Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 05, pp.50651-50656, May, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

TOOTH-IMPLANT SUPPORTED PROSTHESIS - A REVIEW

[1]Dr. Deviprasad Nooji and [*,2]Dr. Mayank R Lunia

[1]Professor, Department of Prosthodontics, KVG Dental College and Hospital, Sullia, D.K., India
[2]Department of Prosthodontics, KVG Dental College and Hospital, Sullia, D.K., India

ARTICLE INFO

Article History:
Received 09th February, 2017
Received in revised form
15th March, 2017
Accepted 29th April, 2017
Published online 23rd May, 2017

Key words:
Dental implants,
Dental prostheses,
Partially edentulous,
Non-rigid attachment,
Rigid attachment, Tooth intrusion,
Tooth-implant supported prostheses

ABSTRACT

Aim: The aim of this review is to summarize and discuss the available information concerned to the tooth-implant supported fixed partial denture and to critically analyse the technical complications, the biological impact of tooth-implant supported prostheses and the guidelines that may be helpful in preventing long term complications.

Background: Implant-supported prostheses (ISP) has substantial biological and biomechanical advantages. Encountering this situation of obligatory connection between tooth and implant is becoming seldom rare due to the extensive use of implants to support prostheses in partially edentulous patients. However, because of biomechanical differences between tooth and implant, long-term prognosis of this treatment modality is of special debate in dental literature.

Materials and Methods: Literature published over the past 25 years were searched which included review articles, research articles and case reports. The search was carried out in PubMed database, Ebscohost, Google scholar, Medline and Science Direct along with manual search of peer reviewed literature using relevant key words. The most valuable and relevant articles were selected and analysed.

Discussion: Literature search revealed studies involving rationale, cause of problems, benefits, complications, risks and guidelines of tooth-implant supported prosthesis (TISP).

Conclusion: The tooth-implant supported prosthesis has its own benefits, risks and complications. Its application is justified by the risk-benefit evaluation with a special attention on patient requirements. Thus, multiple longitudinal studies are to be conducted before this method is declared as the treatment of choice.

Citation: Dr. Deviprasad Nooji and Dr. Mayank R Lunia. 2017. "Tooth-implant supported prosthesis - A review", *International Journal of Current Research*, 9, (05), 50651-50656.

INTRODUCTION

Based on declaration by 'Academy of Osseo Integration' in 2001, one of the most argued topic in the field of fixed prosthodontics regarding support of fixed partial dentures (FPDs) is the connection between implant and natural tooth (Iacono, 2007). The history of splinting implant to tooth dates back to early 1980s, when anti-rotational feature were not incorporated into implant abutments (Spear, 2009). Splinting the implant to the natural tooth or another implant was an obligation to prevent rotation of the restoration and its associated complications (Spear, 2009). In 1986, the first screw-retained abutment was introduced (Spear, 2009). However, due to lack of anti-rotational feature in these abutments, the screw represented the weakest link and was prone to failure (Spear, 2009). In1988, 'The UCLA abutment' the first screw- retained abutment with anti-rotational feature was introduced by Dr John Beumer (Spear, 2009). With this invention, creation of freestanding implant restoration without the obligation to splint it to other implants and teeth became feasible for the first time (Spear, 2009). In the present scenario, splinting implant to tooth is not always a necessity (Rangert, 1991; Rangert, 1995; Cavicchia, 1994 and Van Steenberghe, 1989). However, there are conditions where such a prostheses might be our first choice (Rangert, 1991; Rangert, 1995; Cavicchia, 1994 and Van Steenberghe, 1989). Due to the inherent differences between tooth and implant, particularly in their biomechanics, supporting mechanism, survival rate as well as a higher risk of technical complications in tooth-implant supported fixed prosthesis, this procedure has been a topic of argument and controversies (Rangert, 1991; Rangert, 1995; Cavicchia, 1994 and Van Steenberghe, 1989). Some studies recommended splinting implant to tooth and concluded that it is indeed beneficial to use such connection in fixed prostheses (Rangert, 1991; Rangert, 1995; Cavicchia, 1994 and Van Steenberghe, 1989), Whereas there are few implantologists worldwide who avoid splinting tooth and implant concerning of potential problems such as tooth

Corresponding author: **Dr. Mayank R Lunia,**
Department of Prosthodontics, KVG Dental College and Hospital, Sullia, D.K., India

intrusion and overloading of implant leading to bone loss (McGlumphy, 1989). To have a sound judgment regarding such treatment modality, it is beneficial to review the available literature concerning tooth-implant supported prostheses (TISP).

