

## Occlusal principles and considerations for the osseointegrated prosthesis

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**Abstract :** The utilization of oral implantology in the field of dentistry is growing at a rapid rate. Although the surgical aspect of the field has expanded into many high-profile areas (i.e., immediate implant placement, distraction Osteogenesis, and the orthodontic anchorage implant), it is the prosthetic aspect that is the most critical for long term success. More specifically, the occlusal considerations for implant supported prostheses make a major contribution to ensure predictable results. This article reviews occlusal principles and clinical applications for long term success of endosseous implants.

**Keywords -** Occlusion, Implant protective occlusion, occlusal scheme, biomechanics, occlusal stability.

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### I. Introduction

Rehabilitation of missing teeth with prosthesis has undergone a series of changes over the years. Various treatment options considered are complete dentures, removable partial dentures, fixed partial dentures and overdentures. The quest for replacements as close to natural teeth as possible resulted in the development of implants[1,2].

Presently, implant restorations are considered to be the most ideal restorative option available. Implants provide with advantages such as maintenance of bone, restoration and maintenance of occlusal vertical dimension, maintenance of facial aesthetics, improved esthetics, improved phonetics, improved occlusion, improvement or allowance for regaining of oral proprioception, improved stability and retention of removable prostheses, improved psychological health and elimination of the need to alter adjacent teeth[2,3,4]

Gradually, with the increase in the number of implant cases, an increased number of failure rates were also reported. An increase in failed implants led to an introspection of the various reasons for the same[3,5,6]. Studies proved that occlusal load was one of the primary contributing factors. This resulted in the concept of a restoration driven implant, rather than an implant driven restoration[7,8,9].

The restoring dentist has specific responsibilities to minimize overload to the bone-to-implant interface. These include a proper diagnosis leading to a treatment plan providing adequate support, based on the patient's individual force factors; a passive prosthesis of adequate retention and progressive loading to improve the amount and density of the adjacent bone and further reduce the risk of stress beyond physiologic limits. The final element is the development of an occlusal scheme that minimizes risk factors and allows the restoration to function in harmony with the rest of the stomatognathic system[8,10,11].

Occlusion specific to implants can be termed Implant Protective Occlusion. Implant-Protective Occlusion is that occlusal scheme which reduces the forces at the crestal bone/implant interface. Biomechanical principles form the basis of this concept. The direction of force, force magnification, and implant position relative to arch or location are blended together for a consistent approach to implant reconstruction[12]. The direction of force demonstrates that angled forces increase the type of forces, alter their point of application, and reduce bone strength. Force magnifiers include cantilevers, offset loads, and monumental forces to the implant body. These magnifiers dramatically increase the amount of force applied to a prosthesis[13,14]. The implant position is often determined by the density of bone and the amount of force. Adequate surface area of implant includes width, length, and number[15]. The surface area is a primary component in the resistance of force factors. In addition occlusal table width and occlusal contacts contribute to the amount of force, type and direction and may be modified to reduce crestal loads[16,17,18].

The primary goal of Implant-Protective occlusion is to maintain the occlusal load transferred to the implant within the physiologic limits of each patient. Implant dentistry continues to struggle with what is the appropriate occlusal concept for implant-supported restorations[19]. The biological and mechanical consequences of the loading environment leads to establishing and maintaining an implant interface in a wide

variety of bone quality, implant and prosthesis designs[8,10]. To the restorative dentist, the role occlusion is more focused on extending the service life of the restoration and the connecting abutments than protecting the osseous integration of the implants[20,21].

## **II. Discussion**

### **1. Natural Tooth Versus Implant Biomechanics**

It is critical for the practitioner to appreciate the differences between natural teeth and endosseous implants in regard to the application of stress[22] (Fig. 1). The most significant difference is created by the periodontal ligament and its unique properties (TABLE 1). As a result, ways to decrease stress are a constant concern to minimize the risk of implant complications (TABLE 2).

### **2. General Occlusal Scheme**

The concept of occlusion suitable for osseointegrated prostheses is basically the same as that of gnathologic occlusion.

