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Biological Adaptation to Misfits of Immediately Loaded Fixed Prostheses Following Computer-Guided Surgery

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Keywords
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Abstract

In this clinical report, following computer-guided (3D Procera Software Planning Program, Nobel Biocare, Yorba Linda, CA) placement and immediate provisionalization of 12 dental implants (NobelSpeedy™ Replace, Nobel Biocare), misfits of the prefabricated screw-retained interim prostheses were noted at several implant-abutment junctions. Nevertheless, adaptation of the misfits was observed 10 days later, after the loosened screws were tightened. While a high mean marginal bone loss of 2.1 mm (range: 1.4 to 3.5 mm) was noted, all implants remained osseointegrated at 3-year follow-up.

Immediate loading of implant-supported fixed complete dentures (FCDs) has been documented with high success rates in both the edentulous maxilla and mandible.[1-13] While immediate loading procedures nullify the 3- to 6-month period of undisturbed implant healing and eliminate the need for removable prostheses, immediate loading remains a technique-sensitive and demanding task, both surgically and restoratively. Recently, computer-guided implant surgery was conceived to coordinate optimum treatment planning and execution, resulting in accurate and minimally invasive surgical procedures.[14-19] The original protocol entailed the conversion of the complete denture into a functionally loaded fixed complete dentures (FCDs) immediately following computer-guided implant surgery.[13] Recently, others have advocated immediate placement of either a provisional or definitive FCD prefabricated from computer-simulated implant positions.[17-20] Although efforts have been made to minimize potential processing errors, the risk of prosthetic misfit is not negligible.[20,21]

While a small degree of prosthetic misfit on natural dentition can sometimes be mitigated due to the adaptability of the periodontal ligament, such adaptation has not been observed in integrated implants, as they are ankylotic in nature. This is especially true for screw-retained implant prostheses where the misfit cannot be compensated by the cement space present in the cement-retained implant prosthesis. Although prosthetic misfit has not been shown to result in loss of implant osseointegration,[22-27] it is known to introduce undue stress on the implants, screws, prostheses, and surrounding bone, resulting in mechanical complications of the implants and/or implant components, as well as an increase in crestal bone loss.[24] Thus, passive fit of implant prosthesis framework remains a goal for biomechanical success, especially in immediate provisionalization situations where excessive forces must be avoided.[24]

This clinical report demonstrates a situation in which an implant-prosthesis adaptation was noted 10 days following implant placement in the initially misfit, immediately loaded,

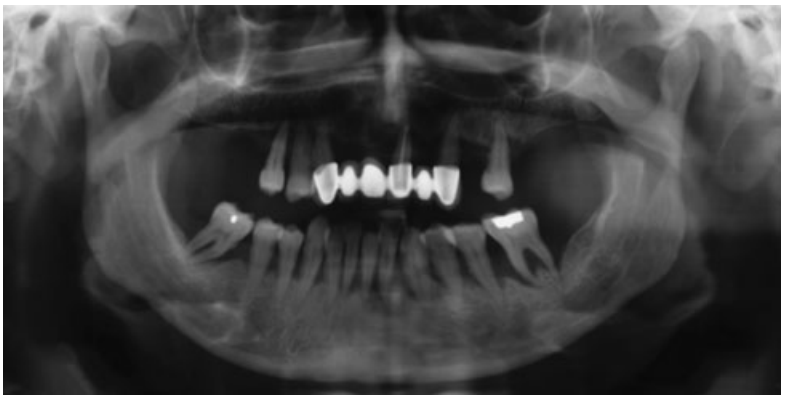

Figure 1 Preoperative panoramic radiograph displayed generalized severe alveolar bone loss.

implant-supported FCDs. The implants were placed using computer-guided protocol.

Clinical report

A 45-year-old female patient presented with severely periodontally compromised maxillary and mandibular dentition, which were deemed hopeless (class III complete edentulism according to the Prosthodontic Diagnostic Index[28]) (Fig 1). While several treatment options were presented, the patient wished to pursue a treatment plan that included implant-supported maxillary and mandibular FCDs following extraction of the remaining dentition. To provide the patient with esthetic and functional convenience, a treatment plan involving computer-guided implant surgery and immediate loading with interim FCDs was proposed and accepted.

After a healing period of 4 months following extractions of the remaining dentition and placement of interim complete dental prostheses, definitive maxillary and mandibular complete dentures were fabricated with the appropriate function, occlusal vertical dimension, and esthetics to serve as a template for the computer-guided implant surgery. After radiopaque markers (Hygenic Temporary Dental Stopping, Coltene/Whaledent Inc., Cuyahoga Falls, OH) were incorporated into the dentures, the patient received a cone beam computed tomography (Newtom 3G, QR SRL, Verona, Italy) using the "double scan" technique. The first scan was made with the patient wearing the complete dentures with the radiopaque markers, while the second scan was performed with the dentures alone in the same orientation as with the first scan.