MATERIALS AND METHODS

Literature published over the past 25 years were searched, those included review articles, research articles, randomized clinical trials, prospective and retrospective clinical studies and case reports. The search was carried out in PubMed database, Ebscohost, Google scholar, Medline and Science Direct along with manual search of peer reviewed literature using relevant key words. Abstracts, opinion articles, technique articles and questionnaire based studies were excluded in this review. The most valuable and relevant articles were selected and analysed for rationale, cause of problems, benefits, complications, available method of connections and the efficacy of the same, potential risks and guidelines for splinting implant to natural teeth.

DISCUSSION

Rationale of tooth-implant supported prostheses (Spear, 2009; Naert, 2001; Chee, 2006 and Misch, 2008)

Local and systemic conditions which preclude the placement of additional implants (Spear, 2009; Naert, 2001 and Chee, 2006).

- To gain support from the tooth or implant. In the patients with bruxism, propioception of the tooth may help to reduce applied stresses to the implants (Spear, 2009; Naert, 2001and Chee, 2006).
- When there are absence of other options. Due to financial constraints for additional implant placement, bone augmentation and insertion of additional implants are not always possible. Cantilever on one implant, implants narrower than 4 mm (type B) or in situations of moderate-to-severe force factors are not recommended (Misch, 2008).
- To preserve a key tooth or teeth with good prognosis (Spear, 2009 and Naert, 2001).
- To provide stability against rotational forces (Spear, 2009; Chee, 2006).
- In periodontally compromised teeth, implants can provide additional support to the remaining natural teeth (Spear, 2009; Naert, 2001 and Chee, 2006).
- When anatomic limitations restrict insertion of additional implant. (e.g. maxillary sinus, mental foramen), (Spear, 2009; Naert, 2001 and Chee, 2006)
- Restoring aesthetics in implant is more challenging than the natural teeth. Whenever possible it is better to preserve the natural teeth and connect it to the implant. (Spear, 2009; Naert, 2001 and Chee, 2006)

Cause of problems in tooth-implant supported prosthesis (Kim, 2005; Bennani, 2008; Yu-Ying Chen, 2008; Thomas, 2006; Palmer, 1999; Gunne, 1999; Brägger, 2005; Steflik, 1995; Lindh, 2008; Lang, 2004; Palmer, 2005; Cordaro, 2005; Brägger, 2001; Lindh, 2001 and Nickenig, 2006)

The natural teeth are attached to the alveolar bone by means of periodontal ligament fibers; whereas osseointegrated implant is rigidly anchored to the bone (Kim, 2005; Bennani, 2008; Yu-Ying Chen, 2008). This difference creates a potential biomechanical mismatch of the supporting units.[11-15] Periodontal ligament causes greater movement in the tooth. Lateral movement of the teeth is about 56 to 108 µm in comparison to 10 to 50 µm in the implant with the same force magnitude; apical movement of the tooth is 25 to 100 µm and that of the implant is 3 to 5 µm.[11] When force is applied to the pontic connecting the tooth to the implant, this difference can cause over loading on the implant, leading to bone loss around implant neck (Kim, 2005; Bennani, 2008; Yu-Ying Chen, 2008; Thomas, 2008; Palmer, 1999; Gunne, 1999). The potential problems are difference in survival rates of tooth and implant. The tooth, as opposed to the implant might decay or need endodontic therapy (Gunne, 1999; Brägger, 2005; Steflik, 1995; Lindh, 2008; Lang, 2004; Palmer, 2005; Cordaro, 2005; Brägger, 2001; Lindh, 2001 and Nickenig, 2006). These problems may cause the whole system failure (Gunne, 1999; Brägger, 2005; Steflik, 1995; Lindh, 2008; Lang, 2004; Palmer, 2005; Cordaro, 2005; Brägger, 2001; Lindh, 2001 and Nickenig, 2006).

Benefits of tooth-implant supported prostheses (Gunne, 1992 and Greenstein, 2009)

- Splinting tooth to implant broadens treatment possibilities.
- TISP reduces cost of the treatment due to reduction of implants to be placed.
- In TISP, protective value of properiception is provided by tooth.
- TISP provides additional support for total load on dentition.
- TISP avoids use of cantilever.

