

# Connecting Teeth to Implants: A Critical Review of the Literature and Presentation of Practical Guidelines

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**Abstract:** Historically, connecting a tooth to an implant to function as an abutment to replace a missing tooth was discouraged. It was believed differences in mobility patterns of a tooth and an implant would result in the prosthesis being cantilevered off the implant, thereby stressing the implant. Several papers concluded increased stress caused technical and biologic complications, which led to a decreased survival rate for a tooth-implant supported prosthesis (TISP) when compared with an implant-only supported prosthesis (ISP). However, problems attributed to TISPs may have been overstated. This paper reviews animal studies and human clinical trials that monitored successful use of TISPs. In addition, numerous issues are addressed that question the data, which have been interpreted to indicate that a tooth should not be connected to an implant. Recommendations are made to facilitate attaining high success rates with TISPs.

A variety of prosthetic techniques can be used to restore the dentition subsequent to loss of teeth. The method of rehabilitation depends on the number, arrangement, and status of residual teeth (eg, periodontal health, remaining tooth structure); cost; patient desires; and adequacy of the bone to support dental implants. Historically, it was believed if a tooth and an implant were used as abutments in the same prosthesis, the implant would be subjected to an increased bending moment because of differences in their mobility patterns. This increased stress could lead to a decreased success rate for a tooth-implant supported prosthesis (TISP) compared with implant-only supported prosthesis (ISP).<sup>1-7</sup> However, potential problems associated with TISPs may have been overstated. Therefore,

this article assesses the literature to determine if evidence-based decisions could be made concerning the utility of connecting teeth to dental implants.

## ADVANTAGES AND POTENTIAL PROBLEMS ASSOCIATED WITH CONNECTING TEETH TO DENTAL IMPLANTS

Broadening treatment possibilities is the main advantage in constructing a TISP (Figure 1). Other reasons a TISP may be advantageous are listed in Table 1. In contrast, some factors suggest it may be prudent to avoid a TISP. For example, a tooth with a healthy ligament can move 200  $\mu\text{m}$  in response to a 0.1 N force, but an implant is displaced  $< 10 \mu\text{m}$ .<sup>8</sup> This movement is primarily due to bone flexure.<sup>9</sup>

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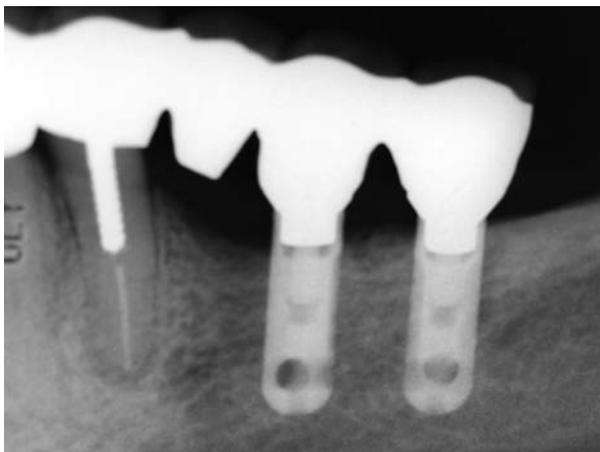
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Therefore, if a three-unit TISP is functioning, differences in mobility patterns between a tooth and an implant could result in the tooth being depressed into the socket, which might cause the prosthesis to be cantilevered off the implant.<sup>10</sup> Theoretically, this could increase stress on the implant and lead to both technical and biologic complications (Table 2).<sup>1,2,5,7</sup> However, the precise biomechanical impact due to dissimilarity in mobility patterns remains controversial.<sup>11</sup> In this regard, despite a 10-fold greater axial and transverse mobility of teeth compared to implants, mitigating factors may accommodate a TISP. For instance, bone has some natural elasticity<sup>12</sup> and some resiliency is in components of implant assemblies.<sup>13-15</sup> Also, a cushion effect may be provided by the cement layer within the prosthesis,<sup>16</sup> and there may be force deflection in the suprastructure of the prosthesis.<sup>13,14</sup> In addition, several studies indicated teeth in a TISP share the occlusal load and all the forces are not transferred to the implant.<sup>13,14</sup> Therefore, to determine the utility of connecting teeth to implants, the data must be evaluated from different perspectives: theoretical concerns, technical and physiologic problems, and functionality of TISPs over time.

### THEORETICAL COMPLICATIONS ASSOCIATED WITH A TISP

The concept that occlusal forces on a TISP result in the prosthesis being cantilevered off the implant was derived from finite elemental analysis and photoelastic stress studies.<sup>17,18</sup> Finite element analysis (FEA) is a computerized-simulation



**Figure 1** A fixed prosthesis, TISP, was constructed on teeth Nos. 22 through 18. The terminal abutments were implants, and they facilitated constructing a fixed prosthesis over the mental foraminal area.