In centric, all of the posterior teeth should have contacts, and anterior teeth should have a clearance of about 30 $\mu$ m. If the entire arches are restored with osseointegrated prostheses such as a fully bone anchored bridge, it will be easier to establish such an occlusion. In the mixed dentition, which is composed of natural teeth and osseointegrated bridgework, the natural tooth sinks approximately 30 $\mu$ m during its function. An osseointegrated bridge, which is supported only by bone, does not sink. Therefore, the centric contacts of the osseointegrated fixed bridge should be slightly more open than the natural teeth. In centric, the osseointegrated bridge should not contact with opposing teeth under the soft bite pressure, while strong bite pressure, the bridge should contact after the natural tooth intrudes approximately 30 $\mu$ m. The osseointegrated bridge begins to contact after the contact of all the natural posterior teeth. In order to avoid the overloading of the occlusal surface, the osseointegrated prosthesis should not have plane-to- plane contact. Point contact especially cusp-to-fossa tripod contact is preferred[23,24,25].

During eccentric movement, the concept of disclusion is generally recommended. Anterior segments of the osseointegrated prosthesis should guide the mandible to produce the posterior disclusion[26]. Canine-guided occlusion is not recommended for the osseointegrated prosthesis as it generates excessive occlusal forces into the single implant fixture, which is placed in the canine area. In order to distribute the stress over the entire fixture, anterior group function is recommended[27].

The specific amount of disclusion to be given to the osseointegrated prosthesis is not clearly understood. The average consensus for the amount of disclusion observed at the mesiobuccal cusp tips of the mandibular first molars while the condyle moves 3mm from the centric are in protrusion is 1.1 $\pm$ 0.6mm, non-working side is 1.0 $\pm$ 0.6mm, working side is 0.5 $\pm$ 0.3mm[28,29].

### **3. Classification Of Osseointegrated Prostheses**

Osseointegrated prostheses can be classified as follows[28,30,31]:

- i. Fully bone anchored bridge.
- ii. Overdenture.
- iii. Free standing bridge –
  - a. Kennedy Class I
  - b. Kennedy Class II
  - c. Kennedy Class III
  - d. Kennedy Class IV
- iv. Bridge connected to the natural teeth.
- v. Single tooth replacement.

The occlusion for each case will be discussed.

#### **3.1 Occlusion For Fully Bone Anchored Bridge**

The occlusion recommended for a fully bone anchored bridge is the mutually protected occlusion. In centric, it is necessary to have a 30 $\mu$ m clearance at the anterior region and to have centric stops on the posterior teeth. In order to eliminate harmful horizontal stress, the disclusion should be employed. To avoid the localization of the stress, anterior group function must be used[32,33]. The anterior guidance should be made slightly flatter than that of the natural teeth to avoid overstress of the fixture. This produces a smaller amount of disclusion. Recommended amounts of disclusion for fully bone anchored bridges are as follows: Protrusive 1mm; Non-working side 0.8 mm; Working side 0.3 mm[32,34].

### **3.2 Occlusion For Overdentures**

The occlusion recommended for the overdenture is the fully balanced occlusion with lingualized occlusion. The concepts that apply to the regular denture are accepted for the osseointegrated overdenture. However, in the case of an edentulous maxillary overdenture and a mandibular fully bone anchored bridge, in centric a small clearance is recommended in the anterior teeth, while the posterior teeth contact simultaneously[35,36]. The amount of disclusion in protrusive and lateral movement non working side and working side is 0 mm.

### **3.3 Occlusion For Free Standing Bridges**

**3.3.1 Kennedy Class I** – In this, both sides of the arch are restored by osseointegrated bridges, and they maintain the vertical height. Careful consideration should be taken to determine the amount of clearance given to the natural anterior dentition. As the osseointegrated prosthesis does not sink during function, the clearance of anterior teeth should be smaller than the one given to natural teeth[22,37,38]. The amount of disclusion required for this case is the same as in the natural dentition because anterior guidance is provided by the natural dentition: Protrusive 1.1 mm, non-working side 1.0 mm; working side 0.5 mm[39].

**3.3.2 Kennedy Class II** – This situation is ideal for the osseointegrated free-standing bridge because the contralateral side of the arch will maintain the vertical height, while the other side is restored by the osseointegrated bridge. It induces less stress to the implant while it holds centric. In centric, the posterior osseointegrated bridge should have 30µm open contacts, while anterior teeth also have 30µm openings, and it begins to contact under strong bite pressure[40,41]. In the Kennedy Class II situation, because the anterior teeth are natural teeth, they can bear the occlusal load safely. The amount of disclusion suggested for this case is the same as for a natural dentition: Protrusive 1.1 mm; Non-working side 1.0 mm, Working side 0.5 mm[42].