Complications of tooth-implant supported prostheses (Naert, 1989; Gunne, 1992; Greenstein, 2009; Nimchuck, 2008; Akpinar, 2000; Naert, 2002; Akça, 2006; Srinivasan, 2008; Ormianer, 2005; Wang, 2004; Block, 2002; Naert, 2001; Garcia, 1998; Pesun, 1997; Sheets, 1997; Abrams, 1996; Sheets, 1993; Singer, 1993; English, 1993; Lill, 1993; Ericsson, 1986; Schlumberger, 1998 and Rieder, 1993)

- Technical complications (Naert, 1989; Gunne, 1992; Greenstein, 2009; Nimchuck, 2008; Akpinar, 2000; Naert, 2002; Akça, 2006; Srinivasan, 2008; Ormianer, 2005; Wang, 2004; Block, 2002; Naert, 2001and Garcia, 1998)

  (i) Implant or tooth fracture
  (ii) Tooth intrusion
  (iii)Cement bond breakdown
  (iv)Screw loosening
  (v) Prosthetic materials (veneer) fracture

- Biological complications (Naert, 1989; Gunne, 1992; Greenstein, 2009; Nimchuck, 2008; Akpinar, 2000; Naert, 2002; Akça, 2006; Srinivasan, 2008; Ormianer, 2005; Wang, 2004; Block, 2002; Naert, 2001 and Garcia, 1998)

  (i) Peri-implantitis
  (ii) Endodontic problems
  (iii) Loss of tooth or implant
  (iv) Caries
  (v) Tooth/root fracture

Intrusion of the tooth is one of the most debated topics in the literature (Naert, 2001; Cordaro, 2005; Lindh, 2001; Akpinar, 2000; Srinivasan, 2008; Ormianer, 2005; Wang, 2004; Block, 2002; Naert, 2001; Garcia, 1998; Pesun, 1997; Sheets, 1997; Abrams, 1996; Sheets, 1993; Singer, 1993; English, 1993; Lill, 1993; Ericsson, 1986 and Schlumberger, 1998). Intrusion of the tooth in TISP has been reported particularly with non-rigid connectors or coping and telescopes with provisional cement or with no cement Cordaro, 2005; Lindh, 2001; Akpinar, 2000; Srinivasan, 2008).

The discussed causes of the intrusion in the reviewed literature are:

(i) Differential energy dissipation (Chee, 2006)
(ii) Friction between the matrix and patrix wall in non-rigid connectors (Naert, 2001; Akpinar, 2000; Schlumberger, 1998)
(iii) Debris impaction in non-rigid connectors (Naert, 2001; Akpinar, 2000; Schlumberger, 1998)
(iv) Impaired rebound memory of the tooth (Naert, 2001; Pesun, 1997)
(v) FDPs flexure (Sheets, 1993; Schlumberger, 1998)
(vi) Disuse atrophy of PDL (Pesun, 1997)
(vii) Mandibular flexure (average value: 0.9 mm) (Ericsson, 1986 and Schlumberger, 1998)
(viii) Transfers of micro-shock waves to the natural tooth (Sheets, 1997; Abrams, 1996)

Potential risks of tooth-implant supported prostheses (Cavicchia, 1994; Naert, 2001; Lang, 2004; Menicucci, 2002 and Naert, 2002)

(i) **Overloading:** Splinting an implant to tooth can overload the implant and its peripheral bone. Based on the literature reviewed, load duration appears to have a greater influence than load intensity on stress distribution in the bone. Due to viscoelastic properties of the periodontal ligament, the stress of transitional load is better distributed whereas static load causes progressive deformation of the periodontal ligament and therefore, the tooth would intrude into the alveolus; then the bridge would act as a cantilever on the implant and overstress it (Cavicchia, 1994; Naert, 2001; Menicucci, 2002)
(ii) Loss of retrievability (whenever the screw is loosenedor broken) (Naert, 2001; Menicucci, 2002; Naert, 2002)
(iii) Progressive bone loss around implant and tooth (Naert, 2001; Naert, 2002)

Available methods of connection and their efficacy (Rangert, 1991; Van Steenberghe, 1989; Lang, 2004; Cordaro, 2005; Nickenig, 2006; Akça, 2006; Pesun, 1997; Hita-Carrillo, 2010; Lin, 2008; Lundgren, 2009; Weinberg, 1994; Mensor, 1998; Uysal, 1997; Chapman, 1990; Nishimura, 1999; Dixon, 1999; Naert, 1992; Lin, 2006 and Lin, 2006)

Celso Hita-Carrillo has classified the methods of connection into two main groups: rigid and non-rigid connection. Non-rigid connections could be in the form of attachment (precision or non-precision or telescopic) or intermobile element (IME), which act as stress breaking elements (Hita-Carrillo, 2010).