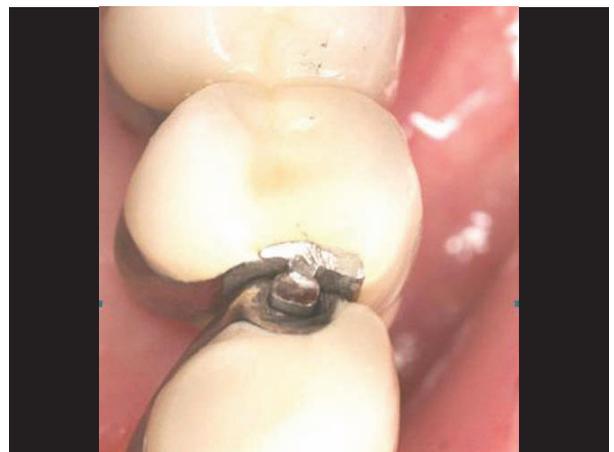
technique used in engineering to assess stresses and strains on solid objects. It employs a numerical approximation of physical properties that can be modeled. However, extrapolating information from FEA studies to humans with respect to stress distribution is difficult because many assumptions are needed concerning biologic factors, such as bone properties, response to applied mechanical force, and stress distribution after force transmission.<sup>19-21</sup> Furthermore, as will be discussed in this article, clinical trials that assessed potential problems associated with TISPs did not usually demonstrate the extent of problems predicted by FEA.

### TECHNICAL PROBLEMS RELATED TO TISPs

Technical complications include mechanical damage to the teeth or implants, implant components, and suprastructures (Table 2). It was assumed that a rigid connection between an implant and a natural tooth would result in additional strain on the implant because the tooth could move in function. Therefore, the use of nonrigid connector or telescopic crowns was advocated to reduce the bending moments on the implant.<sup>22-35</sup> However, this could result in other problems, namely tooth intrusion.

### Intrusion of Teeth

When implants were connected to natural teeth to support a fixed partial denture, the incidence of tooth intrusion varied (movement of a tooth out of its crown in an apical direction) (Figure 2).<sup>1,5,7,31,34-42</sup> Surveys indicated intrusion occurred, on average, in 3% to 5.2% of the cases.<sup>1,29,32</sup> An



**Figure 2** A TISP with an implant at site No. 21 that is connected via a nonrigid connector to a natural tooth abutment No. 22. There is intrusion of the tooth and female portion of the interlock on tooth No. 22.

**Table 1: Benefits of Connecting Teeth to Implants**

1. Splinting teeth to implants broadens treatment possibilities:
  - a. When anatomic limitations restrict insertion of additional implants (eg, maxillary sinus, mental foramen).
  - b. Lack of bone for implant placement.
  - c. Patient refusal to undergo a bone augmentation procedure.
2. Desire to splint a mobile tooth to an implant.
3. Teeth provide proprioception.
4. Reduced cost for teeth replacement.
5. Additional support for the total load on the dentition.
6. Reduction of the number of implant abutments needed for a restoration.
7. Possibly avoid the need for a cantilever.
8. To preserve the papilla adjacent to the tooth for esthetic or functional concerns (eg, phonetics).

**Table 2: Technical and Biologic Complications Associated with Connecting Teeth to Implants<sup>1,2,5,7</sup>**

**Technical Problems**

1. Implant fracture
2. Tooth intrusion
3. Intrusion of teeth with telescopic crowns
4. Cement bond breakdown
5. Abutment tooth fracture
6. Abutment screw loosening
7. Fracturing of veneers
8. Prosthesis fracture

**Biologic Problems**

1. Peri-implantitis
2. Endodontic problems
3. Loss of an abutment tooth
4. Loss of an implant
5. Caries
6. Root fracture

assessment by Reider and Parel<sup>29</sup> found 50% of intrusions happened in individuals with parafunctional habits, specifically bruxism. They also noted it usually occurred in patients with nonrigid semi-precision attachments.