The Digital Imaging and Communications in Medicine (DICOM) data of the two sets of scans were transferred to the 3D Procera Software Planning program (Nobel Biocare, Yorba Linda, CA) and superimposed to evaluate the osseous architecture in relation to the denture for the planning of the number, length, position, and angulation of the implants. Six implants (NobelSpeedy™ Replace, Nobel Biocare) were planned for each arch.

The data were sent to the milling center for the fabrication of the stereolithographic surgical template (Nobel Biocare). To fabricate the maxillary and mandibular working cast, the implant replicas (Nobel Biocare) were mounted in each of the metal sleeves in the surgical template using guided cylinders with unigrip pins (Guided Cylinder with Pin Unigrip™ NobRpl RP, Nobel Biocare). The anchor pins were then inserted into the anchor pin sleeves and secured with utility wax. A silicone-based material (GI Mask, Coltene/Whaledent Inc.) was applied to the intaglio surface of the surgical template and trimmed to expose the replicas and anchor pins. The working casts were then made with dental die stone plaster (Modern Materials Die-Keen Green, Heraeus Kulzer, Inc., South Bend, IN) and mounted on an articulator for the fabrication of full-arch, screw-retained fixed interim prostheses.

At the surgical appointment, after local anesthetic administration, proper seating of the surgical templates was ascertained. Osteotomies were then made through the guided anchor pin sleeves on the surgical template using the guided twist drill (Guided Twist Drill, 1.5 mm × 20 mm, Nobel Biocare). Guided anchor pins (Nobel Biocare) were then inserted to secure the template for the surgical procedure. Sequential osteotomies were made according to the surgical templates, and six implants (NobelSpeedy™ Replace) were placed with a minimum of 35 Ncm insertion torque in each of the patient's edentulous arches (Table 1). The implant platforms were placed at the crest, as designed with preoperative computer simulation, and verified by assuring full contact between the implant drivers and the mating surface of the guide sleeves.

Table 1 Surgical data of the computer-guided surgery

Implant position	Bone quality (I to IV)	Implant diameter (mm)	Implant length (mm)	Last drill diameter (mm)	Insertion torque (Ncm)
4	III	4.0	11.5	3.2	>35
6	II	4.0	13	3.2	>35
7	II	4.0	13	3.2	>35
10	II	4.0	13	3.2	>35
11	II	4.0	13	3.2	>35
13	II	4.0	11.5	3.2	>35
20	II	4.0	10	3.2	>35
22	I	4.0	13	3.2	>35
23	I	4.0	13	3.2	>35
26	I	4.0	13	3.2	>35
27	I	4.0	13	3.2	>35
29	II	4.0	10	3.2	>35

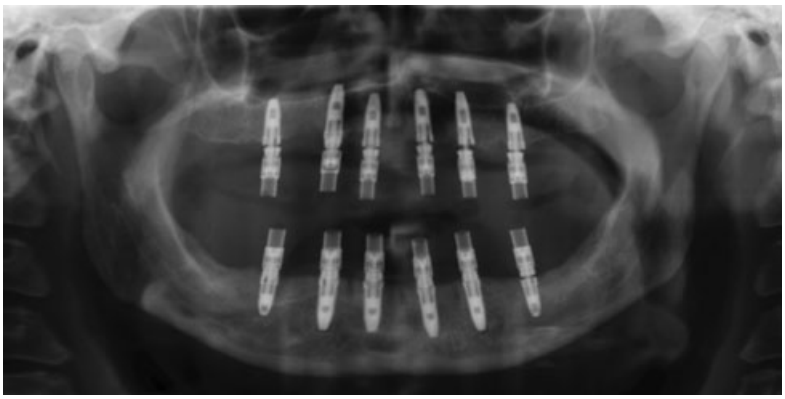

Figure 2 Panoramic radiograph immediately after the placement of maxillary and mandibular provisional fixed complete prostheses. Note the apparent prosthesis misfit at the majority of the implant/abutment interfaces.