Rigid connection (Rangert, 1991; Van Steenberghe, 1989; Lang, 2004; Cordaro, 2005; Nickenig, 2006; Akça, 2006; Pesun, 1997; Hita-Carrillo, 2010; Lin, 2008; Lundgren, 2009; Weinberg, 1994; Mensor, 1998; Uysal, 1997; Chapman, 1990; Nishimura, 1999; Dixon, 1999; Naert, 1992; Lin, 2006 and Lin, 2006)

(i) Some authors believe that rigid connection of tooth to implant is not rational due to adverse effects on the implant in long-term. It will produce greater marginal bone loss, with a corresponding increase in probing depth around the supporting abutment (tooth or implant) (Hita-Carrillo, 2010).
(ii) Clinicians, who advocate splinting tooth to implant rigidly, accept the differential mobility of the implant and natural teeth, but they deem there is sufficient flexibility in the implant complex to compensate this and allow sharing of the load (Rangert, 1991; Ericsson, 1986; Lundgren, 2000)
(iii) Some longitudinal studies suggest that tooth and bone implant components were able to undergo some deformation to compensate for the differences in implant and tooth resiliency under functional load (Van Steenberghe, 1989; Weinberg, 1994; Mensor, 1998; Uysal, 1997; Chapman, 1990; Nishimura, 1999; Dixon, 1995 and Naert, 1992).
(iv) Rigid connection achieves better outcomes with regard to avoiding dental intrusion (Weinberg, 1994; Mensor, 1998; Uysal, 1997; Chapman, 1990; Nishimura, 1999; Dixon, 1995 and Naert, 1992).

The types of such a connection consist of: rigid screw retained abutments, coping with permanent cement and soldered connectors (Greenstein, 2003; Nishimura, 1999).
Several different solutions have been proposed to compensate for different resiliencies of the tooth and implant: Internal flexion elements in the implant- abutment connection, telescopic coping that are cemented or free floating and internal non-rigid keyway attachments (stress breakers) (Nimchuck, 2008).

Non-rigid connection (Rangert, 1991; Van Steenberghe, 1989; Lang, 2004; Cordaro, 2005; Nickenig, 2006; Akça, 2006; Pesun, 1997; Hita-Carrillo, 2010; Lin, 2008; Lundgren, 2009; Weinberg, 1994; Mensor, 1998; Uysal, 1997; Chapman, 1990; Nishimura, 1999; Dixon, 1999; Naert, 1992; Lin, 2006 and Lin, 2006)

Intermobile elements (IME): These elements provide flexibility to compensate for the mobility of the tooth (Babbush, 1987; Kay, 1993; Saxen, 1987; Uysal, 1996). Uysalin 1996 reported that these elements reduced the strain up to 60% compared to the rigid internal elements (Kay, 1993). In an *in vitro* study, it was demonstrated IME did not contribute to the flexibility of the system and the bending force was transmitted to the retaining screw of the implant abutment (Chee, 2006).

Attachments: It has been mentioned that the attachments reduced the level of stresses in the bone (Ozçelik, 2007). because it breaks the stress transfer process and more efficiently compensates for dissimilar mobility of tooth and implant (Lin, 2008; Burak Özcelik, 2011), but intrusion in 3 to 4% of the cases has reported to cause cantilever formation on the implant and increase the unfavourable stress values in implant and prostheses (Garcia, 1998; Rieder, 1993; Lin, 2006 and Al-Ansari, 1996). Von Oosterwyck, Naert and Nishimura mentioned that rigid connection compared to free standing

implants or non-rigid connections overstress the implants and result in greater bone loss around the implant (Naert, 2001; Lin, 2006 and Van Oosterwyck, 1998), however, along with most of other authors, they expressed their preference for rigid connection over non-rigid connectors (Naert, 2001; Lin, 2006; Van Oosterwyck, 1998 and Mamalis, 2010).