Many authors reported that stress-breaking connectors were associated with more intrusion than rigid connections.<sup>1,5,34</sup> Intrusion of teeth associated with nonrigid semi-precision attachments usually contained the female portion of the keyway in the natural tooth.<sup>29,43,44</sup> Others reported no intrusion of teeth associated with rigid connectors.<sup>1,5,7,37,39,45-50</sup> Rigid connection designs include soldered connectors, set screw connectors, and coping-sleeve methods.<sup>43</sup> However, intrusion occurred in some patients with rigid connectors if telescopic crowns were used on abutment teeth.<sup>29,33,35,41</sup> Several investigators also demonstrated when rigid connectors were used, results did not differ if restorations were screw- or cement-retained.<sup>35,48,51</sup>

In conclusion, the potential for intrusion of an abutment tooth cannot be ignored; however, it should not be a deterrent from connecting teeth to implants. This dilemma can be avoided by proper patient selection (avoidance of those with bruxism), use of rigid connectors, avoidance of placing copings on teeth used as abutments, proper abutment preparation (parallel walls) to maximize retention and resistance form, and permanent cementation.<sup>52</sup>

**Other Technical Complications Related to TISPs**

The technical problems listed in Table 2 are dependent on bridge configurations and dimensions, tooth abutment preparation, employed cements, opposing dentition, kinds of screws used, types of implants, etc. Therefore, data from one study cannot be extrapolated with specificity to other patient populations or implant systems. However, trends can be observed; therefore, data from the literature are presented to provide an overview of reported complications.

Several studies noted more technical problems associated with TISPs than ISPs. For example, Naert et al<sup>5,6</sup> monitored 140 ISPs and 140 TISPs (1 to 15 years) and concluded an ISP is preferable because of an increased number of technical problems associated with a TISP. The complication rate for a TISP was 5% to 10%. The incidences of some problems included periapical lesions (3.5%), tooth fracture (0.6%), extraction because of caries or periodontitis (1%), crown cement failure (8%), and framework fracture in three patients. In contrast, only two abutment screws

**Table 3: Cases with TISP\***

Authors	Type of Case	No. of Cases	Observation	
			Period	Comments (Survival Rate for TISP)
Akça et al <sup>54</sup>	three-unit bridges	34	24 mos	Survival rate: 100% Bone levels remained stable
Block et al <sup>35</sup>	three-unit bridge	60	5 yrs	Survival rate: 90%, 6 abutments were lost Rigid vs nonrigid, rigid is better No difference in bone loss around implants
Brägger et al <sup>7</sup>	mixture <sup>†</sup>	18	4 yrs to 5 yrs	Survival rate: ISP (97.5%), TISP (95%)
Brägger et al <sup>53</sup>	mixture <sup>†</sup>	22	10 yrs	Survival rate: ISP (93.9%), TISP (68.2%)
Clarke et al <sup>52</sup>	three-unit bridge	1	32 mos	Survival rate: 100%, no technical problems
Cordaro et al <sup>31</sup>	full-arch prostheses	20	24 mos to 94 mos	Survival rate: 89.5%, 2 of 19 replaced
Ericsson et al <sup>44</sup>	mixture	10	6 mos to 30 mos	Survival rate: 100%
Fartash et al <sup>55</sup>	mixture	27	7 yrs to 13 yrs	Survival rate: unclear for TISP No difference in bone loss around implants connected to teeth or other implants
Fugazzotto et al <sup>37</sup>	mixture	1206	3 yrs to 14 yrs	Survival rate: not reported, appeared to be 100% Screw-secured attachments prevented intrusion TISP functioned without major problems
Gunne et al <sup>49†</sup>	three-unit bridges	20	10 yrs	Survival rate: TISP (85.1%) ISP vs TISP: no difference
Hosny et al <sup>38</sup>	mixture	18	1.25 yrs to 14 yrs	Survival rate: TISP (100%) intraindividual TISP and ISP are both survived well
Jemt et al <sup>56</sup>	mixture	20	15 yrs	Survival rate: 98.7% Authors reported no significant problems
Kindberg et al <sup>36</sup>	mixture	41	14 mos to 9 yrs	Survival rate: TISP (92.85%) TISP and ISP both provided good results
Koth et al <sup>57</sup>	mixture	18	5 yrs	Survival rate: TISP (95.5%)
Kronstrom et al <sup>58</sup>	mixture	17	at least 12 mos	Survival rate: not reported, assumed to be 100% High satisfaction rate reported; no data
Lindh et al <sup>34</sup>	mixture	127	up to 3 yrs	Survival rate: not reported for TISP, TISP as predictable as ISP for bone level and implant survival (95.4%)
Lindh et al <sup>47</sup>	mixture	52	2 yrs	Survival rate: ISP (95%), TISP (96%) Similar success rate
Naert et al <sup>5</sup>	rigid, nonrigid	123	up to 15 yrs	Survival rate: ISP (98.4%), TISP (94.9%) More technical complications with TISP
Nickenig et al <sup>48</sup>	mixture	84	2.2 yrs to 8.3 yrs	Survival rate: 97.7% at 5 yrs With a rigid connection, TISP will function similarly to implant-supported prostheses
Palmer et al <sup>39</sup>	three-unit bridges <sup>§</sup>	19	3 yrs	Survival rate: 100%, fully functional successful restorations in maxilla or mandible, 6 cantilevers
Pylant et al <sup>59</sup>	mixture	13	6 mos to 49 mos	Survival rate: not reported 88.2% overall success rate for the implants
Quirynen et al <sup>50</sup>	mixture	58	up to 6 yrs	Survival rate: not reported for TISP < 2.5% of loaded implants failed, limited bone loss around the implants
Romeo et al <sup>60</sup>	mixture	13	13 yrs	Survival rate: TISP (90.6%), no statistically significant difference with ISP
Steflik et al <sup>61</sup>	mixture	23	10 yrs	Survival rate: 79.8%
Tangerud et al <sup>51</sup>	mixture	29	up to 3 yrs	Survival rate: 100% TISP may be appropriate treatment
van Steenberghe et al <sup>62</sup>	mixture	31	6 mos to 30 mos	Survival rate: 100%