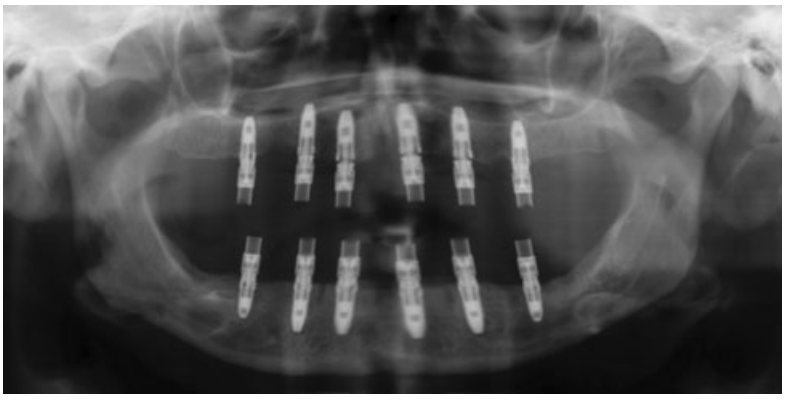

Figure 3 After multiple adjustments, although a significant improvement was observed, passive fit was never achieved.

The prefabricated maxillary and mandibular interim prostheses were hand-tightened onto the implants with self-adjustable abutments designed to compensate for up to 0.4 mm of vertical discrepancies (Guided Abutment NobRpl RP, Nobel Biocare). Despite numerous time-consuming attempts to passively seat the prostheses by alternately hand tightening and loosening the prosthetic screws in different order and sequence, radiographic passive fit was not achieved (Figs 2 and 3). Since only minor adjustments were required to achieve a stable centric and eccentric occlusion without interferences, the patient was dismissed with the misfit interim prostheses to have them either sectioned and reconnected or refabricated for passive fit at a subsequent appointment. All prosthetic screws were hand-tightened, and the screw access holes were sealed with poly(vinyl siloxane) material (Exafast^{TM} NDS Heavy body, GC America Inc., Alsip, IL). Appropriate antibiotics and analgesics were prescribed postoperatively. The patient was instructed not to brush the surgical site, but rinse gently with 0.12% chlorhexidine gluconate (Peridex, Procter & Gamble, Cincinnati, OH), and to be on a liquid diet for 2 weeks. A soft diet was recommended for the remaining duration of the implant healing phase (4 months).

Four days after surgery, the patient complained of severe pressure to the maxilla and mandibular implants. Loosening each of the prosthetic screws by a quarter of a turn instantly relieved the pressure. Nevertheless, periapical radiographs and orthopantomogram (Sirona Dental Systems LLC, Charlotte, NC) still showed incomplete seating of the interim prostheses. Ten days after the surgery, the patient returned with loose mandibular and maxillary prostheses due to the prosthetic screw loosening. All screws were retightened by hand and surprisingly, complete radiographic passive abutment seating was noted (Fig 4).

Six months following implant surgery, despite stability observed in all implants, mean 2.1 mm marginal bone loss (range: 1.4 to 3.5 mm) was noted with sequential standardized periapical radiographs (Fig 5). When assessing marginal bone loss, the implant platform was used as the reference line. Marginal bone loss at the follow-up appointment was defined as the distance from the implant platform to the implant/bone contact point apical to the platform. When the implant/bone contact point was at or coronal to the implant platform, it was considered as 'no change.' The definitive impressions were made using poly(vinyl siloxane) material (Aquasil, Dentsply Caulk, Milford, DE). The screw-retained definitive metal ceramic profile maxillary and mandibular FCDs were seated and torqued to 35 Ncm. Periapical radiographs and orthopantomogram (iCAT) were used to verify the fit of the prostheses (Fig 6).

Discussion

It has been postulated that progressive chronic marginal infection (peri-implantitis) and excessive loading are factors contributing to osseointegrated implant failures.[29] A gap at the implant/abutment interface resulting from implant framework misfit could harbor a large quantity of microorganisms as well

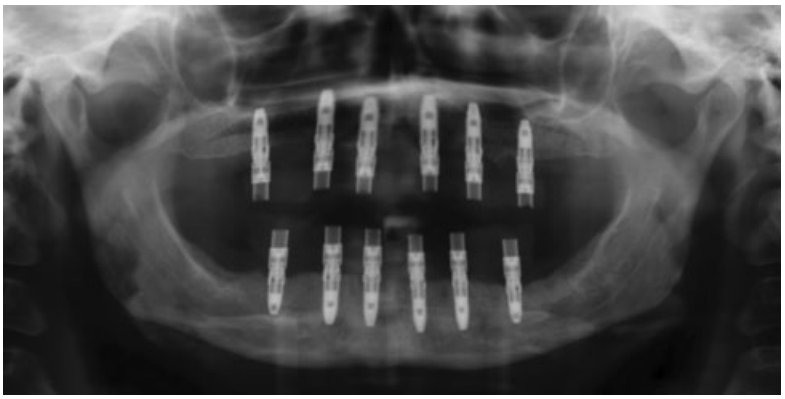

Figure 4 Ten days after the surgery, framework fit was achieved with hand tightening after the patient complained of loose maxillary and mandibular prostheses.