Guidelines to minimize long term complications and improve TISP performance

Several studies reported higher complications in TISP in comparison to ISP and attributed them to the risks of tooth complications, like carious lesions, loss of vitality and periodontal problems that added to the complications correlated to the implant (Brägger, 2005; Lang, 2004; Lindh, 2001; Hosny, 2000 and Kindberg, 2001). In order to reduce the complications and improve TISP performance, some studies proposed useful guidelines to follow (Rangert, 1991; Cavicchia, 1994; Naert, 2001; Chee, 2006; Misch, 2008; Greenstein, 2009; Nimchuck, 2008; Weinberg, 2001)

- The natural tooth should have superior stability through long rooted, multirooted, negligible mobility, adequate periodontal support or splinting to an extra tooth or teeth
- The implant should have substantial size and be in type I or II quality bone (Misch, 2008).
- Permanent cementation should be preferred (Misch, 2008).
- Occlusal forces must be distributed to all supported teeth as evenly as possible (Misch, 2008).
- Cantilever extensions must be avoided (Misch, 2008).
- Using more than one natural tooth support increases the success rate in tooth implant connection (Misch, 2008).
- Non-rigid attachments should be avoided as they increase the incidence of tooth intrusion. In case of inevitable use of these connectors, connect the attachment to the implant restoration (between the pontic and the implant) (Rangert, 1991; Naert, 2001; Chee, 2006; Misch, 2008and Greenstein, 2009).
- The pontic should be of short span (Misch, 2008; Greenstein, 2009).
- The implant component and retaining screw must exhibit some degree of flexibility (Rangert, 1991).
- Take care to eliminate or minimize lateral forces and unbalanced tooth contacts in centric and excursive movements (Misch, 2008; Kim, 2005 and Weinberg, 2001).
- Consider bruxism to be a risk factor and manage it with an anti-bruxism splint (Weinberg, 2001)
- Use highly retentive cement with superior retentive preparation design on the tooth abutment (Misch, 2008)
- If telescopic crown or coping are utilized, avoid using temporary cements, particularly avoid the no cement coping technique (Rangert, 1991; Naert, 2001; Misch, 2008; Kim, 2005 and Greenstein, 2009)
- Because of the potential tooth intrusion, consider frequent occlusal adjustment as an important follow up procedure (Weinberg, 2001).

Conclusion

The best prosthetic option for partially edentulous patients appears to be totally implant-supported prostheses. However, there are few specific conditions in which restorative dentist might select either splinting the implant to the tooth in a fixed partial denture or fabricating a removable partial denture. Based on literatures reviewed, using implant-tooth splinting could be considerable treatment option in such patients. The success of tooth-implant supported prosthesis might depend on proper patient selection and complete attention to all the details. This treatment modality has its own benefits, risks and complications. Its application is justified by risk-benefit evaluation with attention to patient requirements. However, multiple longitudinal studies are to be conducted before this method can be recommended as the first choice of treatment. Yet, in specific situations, it can be a viable alternative method with an acceptable success rate.

REFERENCES

Abrams L. The phenomenon of natural root intrusion in combined root-form implant cases. *Dent Implantol Update* 1996; 7(5):33-36.

Akça K, Uysal S, Cehreli MC. Implant-tooth-supported fixed partial prostheses: Correlations between in vivo occlusal bite forces and marginal bone reactions. *Clin Oral Implants Res.,* 2006;17(3):331-36.

Akpinar I, Anil N, Parnas L. A natural tooth's stress distribution in occlusion with a dental implant. *J Oral Rehabil.,* 2000;27(6):538-45.

Al-Ansari BH. Use of non-rigid connection between natural teeth and implants to support fixed partial denture. Two years clinical evaluation. *Saudi Dental Journal,* 1996; 8(2):96-99.

Babbush CA, Kirsch A, Mentag PJ, Hill B. Intramobile cylinder (IMZ) two-stage osseointegrated implant system with the intramobile element (IME): part I. Its rationale and procedure for use. *Int J Oral Maxillofac Implants*, 1987;2(4):203-16.

Bennani V, Schwass D, Chandler N. Gingival retraction techniques for implants versus teeth: Current status. *J Am Dent Assoc.,* 2008;139(10):1354-63.

Block MS, Lirette D, Gardiner D, Li L, Finger IM, Hochstedler J, *et al*. Prospective evaluation of implants connected to teeth. *Int J Oral Maxillofac Implants,* 2002;17(4):473-87.

Brägger U, Aeschlimann S, Bürgin W, Hämmerle CH, Lang NP. Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function. *Clin Oral Implants Res.,* 2001;12(1): 26-34.

Brägger U, Karoussis I, Persson R, Pjetursson B, Salvi G, Lang N. Technical and biological complications/failures with single crowns and fixed partial dentures on implants: A 10-year prospective cohort study. *Clin Oral Implants Res.,* 2005;16(3):326-34.