\*TISP = tooth-implant supported prosthesis, ISP = implant-supported prosthesis. <sup>†</sup>Mixture refers to different combinations of teeth and implants.

<sup>‡</sup>Includes studies by Astrand et al<sup>63</sup> (3-year results) and Olson et al<sup>46</sup> (5-year results). <sup>§</sup>Cases in maxilla, mixed number of teeth and implants, no difference in failure rates when teeth connected to implants; 6 cases with distal cantilever, 13 cases with terminal abutment as an implant.

**Table 4: Meta-analyses for Prosthesis and Implant Survival Rate After 5 and 10 Years**

Study	No. of Studies	Abutments	Survival Rate: Percentage			
			Protheses		Implants	
			5 yrs	10 yrs	5 yrs	10 yrs
Tan et al <sup>64</sup>	19	Teeth	89.1			
Pjetursson et al <sup>65</sup>	21	Implants	95	86.7	95.4	92.8
Lang et al <sup>1</sup>	13	Implants/teeth	94.1	77.8	90.1	82.1

**Table 5: Studies Addressing TISP\*/Survival Rate of Implants and TISP<sup>1</sup>**

Authors	No. of Implants	No. of Failures	Survival Rate	No. of TISPs	No. of Failures	Survival Rate	Implant Type
<b>5-Year Follow-up</b>							
Block et al <sup>35</sup>	80	1	98.6	-	-	-	Omni Lock
Mau et al <sup>66</sup>	297	51	79.5	-	-	-	IMZ
Naert et al <sup>5</sup>	339	19	95.4	-	-	-	Brånemark
Brägger et al <sup>7</sup>	19	1	94.8	18	1	94.5	ITI
Kindberg et al <sup>36</sup>	115	9	90.1	41	3	92.8	Brånemark
Hosny et al <sup>38</sup>	31	1	97.5	18	0	100	Brånemark
Olsson et al <sup>46</sup>	23	2	90.5	23	2	90.5	Brånemark
Koth et al <sup>57</sup>	28	6	75.7	15	1	93.4	Bioceram
<b>10-Year Follow-Up</b>							
Brägger et al <sup>53</sup>	22	5	77.7	22	7	70.2	ITI
Gunne et al <sup>49</sup>	23	2	89.8	23	3	85.1	Brånemark
Fartash et al <sup>55</sup>	27	0	100	-	-	-	Bioceram
Steflik et al <sup>61</sup>	28	9	64.7	15	3	79.8	Bioceram
Jemt et al <sup>67</sup>	43	8	n/a	12	1	n/a	Brånemark

\*Adapted from Lang et al.<sup>1</sup>  
 -Data not provided in Lang et al.

fractured in the ISP group. However, these data can be misleading because some ISPs had multiple implants providing additional overall support for the prosthesis compared with the TISPs.

Brägger et al<sup>7</sup> reported that after 5 years, TISPs did not have a higher risk of technical or biologic complications compared with ISPs. However, after 10 years, TISPs had more failures than ISPs. In general, after a 10-year monitoring period, 11 out of 22 TISPs (50%) remained free of any technical and biologic complications, whereas 18 out of 33 ISPs (54.5%) had no technical or biologic problems.<sup>53</sup> In

contrast, other investigators reported only minor technical complications associated with TISPs<sup>34,36,39,52</sup> or no differences when ISPs and TSPs were compared intraindividually.<sup>38,47,49</sup> In this regard, Lang et al<sup>1</sup> determined in their meta-analysis that most of the technical complications associated with TISPs (Table 2) occurred when there was a nonrigid connection between abutment teeth. They also concluded screw-retained restorations needed more maintenance than cemented crowns.