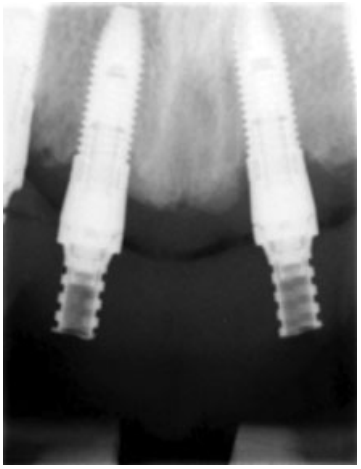

Figure 5 Periapical radiograph 6 months after the surgery showed significant peri-implant marginal bone loss.

as induce an excessive static force when an attempt is made to secure the framework to the implants.[30] Therefore, implant framework misfit could be a contributing factor to peri-implant bone loss and/or implant failure; however, findings from current literature have been controversial.[25,29,31]

Implant stability decreases during the first 4 weeks following implant placement before rebounding, as measured by resonance frequency analysis.[32,33] This may result in a short time period during which implants are more likely to move slightly under load. It has also been shown that deformations of the implant framework and the surrounding bone can occur when tightening a vertically misfit implant framework.[30,34] Jemt and Lekholm reported a mean framework displacement of 177 μm (range: 100–300 μm) and a mean implant displacement of 123 μm (range: 60–200 μm) when an implant framework with approximately 1 mm vertical misfit was tightened to implants that had been osseointegrated under a mean preload of 246 N (mean torque: 25.9 Ncm).[30] This corresponded to a mean 300 μm (30%) total gap closure; however, immediately loaded implants may be able to further close a prosthetic misfit gap, as compared to integrated implants. When comparing gap closure under a 35 Ncm torque in ~500 μm vertically misfit frameworks on the statically immediately loaded and healed implants, Duyck et al observed a mean gap closure of 71% and 39%, respectively.[34] They attributed this phenomenon principally to the implant movement caused by bone deformation, owing to strain and microfracture.[34] Interestingly, all immediately loaded implants were in contact with the prostheses at some point, but the gaps were not closed completely due to additional horizontal discrepancies between implant and prosthesis cylinder inclination.[34]

In this report, the provisional framework misfits noted immediately after implant placement seemed to be completely closed after being repeatedly hand-tightened over a 2-week period. This suggests that in addition to the apparent adaptation of vertical discrepancies, hand-tightening force may also

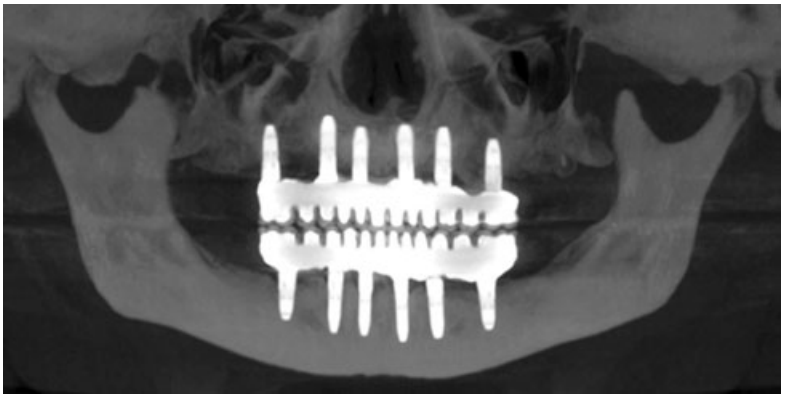

Figure 6 CBCT image of the final prosthesis 3 years after the surgery. Despite initial peri-implant marginal bone loss, the bone levels had been well maintained since 6 months after the surgery.

allow for adaptation of horizontal and angular discrepancies, if minimal enough. Furthermore, it is possible that the initial framework displacement by hand-tightening would be greater with an acrylic than a metal framework due to the former's lower modulus of elasticity; however, the resulting implant adaptation to the strain of a misfit acrylic prosthesis compared to one with a metal framework is unknown.