Burak Özcelik T, Ersoy E, Yilmaz B. Biomechanical evaluation of tooth- and implant-supported fixed dental prostheses with various nonrigid connector positions: A finite element analysis. *J Prosthodont.,* 2011;20(1):16-28.

Cavicchia F, Bravi F. Free-standing vs tooth-connected implant supported partial fixed restorations: A comparative retrospective clinical study of the prosthetic results. *International Journal of Oral and Maxillofacial Implants,* 1994;9:711-18.

Chapman RJ, Kirsch A. Variations in occlusal forces with a resilient internal implant shock absorber. *Int J Oral Maxillofac Implants,* 1990;5(4):369-74.

Chee W, Jivraj S. Connecting implants to teeth. *Br Dent J* 2006; 201(10):629-32.

Cordaro L, Ercoli C, Rossini C, Torsello F, Feng C. Retrospective evaluation of complete-arch fixed partial dentures connecting teeth and implant abutments in patients with normal and reduced periodontal support. *J Prosthet Dent* 2005;94(4):313-20.

Dixon DL, Fincher M, Breeding LC, Mueninghoff LA. Mechanical properties of a light-polymerizing provisional restorative material with and without reinforcement fibers. *J Prosthet Dent* 1995;73(6):510-14.

English CE. Root intrusion in tooth-implant combination cases. *Implant Dent* 1993;2(2):79-85.

Ericsson I, Lekholm U, Brånemark PI, Lindhe J, Glantz PO, Nyman S. A clinical evaluation of fixed-bridge restorations supported by the combination of teeth and osseointegrated titanium implants. *J Clin Periodontol* 1986;13(4):307-12.

Garcia LT, Oesterle LJ. Natural tooth intrusion phenomenon with implants: A survey. *Int J Oral Maxillofac Implants* 1998;13(2):227-31.

Greenstein G, Cavallaro J, Smith R, Tarnow D. Connecting teeth to implants: A critical review of the literature and presentation of practical guidelines. *Compend Contin Educ Dent* 2009;30(7):440-53.

Gunne J, Astrand P, Ahlén K, Borg K, Olsson M. Implants in partially edentulous patients. A longitudinal study of bridges supported by both implants and natural teeth. *Clin Oral Implants Res* 1992;3(2):49-56.

Gunne J, Astrand P, Lindh T, Borg K, Olsson M. Tooth-implant and implant-supported fixed partial dentures: A 10-year report. *Int J Prosthodont* 1999;12(3):216-21.

Hita-Carrillo C, Hernández-Aliaga M, Calvo-Guirado JL. Tooth implant connection: A bibliographic review. Med *Oral Patol Oral Cir Bucal* 2010 Mar 1;15(2):387-94.

Hoffmann O, Zafiropoulos GG. The Tooth-Implant Connection: A Review. *J Oral Implantol* 2011 Jul 22.

Hosny M, Duyck J, van Steenberghe D, Naert I. Within-subject comparison between connected and nonconnected tooth to implant fixed partial prostheses: Up to 14-year follow-up study. *Int J Prosthodont* 2000;13(4):340-46.

Iacono VJ, Cochran DL. State of the science on implant dentistry: A workshop developed using an evidence-based approach. *Int J Oral Maxillofac Implants* 2007;22(Suppl):7-10.

Kay HB. Free-standing versus implant-tooth-interconnected restorations: Understanding the prosthodontic perspective. *Int J Periodontics Restorative Dent* 1993;13(1):47-69.

Kim Y, Oh TJ, Misch CE, Wang HL. Occlusal considerations in implant therapy: Clinical guidelines with biomechanical rationale. *Clin Oral Implants Res* 2005;16(1):26-35.

Kindberg H, Gunne J, Kronström M. Tooth- and implant supported prostheses: A retrospective clinical follow-up up to 8 years. *Int J Prosthodont* 2001;14(6):575-81.

Lang NP, Pjetursson BE, Tan K, Brägger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. II. Combined tooth-implant-supported FPDs. *Clin Oral Implants Res* 2004;15(6):643-53.

Lill W, Thornton B, Reichsthaler J, Schneider B. Statistical analyses on the success potential of osseointegrated implants: A retrospective single-dimension statistical analysis. *J Prosthet Dent* 1993;69(2):176-85.

Lin CL, Chang SH, Wang JC, Chang WJ. Mechanical interactions of an implant/tooth-supported system under different periodontal supports and number of splinted teeth with rigid and non-rigid connections. *J Dent* 2006; 34(9):682-91.