**3.3.3 Kennedy Class III** – This situation is also ideal for osseointegrated implants because the vertical height is maintained by natural teeth. In centric, the osseointegrated bridge only contacts under strong bite pressure. Eccentric movement is guided by the natural dentition. The amount of disclusion suggested for this case is the same as for a natural dentition: Protrusive 1.1 mm; Non-working side 1.0 mm, Working side 0.5 mm[43,44].

**3.3.4 Kennedy Class IV** - In this case, posterior disclusion is guided by the osseointegrated bridge[45]. In order to minimize the horizontal load introduced to the implant site, group-function occlusion is preferred. During lateral movement, posterior teeth on the working side can help bear the horizontal load, while the non-working side is discluded[39,46]. During protrusive movement, an osseointegrated bridge will guide the mandible and produce posterior disclusion. In order to minimize the load induced to the fixtures during protrusive movement, anterior guidance should be flatter than the natural dentition. The amount of disclusion suggested for this case is as follows: Protrusive 0.8mm; Non-working side 0.4mm; Working side 0.0mm[47,48]. Because an anterior fixed bridge does not sink like natural teeth, the clearance of natural teeth must be greater than the one given to natural anterior teeth (> 30µm)[40,49].

### **3.4 Connection For Natural Teeth**

When single fixtures are used to restore the bridge, in order to prevent loosening of the screw by the rotation of the bridge, the mesial end of the bridge must be connected to natural teeth. As mentioned earlier, the natural tooth is depressed during its function, while the osseointegrated implant is not. If the osseointegrated implant prosthesis and the natural teeth are connected rigidly, under the occlusal loads, the implant receives the majority of the stress and is overloaded[50]. To avoid this, a non-rigid connector is used. The female (keyway) is placed on the distal end of the retainer supported by the natural tooth; the key connected to the osseointegrated bridge is engaged into the keyway. Thus, the natural tooth can be depressed freely without interference of the osseointegrated bridge[51,52,53].

However, based on long term observation[54,55,56], it was found that the natural tooth depressed permanently and produced a gap between key and keyway. The osseointegrated prosthesis with the key is extruded a visible amount and the retainer cemented to the natural tooth is depressed. The reasons are not clear. It has been stated that this phenomenon may have been caused when the key and keyway are made very precisely[57,58]. When the natural tooth is depressed, the key and keyway are sometimes locked; then the natural tooth is depressed permanently[59,60,61].

In order to avoid this phenomenon, some suggested[62,63,64] the use of telescopic crown to connect the osseointegrated bridge. However through a long term observation[65,66,67], it was found again that the natural tooth depressed often, the cement connecting the outer crown to the inner coping was broken down and the cement washed out, producing plaque accumulation.

At present, the use of a rigid connector between the osseointegrated bridge and the natural tooth is suggested, rather than a non-rigid connector[68,69]. This may result in the ankylosis of the root of the abutment tooth, creating resorption of the root or absorption of the alveolar bone[70]. This progresses more slowly. It may be better to have this than the situation mentioned above. The connection of natural teeth is questionable and the freestanding procedure preferred[71,72].

### 3.5 Occlusion For Single Tooth Replacement

Occlusion required for this restoration is equal to the natural dentition. In centric for anterior teeth, it must have a clearance of 30 $\mu$ m; for premolar, it should contact only under heavy load[73,74,75] (Fig. 2) . Because natural teeth depresses under heavy load, the amount of contact to be given to the osseointegrated restoration must be designed carefully (Fig. 3) .

During eccentric movement, the anterior restoration should contact with opposing teeth in order to create anterior group function. This eccentric contact is essential to prevent the extrusion of opposing teeth[75,76,77]. Because the restoration does not contact in centric, contact during eccentric movement is required. For premolars, the restoration must disclude during eccentric movement and avoid lateral stress.