In summary, the literature indicates use of rigid connections between teeth and implants in a TISP usually reduces

mechanical complications to a level that appears to be comparable with problems associated with an ISP. However, it needs to be noted that studies were conducted for various lengths of time (Table 3,<sup>5,7,31,34-38,44,47,49,51-63</sup> Table 4,<sup>1,64,65</sup> and Table 5<sup>5,7,35,36,38,46,49,53,55,57,66,67</sup>) and many papers did not provide long-term follow-up on technical complications.

## BIOLOGIC COMPLICATIONS ASSOCIATED WITH TISP

### Bone Loss

The amount of bone loss around abutments is often used as a critical determinant to evaluate the durability of TISPs and ISPs. To assess the prevalence of this occurrence, issues need to be discussed from four different points of view: conceptual effect of occlusal load on bone loss, usual amount of osseous resorption around freestanding implants, bone loss around implants in an ISP, and bone loss around natural tooth abutments in a TISP.

### Theoretical Concept: Occlusion Related to Bone Loss

The influence of occlusal forces on peri-implant bone was reviewed by Isidor.<sup>68</sup> He concluded the literature had conflicting information as to whether overloading an implant can lead to implant failure, which can consist of progressive bone loss or total deosseointegration. It was also noted that animal studies have shown occlusal load may contribute to complete loss of osseointegration<sup>69</sup> or marginal bone loss.<sup>70</sup> However, in human clinical investigations, despite many authors referring to occlusal trauma as a cause for implant loss,<sup>3,11,50,67,71,72</sup> others indicated this relationship has not been clearly demonstrated.<sup>2,68,73-76</sup> A review by Vidyasagar and Apse<sup>77</sup> reached the same conclusion as Isidor. Therefore, it can be summarized that in some situations, occlusal forces may affect the bone around implants; however, numerous confounding variables (eg, density of bone, strength of loading force) make it difficult to delineate the circumstances when this occurs.

### Clinical Trials Assessing Bone Loss around Freestanding Implants

Studies noted the mean bone loss around freestanding dental implants ranged from 0.14 mm to 1.6 mm (mean 0.93 mm) during the first year and subsequently 0 mm to 0.2 mm annually (mean 0.1 mm).<sup>49,50,59,71,72</sup> Therefore, the question is whether stress placed on an implant connected

to a tooth would result in more bone resorption than is expected normally around a freestanding implant.

### Clinical Trials Assessing Bone Loss around TISP

Bone loss that occurred around the implants incorporated into a TISP was discussed by Naert et al.<sup>6</sup> They reported more bone resorption around rigid than around nonrigid connectors. However, the total additional bone loss (0.7 mm) occurred over 15 years. This amount of bone loss is within the acceptable standards established by Albrektsson et al.<sup>78</sup> Their criteria was < 1.5-mm bone loss the first year after implant insertion followed by < 0.2-mm per year in subsequent years. Kindberg et al<sup>36</sup> also observed minor bone loss around abutment teeth and implants after 1 year, with a few exceptions.

Akça et al<sup>54</sup> conducted a study to evaluate the findings by Naert et al.<sup>6</sup> They concluded a rigid connection did not jeopardize the marginal bone levels around dental implants and the bone remained stable after 2 years of function.<sup>54</sup> Similarly, Hosny et al<sup>38</sup> determined the amounts of marginal bone loss around freestanding and tooth-connected implants did not differ significantly. They reported 1 mm of bone loss in the first 3 to 6 months after abutment connection and then 0.015 mm annually for 14 years. Stable bone levels around the implants suggest excessive loads to the implants did not occur when they were connected to teeth. Gunne et al<sup>49</sup> and Lindh et al<sup>34</sup> also reported bone resorption around implants incorporated in a TISP was similar to bone loss adjacent to implants in an ISP when assessed within the same individual.

In another study, Block et al<sup>35</sup> reported no difference in the amount of bone loss around implants that employed a rigid or nonrigid connection. They noted teeth around a rigid connection tended to lose more bone; however, the amount of bone resorption was within the criteria defined as success by Albrektsson et al.<sup>78</sup> Other investigators also did not report any bone resorption after construction of a TISP.<sup>39,52,55</sup>

In conclusion, the amount of bone degradation around dental implants used as abutments after teeth and implants are connected is usually within a range of acceptable bone loss for freestanding implants. Therefore, these data indicate that bone resorption around a TISP is not excessive.

### Endodontics

The literature contains limited and conflicting data that addresses inclusion of abutment teeth with endodontic therapy in a TISP; therefore, no conclusions can be drawn

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regarding the affect of root canal therapy on survivability of a TISP.<sup>34,35,53</sup> Furthermore, with respect to survival of endodontically treated teeth, it should also be noted that other clinical factors that may influence their retention were not recorded: amounts of remaining tooth structure or the presence of a reinforcing ferrule around the endodontically treated teeth.<sup>79</sup>

### ANIMAL AND HUMAN CLINICAL TRIALS ASSESSING THE UTILITY OF TISPs

Several lines of evidence can be assessed to help evaluate the predictability of employing a TISP. Animal studies provide histologic data that are difficult to obtain in humans, and clinical trials supply comparisons of efficacy of TISP and ISP over a prolonged period.