Lin CL, Chang SH, Wang JC. Finite element analysis of biomechanical interactions of a tooth-implant splinting system for various bone qualities. *Chang Gung Med J* 2006; 29(2): 143-53.

Lin CL, Wang JC, Chang WJ. Biomechanical interactions in tooth-implant supported fixed partial dentures with variations in the number of splinted teeth and connector type: A finite element analysis. *Clin Oral Implants Res* 2008; 19(1):107-17.

Lin CL, Wang JC, Kuo YC. Numerical simulation on the biomechanical interactions of tooth/implant-supported system under various occlusal forces with rigid/non-rigid connections. *J Biomech* 2006;39(3):453-63.

Lindh T, Bäck T, Nyström E, Gunne J. Implant versus tooth implant supported prostheses in the posterior maxilla: A 2-year report. *Clin Oral Implants Res* 2001;12(5):441-49.

Lindh T, Dahlgren S, Gunnarsson K, Josefsson T, Nilson H, Wilhelmsson P, Gunne J. Tooth-implant supported fixed prostheses: A retrospective multicenter study. *Int J Prosthodont* 2001;14(4):321-28.

Lindh T. Should we extract teeth to avoid tooth-implant Combinations. *J Oral Rehabil* 2008;35 Suppl 1:44-54.

Lundgren D, Laurell L. Biomechanical aspects of fixed bridgework supported by natural teeth and endosseous implants. *Periodontol* 2000;1994 Feb;4:23-40.

Mamalis A, Markopoulou K, Kaloumenos C, Analitis A.Splinting osseointegrated implants and natural teeth in partially edentulous patients: A systematic review of the literature and a case report. *J Oral Implantol* 2010 Nov 12.

McGlumphy EA, Campagni WV, Peterson LJ. A comparison of the stress transfer characteristics of a dental implant with a rigid or a resilient internal element. *J Prosthet Dent* 1989;62:586-93.

Menicucci G, Mossolov A, Mozzati M, Lorenzetti M, Preti G. Tooth-implant connection: Some biomechanical aspects based on finite element analyses. *Clin Oral Implants Res* 2002;13(3):334-41.

Mensor MC, Ahlstrom RH, Scheerer EW. Compliant Keeper system replication of the periodontal ligament protective damping function for implants: Part I. *J Prosthet Dent* 1998;80(5):565-69.

Misch CE. Contemporary implant dentistry (3rd ed). Mosby Elsevier; 2008;Ch. 12.:258-64.

Naert I, Koutsikakis G, Quirynen M, Duyck J, van Steenberghe D, Jacobs R. Biologic outcome of implant-supported restorations in the treatment of partial edentulism. Part 2: A longitudinal radiographic study. *Clin Oral Implants Res* 2002;13(4):390-95.

Naert I, Quirynen M, van Steenberghe D, Darius P. A six-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism. *J Prosthet Dent* 1992;67(2): 236-45.

Naert IE, Duyck JA, Hosny MM, Quirynen M, van Steenberghe D. Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients Part II: An up to 15-year radiographic evaluation. *Clin Oral Implants Res* 2001;12(3):245-51.

Naert IE, Duyck JA, Hosny MM, Van Steenberghe D. Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients. Part I: An up to15-year clinical evaluation. *Clin Oral Implants Res* 2001;12(3):237-44.

Nickenig HJ, Schäfer C, Spiekermann H. Survival and complication rates of combined tooth-implant-supported fixed partial dentures. *Clin Oral Implants Res* 2006;17(5):506-11.

Nimchuck D. Can dental root form implants be successfully bridged to natural teeth. *Canadian Journal of Restorative Dentistry and Prosthodontics* 2008 Aug;1-2:35-37.

Nishimura RD, Ochiai KT, Caputo AA, Jeong CM. Photoelastic stress analysis of load transfer to implants and natural teeth comparing rigid and semirigid connectors. *J Prosthet Dent* 1999; 81(6):696-703.

Ormianer Z, Brosh T, Laufer BZ, Shifman A. Strains recorded in a combined tooth-implant restoration: An in vivo study. *Implant Dent* 2005;14(1):58-62.

Ozçelik T, Ersoy AE. An investigation of tooth/implant supported fixed prosthesis designs with two different stress analysis methods: An in vitro study. *J Prosthodont* 2007;16(2): 107-16.

Palmer R. Teeth and implants. Br Dent J 1999;187(4):183-88.