### III. FIGURES AND TABLES

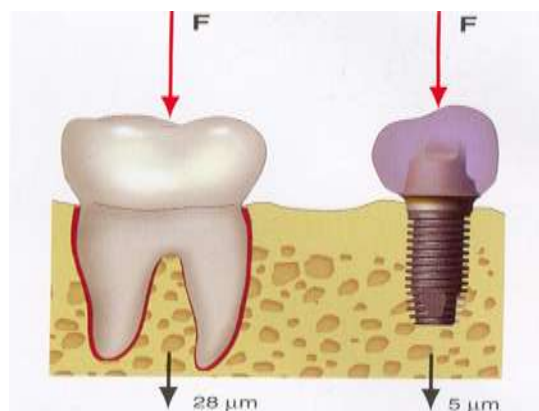


Fig. 1: A tooth exhibits more vertical movement than an implant.



Fig. 2: A light occlusal force is applied first to the implant and teeth. The first molar implant crown has less initial contact than the teeth.



Fig. 3: The first molar crown is then evaluated with heavy bite force. The occlusal contacts ideally should be similar to the teeth under a heavy load.

TABLE 1 : NATURAL TOOTH VERSUS IMPLANT BIOMECHANICS.

TOOTH	IMPLANT
1. Periodontal membrane. a) Shock absorber. b) Longer force duration (decrease impulse of force). c) Distribution of force around tooth. d) Tooth mobility can be related to force. e) Mobility dissipates lateral force. f) Fremitus related to force. g) Radiographic changes to force – reversible.	1. Direct bone-implant. a) Higher impact force. b) Short force duration (increased force impulse). c) Force primarily to crest. d) Implant is always rigid (mobility is failure). e) Lateral force increases strain to bone. f) No fremitus. g) Radiographic changes at crest (bone loss)- not reversible.
2. Biomechanical design. a) Cross-section related to direction and amount of stress. b) Elastic modulus similar to bone. c) Diameter related to force magnitude.	2. Implant design. a) Round cross-section and designed for surgery. b) Elastic modulus 5 to 10 times that of cortical bone. c) Diameter related to existing bone.
3. Sensory nerve complex in and around tooth. a) Occlusal trauma induces hyperemia and leads to cold sensitivity. b) Proprioception (reduced maximum bite force). c) Less functional bite force.	3. No sensory nerves. a) No precursor sign of slight occlusal trauma. b) Occlusal awareness of 2 to 5 times less (higher maximum bite force functional). c) Functional bite force 4 times higher.
4. Occlusal material: Enamel. a) Enamel wear, stress lines, abfractions, pits.	4. Occlusal material: Porcelain (metal crown) a) No early signs of force.
5. Surrounding bone is cortical. a) Resistant to change.	5. Surrounding bone is trabecular. a) Conducive to change.

TABLE 2 – NATURAL TOOTH VERSUS IMPLANT CHARACTERISTICS UNDER LOAD.

CRITERION	TOOTH	IMPLANT
Connection	Periodontal ligament	Function ankylosis
Impact force	Decreased	Increased
Mobility	Variable Anterior teeth more than posterior teeth	None
Movement	Shock breaker effect of Periodontal ligament	Stress captured at crest
Apical	Intrude quickly 28µm	No initial movement
Lateral	56 to 108µm	10 to 50µm
Diameter	Large	Small
Cross section	Not round	Round
Modulus of elasticity	With or without cortical bone	5 to 10 times greater than trabecular bone
Signs of hyperemia	Yes	No
Orthodontic movement	Yes	No
Fremitus	Yes	No
Radiographic changes	Periodontal thickening and cortical bone resorption	No
Progressive loading	Since childhood	Shorter loading period
Wear	Enamel wear facets, Localized fatigue, stress fracture, cervical abfraction, pitting on occlusal cusps.	Minimal wear, screw loosening, stress, fracture of prosthetic components or implant body
Tactile sensitivity	High	Low
Occlusal awareness (proprioception)	High detection of premature contacts	Low; higher loads to premature occlusal contacts

#### IV. CONCLUSION

The objectives of implant occlusion are to minimize overload on the bone-implant interface and implant prosthesis, to maintain implant load within the physiologic limits of individualized occlusion, and finally to provide long-term stability of implants and implant prostheses. To accomplish these objectives, increased support area[78], improved force direction[79], and reduced force magnification[80] are indispensable factors in implant occlusion. In addition, systematic individualized treatment plans[81] and precise surgical/prosthetic procedures based on biomechanical principles[82,83] are prerequisites for optimal implant occlusion.