Based on animal studies<sup>80-83</sup> that provided histologic evidence, the following conclusions can be drawn: teeth connected to implants in a TISP did not usually undergo periodontal ligament atrophy,<sup>82</sup> bone around teeth was able to remodel under stress caused by the bridgework,<sup>81</sup> a TISP usually functioned as well as a bridge supported by natural teeth, and, if rigid connections are used, these constructions functioned successfully.<sup>80,83</sup> However, these results need to be interpreted with regard to the length of the observation periods, which were relatively short.

### Human Clinical Trials: Evidence Supporting Use of Connecting Implants to Teeth

A high level of evidence supporting the use of TISPs is derived from investigations that assessed their functionality for many years. In this regard, numerous studies indicated implants can be splinted to teeth and function successfully (Table 3). Different types of studies have been conducted: a limited number of clinical trials compared same-sized TISP and ISP intraindividually, comparisons of dissimilarly sized TISP and ISP intraindividually, comparisons of different-sized ISPs and TISPs in various patient populations, and case reports assessing various combinations of implants and teeth. In addition, a meta-analysis can summarize trends demonstrated by similar studies employing comparable treatment methods.

### Meta-analyses in the Literature Assessing Success of Fixed Protheses

Systematic reviews addressed the survivability of protheses supported by teeth alone,<sup>64</sup> implants alone,<sup>65</sup> and TISPs<sup>1</sup>

(Table 4). Comparison of results with respect to implant and protheses survivability indicate for the first 5 years, no disadvantage is associated with fabricating a TISP (Table 5). Yet, by the tenth year, a TISP has a reduced survival rate when compared with an ISP or a tooth-supported prothesis (Table 5). However, careful inspection of the data used in the meta-analysis to assess TISPs after 10 years reveals many shortcomings of the analysis.<sup>1</sup> Specifically, the analysis included only three studies (60 patients) because of its exclusion criteria.<sup>1</sup> Furthermore, these data are based on protheses supported by the following implant systems that are not used anymore or their surfaces have been improved: 22 protheses with ITI implants (placed before 1990, thus the titanium plasma spray surface is outdated), 23 cases with machined-surfaced implants, and 15 protheses using Bioceram<sup>®</sup> sapphire implants (Kyocera Corporation, Kyoto, Japan). Therefore, with regard to bone loss, prothesis failure, or implant survivability, the data used in the meta-analysis may not be relevant to contemporary implants with better surfaces, such as textured. Furthermore, improved technologies with respect to casting, porcelain materials, etc, may enhance prothesis survivability.

Other issues also remain unresolved. For instance, Lang et al<sup>1</sup> performed a meta-analysis to specifically determine the survivability of TISPs. They found the survival rate was similar after 5 years for an ISP and a TISP, but a TISP had a reduced survival rate between the fifth and tenth years (Table 5). However, after 10 years, Lang et al<sup>1</sup> did not find a significant difference in the failure rates of abutment teeth or implants in the TISP group (respectively, 5 out of 47, 10.6%, vs 7 out of 45, 15.6%). Thus, they concluded something other than loss of abutment teeth contributes to the additional loss of protheses in the TISP group. However, they could not identify a reason.

### STUDIES ADDRESSING SURVIVABILITY OF PROTHESES

#### Controlled Clinical Trials: Intraindividual Studies

Gunne et al conducted a randomized, controlled study that compared the use of TISPs vs ISPs (N = 10, 20 protheses).<sup>49</sup> They assessed contralateral three-unit constructions for 10 years; one mandibular posterior side received a three-unit TISP and the other side had a three-unit ISP. They reported that TISPs did not result in increased technical or biologic problems. No statistically significant differences

were found with regard to implant failure rate or bone loss. The total marginal bone loss for TISP and ISP was 0.5 mm and 0.6 mm to 0.7 mm, respectively. Implants that were 7-mm long were as effective as 10-mm implants, and most of the ISPs were cantilevered bridges. The opposing dentition was a denture. This was a small study and lacked adequate power to find small differences between the test and control groups.<sup>1</sup> Data related to this one cohort of patients were published at three different times: 3 years,<sup>63</sup> 5 years,<sup>46</sup> and 10 years.<sup>49</sup>

Block et al<sup>35</sup> placed 60 TISPs contralaterally in 30 patients and compared rigid with nonrigid connections. After 5 years, no significant difference in crestal bone levels on the implants were noted with either type of connection and most patients were treated successfully with both kinds. However, the two groups had a high incidence of intrusion because of the use of temporary cementation. In addition, patients with nonrigid connections needed more maintenance visits. The high incidence of tooth intrusion and additional visits for maintenance led to the authors suggesting that other treatment methods that do not connect teeth to implants may be needed. However, they mentioned a conventionally cemented prosthesis with an extremely retentive preparation may have overcome the high incidence of intrusion that they experienced.

