TISFDP could be a reliable alternative treatment option for the rehabilitation of the partially edentulous patient with implant and prosthesis failure rates and biologic and technical complication rates that are comparable to those of the ISFDP. Further well-designed RCTs addressing patient-reported outcomes and cost-effectiveness analyses of TISFDPs are required for routine clinical application in the partially edentulous patient.

**ACKNOWLEDGMENTS**

The authors declare no conflict of interest.

**REFERENCES**


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