Occlusion has been an important variable in the success or failure of most prosthodontic reconstructions. With natural teeth, a certain degree of flexibility permits compensation for any occlusal irregularities. Implant occlusion is not as forgiving as natural occlusion. Implant occlusion should be re-evaluated and adjusted, if needed, on a regular basis to prevent from developing potential overloading on dental endosseous implants, thus providing implant longevity[84,85].

It must be emphasized that there is no evidence-based, implant-specific concept of occlusion. Further studies in this area are needed to clarify the relationship between occlusion and implant success.

#### REFERENCES

- [1] Falk H, On occlusal forces in dentitions with implant- supported fixed cantilever prostheses. *Swed Dent J Suppl* 1990; 69:1-40.
- [2] Hobo S, Ichida E, Garcia LT: Osseointegration and Occlusal Rehabilitation Ed 1. Quintessence Publishing Company, Tokyo. Page: 323- 327, 1991.
- [3] Weinberg LA, Kruger B: A Comparison of implant/ prosthesis loading with four clinical variables. *Int J Prosthodont* 1995; 8:421-433.
- [4] Kayacan R, Ballarini R, Mullen RL: Theoretical study of the effects of tooth and implant mobility differences on occlusal force transmission in tooth/implant-supported partial prostheses. *J Prosthet Dent* 1997; 78:391-99.
- [5] Sertgöz A: Finite element analysis study of the effect of superstructure material on stress material in an implant- supported fixed prosthesis. *Int J Prosthodont* 1997; 10:19-27.
- [6] Gunne J, Rangert B, Glantz PO, Svensson A: Functional loads on Freestanding and Connected Implants in Three-unit Mandibular Prostheses opposing complete dentures: An In Vivo Study. *Int J Oral Maxillofac Implants* 1997;12:335-341.
- [7] Barbier L, Evert S: Adaptive Bone Remodeling around Oral Implants under axial and nonaxial loading conditions in the dog mandible: *Int J Oral Maxillofac Implants* 1997; 12: 215-223.
- [8] Richter EJ: In Vivo horizontal Bending Moments on Implants: *Int J Oral Maxillofac Implants* 1998; 13:232-244.
- [9] Stegaroiu R, Kusakari H, Nishiyama S, Miyakawa O: Influence of Prosthesis Material on stress distribution in bone and implant: A 3-Dimensional Finite Element Analysis. *Int J Oral Maxillofac Implants* 1998; 13:781-790.
- [10] Weinberg LA: Reduction of implant loading using a modified centric occlusal anatomy. *Int J Prosthodont* 1998; 11:55-69.
- [11] Suzuki T, Kumagai H, Yoshitomi N, McGlumphy EA: Occlusal contacts of edentulous patients with mandibular hybrid dentures opposing maxillary complete dentures. *Int J Oral Maxillofac Implants* 1999; 14:504-509.
- [12] Taylor TD, Belser U: Prosthodontic considerations. *Clin Oral Impl Res* 2000;11 (Suppl):101-107.
- [13] 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; 14:321-328.
- [14] Babbush CA : Dental Implants – The Arts and Science. Ed 1. Philadelphia : W B Saunders Co, 2001.
- [15] Morneburg TR, Proschel PA: Measurement of masticatory forces and Implant loads: A methodologic clinical study. *Int J Prosthodont* 2002; 15:20-27.
- [16] Wang TM, Leu LJ, Wang JS, Lin LD: Effects of prosthesis materials and prosthesis splinting on peri-implant bone stress around implants in poor-quality bone: A Numeric Analysis. *Int J Oral Maxillofac Implants* 2002; 17:231-237.
- [17] Guichet DL, Yoshinobu D, Caputo AA: Effect of splinting and interproximal contact tightness on load transfer by implant restorations. *J Prosthet Dent* 2002; 87:528-35.
- [18] Bassit R, Lindstrom H, Rangert B: In Vivo Registration of force development with ceramic and acrylic resin occlusal materials on Implant-supported prostheses. *Int J Oral Maxillofac Implants* 2002; 17:17-23.
- [19] Morneburg TR, Proschel PA: In vivo forces on implants influenced by occlusal scheme and food consistency. *Int J Prosthodont* 2003; 16:481-486.
- [20] Jackson BJ: Occlusal principles and clinical applications for endosseous implants. *Journal of Oral Implantology* 2003; XXIX: 5: 230-234.
- [21] Lin CL, Wang JC: Nonlinear Finite Element Analysis of a splinted implant with various connectors and occlusal forces. *Int J Oral Maxillofac Implants* 2003; 18:331-340.
- [22] Ishigaki S, Nakano T, Yamada S, Nakamura T, Takeshima F: Biomechanical stress in bone surrounding an implant under simulated chewing. *Clin. Oral Impl. Res* 2003; 14:97-102.
- [23] Eskitascioglu G, Usumez A, Sevimay M, Soykan E, Unsal E: The influence of occlusal loading location on stresses transferred to implant-supported prostheses and supporting bone: A three-dimensional finite element study. *J Prosthet Dent* 2004; 91:144-50.
- [24] Hekimoglu C, Aml N, Cehreli MC: Analysis of strain around endosseous dental implants opposing natural teeth or implants. *J Prosthet Dent* 2004; 92:441-6.
- [25] 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; 92:418-22.
- [26] Stegaroiu R, Khraisat A, Normura S, Miyakawa O: Influence of superstructure materials on strain around an implant under 2 loading conditions: A Technical investigation. *Int J Oral Maxillofac Implants* 2004; 19:735-742.
- [27] Torrado E, Ercoli C, Mardini MA, Graser GN, Tallents RH, Cordaro: A comparison of the porcelain fracture resistance of screw-retained and cement retained implant- supported metal ceramic crowns. *J Prosthet Dent* 2004; 91:532-7.
- [28] Sütüpedeler M, Eckert SE, Zobitz M, Kai KN : Finite element Analysis of effect of prosthesis height, angle of force application, and implant offset on supporting bone. *Int J Oral Maxillofac Implants* 2004; 19:819-825.