Hosny et al<sup>38</sup> monitored different combinations of abutment teeth: single tooth and single implant, multiple teeth connected to an implant, and multiple implants connected to a tooth. A total of 18 patients received either TISPs (test group) or ISPs (control group), each within the same jaw. No prostheses demonstrated adverse results. The cases (12 maxillary and six mandibular prostheses) were monitored 1 to 14 years. No implants were lost, and no differences in marginal bone loss were observed between the treatment groups.

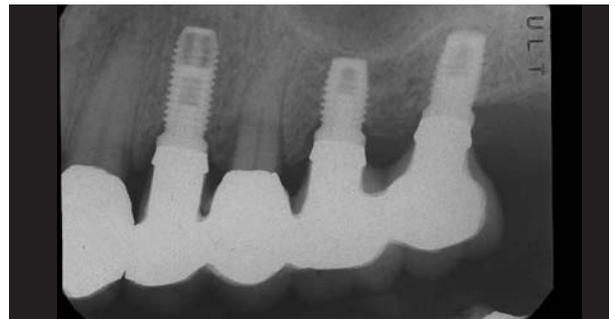
Lindh et al<sup>47</sup> conducted a 2-year follow-up of various maxillary prostheses (N = 26 patients). One side received an ISP and the other a TISP. Different prostheses sizes were fabricated depending on patients' needs. The researchers found no difference in the failure rate of implants (88% cumulative survival rate) with different prosthetic designs and no additional bone loss with the TISP.

### Controlled Clinical Trial: Different Patient Populations Were Compared

Brägger et al<sup>7</sup> for a 4- to 5-year period monitored two patient groups: 40 ISPs and 18 TISPs. Loss of prostheses



**Figure 3** Metal assemblage of rigidly connected four-unit TISP demonstrating substantial occluso-gingival dimensions of solder joints (4 mm).



**Figure 4A** TISP on teeth Nos. 12 through 15. Tooth No. 13 is a natural tooth with a telescopic crown.



**Figure 4B** The natural tooth has intruded, and the telescopic crown is now visible beneath the crown.



**Figure 5** Intraoral view of four-unit TISP (teeth Nos. 2 through 5); implant is acting as pier abutment No. 4. Note retentive boxes placed on tooth abutment No. 2.

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occurred at the same rate in both groups (each group lost one prosthesis). Survivability after 5 years was 97.5% (ISP) vs 95% (TISP). However, after 10 years, the survivability of the prostheses was significantly better with an ISP (93.9%, 31 out of 33) than a TISP (68.2%, 15 out of 22).<sup>53</sup> The main reason for the difference between 5 and 10 years was because of loss of crown retention on teeth, which led to caries and subsequent failure of four abutments, resulting in loss of four prostheses. The 10-year follow-up included only 22 prostheses, thus a small number of lost abutments (four carious teeth) translated into a large percentage of failed prostheses. Furthermore, most of the lost tooth abutments were nonvital teeth restored with a cast post and core.

Naert et al<sup>5</sup> also monitored patients with ISPs (140 prostheses, 123 patients) and TISPs (140 prostheses, 123 patients). The loading time for TISP was 1.5 years to 15 years (mean 6.5 years) and ISP was 1.3 years to 14.5 years (mean 6.2 years). The cumulative success rates of the implants for ISPs and TISPs were 98.5% and 95%, respectively. There were no significant differences with regard to loss of implants even though more implants were lost with TISP (10

out of 339 TISPs vs one out of 329 ISPs). With regard to the cumulative success rate of the prostheses, no statistically significant differences between ISP (98.4 %) vs TISP (94.9%) were noted.

Nickenig et al<sup>48</sup> compared rigid (n = 56) and nonrigid connections (n = 28) in various sizes of TISPs (84 prostheses, 83 patients), which were in service 2.2 years to 8.3 years (mean 4.73 years). Brånemark System® (Bio-Dent Laboratories, Ontario, Canada) and Straumann (Andover, MA) implants were used. After 5 years, 8% of the abutment teeth needed a therapeutic measure, eg, periodontal therapy (5%) or restoration (2.5%). However, the researchers found an increased incidence of technical problems was usually associated with nonrigid connections. Among the TISPs with rigid connections, only three out of 56 prostheses had technical problems. The authors concluded TISPs with rigid connection provided a high success rate.