Palmer RM, Howe LC, Palmer PJ. A prospective 3-year study of fixed bridges linking Astra Tech ST implants to natural teeth. *Clin Oral Implants Res* 2005;16(3):302-07.

Pesun IJ. Intrusion of teeth in the combination implant-to-natural tooth fixed partial denture: A review of the theories. *J Prosthodont* 1997;6(4):268-77.

Pjetursson BE, Brägger U, Lang NP, Zwahlen M. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clin Oral Implants Res* 2007 Jun;18(Suppl 3): 97-113.

Rangert B, Gunne J, Sullivan DY. Mechanical aspects of a Brånemark implant connected to a natural tooth: An in vitro study. *Int J Oral Maxillofac Implants* 1991;6(2):177-86.

Rangert B. Biomechanics of the Brånemark system. *Aust Prosthodont J* 1995;9(Suppl):39-48.

Rieder CE, Parel SM. A survey of natural tooth abutment intrusion with implant-connected fixed partial dentures. *Int J Periodontics Restorative Dent* 1993;13(4):334-47.

Saxen M. The new implant systems: A comparative analysis. *Dent Manage* 1987;27(6):38-42.

Schlumberger TL, Bowley JF, Maze GI. Intrusion phenomenon in combination tooth-implant restorations: A review of the literature. *J Prosthet Dent* 1998;80(2):199-203.

Sheets CG, Earthman JC. Tooth intrusion in implant-assisted prostheses. *J Prosthet Dent* 1997;77(1):39-45.

Sheets CG, Earthmann JC. Natural tooth intrusion and reversal in implant-assisted prosthesis: Evidence of and a hypothesis for the occurrence. *J Prosthet Dent* 1993;70(6):513-20.

Singer A. Apparent intrusion of natural teeth under an implant supported prosthesis: A clinical report. *J Prosthet Dent* 1993;70(1):100.

Spear F. Connecting teeth to implants: The truth about a debated technique. *J Am Dent Assoc* 2009;140(5):587-93.

Srinivasan M, Padmanabhan TV. Intrusion in implant-toothsupported fixed prosthesis: An in vitro photoelastic stress analysis. *Indian J Dent Res* 2008;19(1):6-11.

Steflik DE, Koth DL, Robinson FG, McKinney RV, Davis BC, Morris CF, Davis QB. Prospective investigation of the single crystal sapphire endosteal dental implant in humans: Ten-year results. *J Oral Implantol* 1995;21(1):8-18.

Thomas MV, Beagle JR. Evidence-based decision-making: Implants versus natural teeth. *Dent Clin North Am* ;50(3):451-61.

Uysal H, Iplikcio—lu H, Avci M, Bilir OG, Kural O. Efficacy of the intramobile connector in implant tooth-supported fixed prostheses: An experimental stress analysis. *Int J Prosthodont* 1996;9(4):355-61.

Uysal H, Iplikçio—lu H, Avci M, Gündüz Bilir O, Kural O. An experimental analysis of the stresses on the implant in an implant tooth- supported prosthesis: A technical note. *Int J Oral Maxillofac Implants* 1997;12(1):118-24.

Van Oosterwyck H, Duyck J, Vander Sloten J, Van der Perre G, De Cooman M, Lievens S, *et al*. The influence of bone,mechanical properties and implant fixation upon bone loading around oral implants. *Clin Oral Implants Res* 1998;9(6): 407-18.

Van Steenberghe D. A retrospective multicenter evaluation of the survival rate of osseointegrated fixtures supporting fixed partial prostheses in the treatment of partial edentulism. *J Prosthet Dent* 1989 Feb;61(2):217-23.

Wang TM, Lee MS, Kok SH, Lin LD. Intrusion and reversal of a free-standing natural tooth bounded by two implant-supported prostheses: A clinical report. *J Prosthet Dent* 2004;92(5): 418-22.

Weinberg LA, Kruger B. Biomechanical considerations when combining tooth-supported and implant-supported prostheses. *Oral Surg Oral Med Oral Pathol* 1994;78(1):22-27.

Weinberg LA. Therapeutic biomechanics concepts and clinical procedures to reduce implant loading. Part II: Therapeutic differential loading. *J Oral Implantol* 2001;27(6):302-10.

Yu-Ying Chen, Chung-Ling Kuan, Yi-Bing Wang. Implant occlusion: Biomechanical considerations for implant-supported prostheses. *J Dent Sci* 2008; 3(2):65-74.

****