- [29] Flanagan D: Complete artificial dentition supported by endosseous Implants: A case report of total In-Office treatment. *Journal of Oral Implantology* 2005 Vol XXXI,(2),Two; 56-61.
- [30] Satoh T, Maeda Y, Yataro K. Biomechanical rationale for Intentionally inclined implants in the posterior mandible using 3D- Finite Element Analysis. *Int J Oral Maxillofac Implants* 2005; 20:533- 539.
- [31] Caglar A, Aydin C, Ozen J, Yilmaz C, Korkmaz T: Effect of mesiodistal inclination of implants on stress distribution in implant supported Fixed prostheses. *Int J Oral Maxillofac Implants* 2006; 21:36-44.
- [32] Tawil G, Aboujaoude N, Younan R: Influence of prosthetic parameters on the survival and complication rates of short implants. *Int J Oral Maxillofac Implants* 2006;21:275-282.
- [33] Misch CE ; Dental Implant Prosthetics. St Louis, Missouri : Elsevier Mosby, 2005.
- [34] Misch CE : Prosthodontic Considerations. In Misch CE, editor : Contemporary Implant Dentistry, St Louis, Mosby, 1993.
- [35] English CE : The mandibular overdenture supported by implants in the anterior symphysis : A prescription for implant placement and bar prosthesis design, *Dent Implantol Update* 1993, 4 :9-14.
- [36] Babbush CA, Kent JN, Misiak DJ : Titanium Plasma Spray (TPS) Swiss screw implants for the construction of the edentulous mandible, *J Oral Maxillofac Surgery* 1986, 44 :247-282.
- [37] Engquist B, Bergendal T, Kallus T : A retrospective multicenter evaluation of osseointegrated implant supporting overdentures, *Int J Oral Maxillofac Implants* 1988, 3 : 129-134.
- [38] Jemt T, Chai J, Harnett J : A 5- year prospective multicenter follow-up report on overdentures supported by osseointegrated implants, *Int J Oral Maxillofac Implants* 1996, 11 : 291-298.
- [39] Weismeijer D, van Maas MAJ, Vermeeren J : Overdentures supported by implants : A 6.5 year evaluation of patient satisfaction and prosthesis aftercare, *Int J Oral Maxillofac Implants* 1995, 10 :744- 749.
- [40] Kline R, Hoar J, Beck GH : A prospective multicenter clinical investigation of a bone quality based implant system. *Int J Oral Maxillofac Implants* 2002, 11 : 224-234.
- [41] Tallgren A : The continuing reduction of the residual alveolar ridge in complete denture wearers : A mixed longitudinal study covering 25 years, *J Prosthet Dent* 1972, 27 :120-132.
- [42] Adell R, Lekholm U, Rockler B : A 15- year study of osseointegrated implants in the treatment of the edentulous jaw, *Int J Oral Surg* 1981, 10 : 387-416.
- [43] Jemt T, Stallard PA : The effect of chewing movements on changing mandibular complete dentures to osseointegrated overdentures, *J Prosthet Dent*,1986, 55 : 357-361.
- [44] Geertman ME, Slagter AP, van Maas MAJ : Comminution of food with mandibular implant-retained overdentures, *J Dent Res* 1994, 73 :1858-1864.
- [45] Sposetti VJ, Gibbs CH, Alderson TH : Bite force and muscle activity in overdenture wearers before and after attachment placement, *J Prosthet Dent* 1986, 55 : 265- 273.
- [46] Mericke Stern R : The force on implant supporting overdenture : A preliminary study of morphologic and cephalometric considerations, *Int J Oral Maxillofac Implants* 1993,8 (3) : 256-263.
- [47] Mericke Stern R, Hofman J, Wedig A : In vivo measurements of maximum occlusal force and minimal pressure threshold on overdentures supported by implants or natural roots : A comparative study, Part I, *Int J Oral Maxillofac Implants* 1993, 8 : 641-649.
- [48] Jemt T, Book K, Karlsson S : Occlusal force and mandibular movements in patients with removable overdentures and fixed prosthesis supported by implants in the maxilla, *Int J Oral Maxillofac Implants* 1993, 8 :301-308.