## CASE REPORTS

In 1997, Gross and Laufer<sup>45</sup> addressed splinting implants to natural teeth in a review paper and concluded this should



**Figure 6** Lingualized occlusal scheme with palatal cusps of maxillary restorations contacting occluding areas of mandibular teeth. Lateral excursions are free of eccentric contacts.



**Figure 7** Cantilever TISP (teeth Nos. 8 and 9, No. 10 is a pontic, Nos. 11 and 12 are implants, and No. 13 is a cantilever) with intact interim cement seal at 3 months.



**Figure 8** Patient with TISP at 5 years who demonstrates extensive recurrent caries. Patients with high caries rates would benefit from restoration with an all-implant supported prosthesis.



**Figure 9** Radiograph in 1998. A TISP was created with two pontics because the implants used as terminal abutments were placed too posteriorly.

be approached cautiously. However, they noted if the teeth were well supported, immobile, and positioned close to the implant, a TISP was not destructive. They reported root intrusion was a problem when nonrigid connectors were used and cited numerous studies that monitored patients with successful TISPs.<sup>24,44,62,67</sup> Table 3 includes an additional 11 studies addressing successful splinting of teeth to implants not mentioned by Gross and Laufer<sup>45</sup> or published after their review.<sup>24,31,36,37,39,47,51,52,54,58,60</sup>

## CONCLUSION

Despite the fact that the potential mobility between a tooth and an implant are different and the precise etiology of tooth intrusion is unknown, it is reasonable to rigidly connect a tooth to an implant. This is particularly true if the anatomy dictates that placement of an additional implant(s) is contraindicated or if there are economic concerns. This deduction is based on almost every study that addressed this issue and found the survival rates were similar when TISPs and ISPs were compared. At present, there are no large long-term studies that assessed textured surface implants as an integral part of a TISP.

The literature supports the idea that a rigid connection between a tooth and an implant usually precludes intrusion of teeth. The following guidelines can help prevent intrusion of teeth (items 1 to 9) and enhance patient care when contemplating fabricating a TISP.

1. Select healthy teeth—periodontally stable and in dense bone.
2. Rigidly connect the tooth and implant (no stress breakers), employ large solder joints to enhance rigidity (Figure 3), or use one-piece castings.
3. Avoid telescopic crowns (no copings) (Figure 4A and Figure 4B).
4. Provide retention form with minimal taper of axial walls on abutment teeth. Enhance resistance form with boxes and retention grooves if the clinical crown is not long (Figure 5).
5. Parallel the implant abutment to the preparation of the tooth and use a rigid connection.
6. Use permanent cementation (no screw retention or temporary cementation).
7. The bridge span should be short. Preferably, place one pontic between two abutments. However, with additional tooth or implant support or cross-arch stabilization, additional pontics can be used.



**Figure 10** Radiograph in 2002 demonstrating de-ossification of both implants supporting the TISP in Figure 9. The patient had parafunctional habits.



**Figure 11** TISP after 5.5 years where the papilla between tooth No. 11 and No. 12 implant has been preserved by the presence of the tooth. Distal buccal recession around the implant is evident between the implant and cantilever pontic No. 13. The supracrestal gingival fibers of the tooth are a benefit to preservation of the papilla while the implant has no such effect.

8. Occlusal forces should be meticulously directed to the opposing arch (Figure 6).
9. In general, do not use TISPs in patients with parafunctional habits. If they are treated with TISPs, overengineer the case by maximizing the number of implants and splinting.
10. Cantilever extensions should be used cautiously; however, they may be employed when tooth or implant support is adequate, eg, cantilever-implant-implant-pontic-tooth-tooth (Figure 7).
11. TISPs in patients with uncontrolled caries should be avoided; ISPs are preferred (Figure 8).
12. Pulpless teeth with extensive missing coronal tooth structure or root canal anatomy that is inadequate to predictably retain a core or post and core should not be used in a TISP.

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13. High-risk TISPs (eg, multiple adjacent pontics, double cantilevered pontics) or prostheses with minimal abutment support should be expected to have a higher failure rate even though these treatment plans may benefit certain patients (Figure 9 and Figure 10).
14. In the esthetic zone, if a papilla or papillae is crucial for esthetics or function (eg, phonetics), consider using natural teeth (TISPs) because the supracrestal gingival fibers associated with healthy teeth will provide interproximal soft-tissue support (Figure 11).
15. If appropriate case selection principles are applied (eg, minimal caries rate, good root anatomy, minimal tooth mobility, adequate retention and resistance form, rigid prosthesis design, adequate overall abutment support for the prosthesis), then combining implants and natural teeth may permit segmentation of a prosthesis into smaller sections, which may provide an alternate treatment plan to a large one-piece bridge.

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