- [49] Roumanas E, Nishimura RD, David BK : Clinical evaluation of implant retaining maxilla obturator prostheses, *J Prosthet Dent* 1997, 77 :184- 190.
- [50] Watson RM, Jemt T, Chai J : Prosthodontic treatment, Patient response and the need for maintenance of complete implant supported overdentures : An appraisal of 5 years of prospective study, *Int J Prosthodont* 1997, 10 : 245-254.
- [51] Jacobs R, Schulte A, Van Steenberghe D : Posterior jaw bone resorption in osseointegrated implant supported overdentures, *Clin Oral Implant Res* 1992, 3 : 63-70.
- [52] Jacobs R, Van Steenberghe D, Nys M : Maxilla bone resorption in patients with mandibular implant supported overdentures or fixed prosthesis, *J Prosthet Dent* 1993,70 : 135-140.
- [53] Naert I, Quirynen M, Hooghe MA : A comparative prospective study of splinted and unsplinted Brånmark implant in mandibular overdenture therapy, *J Prosthet Dent* 1994, 71 :486-492.
- [54] Bidez MW, Misch CE : The Biomechanical inter- implant spacing. Proceedings of the fourth International Congress of Implants. *Biomaterials in Stomatology*, 1990 (2)24-25.
- [55] English CE : Finite Element Analysis of two abutment bar designs, *Implant Dent* 1993,2(2) :107-114.
- [56] Jemt T, Lewis, Sullivan : A 5- Year prospective follow- up report on implant supported free- standing bridges, *Int J Oral Maxillofac Implants* 1996,11 : 291-298.
- [57] Cummer WE : Possible combinations of teeth present and missing in partial restorations, *Oral health* 1990,10 :421.
- [58] Kennedy E : Partial Denture Construction, Brooklyn, NY 1928, Dental Items of Interest.
- [59] Bailyn M : Tissue support in partial denture construction, *Dent Cosmos* 1928,70 : 988.
- [60] Applegate OC : Essentials of removable partial denture prosthesis, Ed 3, Philadelphia, 1965, W B Saunders.
- [61] Misch CE, Judt WMK : Classification of the partially edentulous arches for implant dentistry, *Int J Oral Implantol* 1987,4 : 7-12.
- [62] Naert I, Quirynen M, van Steenberghe D : A 6-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism, *J Prosthet Dent* 1992,67 : 236- 245.
- [63] Walton JN, Gardner MF, Agar JR : A survey of crown and fixed partial denture failures : Length of service and reasons for replacement, *J Prosthet Dent* 1986,56 : 416-420.
- [64] Anderson B, Odman P, Lidvall AM : Single tooth restorations supported by osseointegrated implants, *Int J Oral Maxillofac Implants* 1995,10 : 702- 711.
- [65] Henry PJ, Laney WR, Jemt T : Osseointegrated implants for single tooth replacement : A 5- year prospective multicenter study, *Int J Oral Maxillofac Implants* 1996,11 : 450-455, 1996.
- [66] Misch CE, Bidez MW : Implant Protected Occlusion. A biomechanical rationale, *Compend Contin Educ Dent* 15 : 1330-1344,1994.
- [67] Picton DCA : On the part played by the socket in tooth support, *Arch Oral Biol* 1965,10 : 945-955.
- [68] Parfitt GS : Measurement of the physiologic mobility of individual teeth in an axial direction, *J Dent Res* 1960,39 : 608-612.
- [69] Muhlemann HR : Tooth mobility : A review of clinical aspects and research findings, *J Periodontol* 1967,38 : 686- 708.
- [70] Bidez MW, Lemons JE, Isenberg BF : Displacements of precious and non- precious dental bridge utilizing endosseous implants as distal abutments, *J Biomed Mater Res* 1986,20 : 785-787.
- [71] Rangert B, Gunne J, Sullivan DY : Mechanical aspects of a Brånemark implant connected to a natural tooth : An invitro study, *Int J Oral Maxillofac Implants* 1991,6 : 177-186.

- [72] Sekine H, Komiyama Y, Hotta H : Mobility characteristics and tactile sensitivity of osseointegrated fixture- supporting system, *J Prosthet Dent* 1986,56 : 416-421.
- [73] Komiyama Y : Clinical and research experience with osseointegrated implants in Japan, *J Prosthet Dent* 1989,61 : 217-222.
- [74] Fenton AM, Jamshaid A, David D : Osseointegrated fixture mobility, *J Dent Res* 1987,66 :114.
- [75] Wylie R, Capulo AA : Force distribution to periodontally involved teeth by fixed splints, *J Dent Res* 1982,61 : 1030.
- [76] Shillingberg HT, Fischer DW : Non rigid connectors for fixed partial dentures, *J Am Dent Assoc* 1973, 87 : 1195-1199.
- [77] Cho GC, Chee WL : Apparent intrusion of natural teeth under an implant supported prosthesis : A Clinical Report, *J Prosthet Dent* 1992,68 :3-5.
- [78] De Clercg M, Naert I : Damages at implant parts and prosthetical superstructures supported by osseointegrated implants, *J Dent Res* 1989,68 : 901-910.
- [79] Adell R : A 10- year prospective study of implant supported prosthesis in edentulous and partially edentulous patients, *J Prosthet Dent* 1990,69, 222-227.
- [80] Schmitt A, Zarb GA : The longitudinal clinical effectiveness of osseointegrated dental implants for single tooth replacement, *Int J Prosthodont* 1993,6, 187-202.
- [81] Laney WJ, Jemt T, Harris D : Osseointegrated implants for single tooth replacement : A progress report from a multicenter prospective study after 3 years, *Int J Oral Maxillofac Implants* 1994,9 :49-54.
- [82] Malavez C, Herman M : Marginal bone levels at Brånemark system implants used for single tooth restorations, *Clin Oral Implants Res* 1996,7 : 162-169.
- [83] Gomez-Roman G, Schulte W : The FRIALIT- 2 implant system : 5 years clinical experience in single tooth and immediately post-extraction applications, *Int J Oral Maxillofac Implants* 1997,12 : 209-309.
- [84] Kline R, Hoar JE : A prospective clinical evaluation of a bone quality based dental implant system, *Implant Dent*, 2002,11 ; 224-234.
- [85] Thilander B, Odman J, Grondahl K : Osseointegrated implants in adolescents : An alternative in replacing missing teeth ? *Eur J Orthod* 1994, 16 : 84-95.