Both aforementioned studies[30,34] also concluded that static forces induced by prosthesis misfit did not lead to biologic failure of the already osseointegrated or statically immediately loaded implants. While an ~700 μm mean crestal bone loss was observed in the latter study, this is not beyond the expected observed peri-implant marginal bone loss values.[35] However, a study that investigated the influence of static and dynamic implant loading has shown that less bone density and crater-like bone defects lateral to osseointegrated implants were observed with excessive dynamic loads.[36] Granted, these studies were conducted in the rabbit tibia and not in the human oral cavity where other factors such as intraoral microflora and oral hygiene might have affected the outcome. In the patient situation presented, a significant mean marginal bone loss of 2.1 mm (range: 1.4 to 3.5 mm) was observed 6 months after the implant surgery and interim prostheses placement (Fig 5). Since this value is considerably higher than mean bone loss reported in immediately loaded implants supporting FCDs, with (0.6 to 0.9 mm)[37,38] or without (1.2 to 1.6 mm)[39,40] flap reflection, a combination of framework misfit (static load) and immediately loaded implants (dynamic load) might contribute to the substantially excessive loads that lead to such significant bone loss; however, at 3 years, all implants remained osseointegrated, and minimal further marginal bone level change was observed, suggesting that unfavorable conditions had been reversed, and equilibrium had been reached (Fig 6).

Conclusions

Prosthetic misfit can occur during computer-guided implant placement and the immediate provisionalization procedure, especially when multiple implants are involved. In this report, biologic adaptation of immediately loaded implants under static force seems to be responsible for the misfit correction; however, a combination of framework misfit (static load) and immediately loaded implants (dynamic load) might contribute to the substantially excessive loads that lead to significant bone loss. Therefore, it is recommended that framework misfit be avoided or corrected in immediate loading situations. Nevertheless, it should be noted that this is an individual clinical report, and the outcome should not be generalized. Further studies related to prosthetic misfit and biological adaptation are needed to substantiate or refute the finding of this clinical report.

References

1. Schnitman PA, Wohrle PS, Rubenstein JE, et al: Ten-year results for Branemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac Implants 1997;12:495-503
2. Balshi TJ, Wolfinger GJ: Immediate loading of Branemark implants in edentulous mandibles: a preliminary report. Implant Dent 1997;6:83-88
3. Tarnow DP, Emtiaz S, Classi A: Immediate loading of threaded implants at stage 1 surgery in edentulous arches: ten consecutive case reports with 1- to 5-year data. Int J Oral Maxillofac Implants 1997;12:319-324
4. Salama H, Rose LF, Salama M, et al: Immediate loading of bilaterally splinted titanium root-form implants in fixed prosthodontics—a technique reexamined: two case reports. Int J Periodontics Restorative Dent 1995;15:344-361
5. Jaffin RA, Kumar A, Berman CL: Immediate loading of implants in partially and fully edentulous jaws: a series of 27 case reports. J Periodontol 2000;71:833-838
6. Chatzistavrou M, Felton DA, Cooper LF: Immediate loading of dental implants in partially edentulous patients: a clinical report. J Prosthodont 2003;12:26-29
7. Chiapasco M, Gatti C, Rossi E, et al: Implant-retained mandibular overdentures with immediate loading. A retrospective multicenter study on 226 consecutive cases. Clin Oral Implants Res 1997;8:48-57
8. Gatti C, Haefliger W, Chiapasco M: Implant-retained mandibular overdentures with immediate loading: a prospective study of ITI implants. Int J Oral Maxillofac Implants 2000;15:383-388
9. Rungcharassaeng K, Lozada JL, Kan JY, et al: Peri-implant tissue response of immediately loaded, threaded, HA-coated implants: 1-year results. J Prosthet Dent 2002;87:173-181
10. Ericsson I, Nilson H, Lindh T, et al: Immediate functional loading of Branemark single tooth implants. An 18 months' clinical pilot follow-up study. Clin Oral Implants Res 2000;11:26-33
11. Balshi SF, Wolfinger GJ, Balshi TJ: A prospective study of immediate functional loading, following the Teeth in a Day protocol: a case series of 55 consecutive edentulous maxillas. Clin Implant Dent Relat Res 2005;7:24-31
12. Wolfinger GJ, Balshi TJ, Rangert B: Immediate functional loading of Branemark system implants in edentulous mandibles: clinical report of the results of developmental and simplified protocols. Int J Oral Maxillofac Implants 2003;18:250-257
13. Balshi TJ, Wolfinger GJ: Immediate loading of dental implants in the edentulous maxilla: case study of a unique protocol. Int J Periodontics Restorative Dent 2003;23:37-45
14. Tardieu PB, Vrielinck L, Escolano E: Computer-assisted implant placement. A case report: treatment of the mandible. Int J Oral Maxillofac Implants 2003;18:599-604
15. van Steenberghe D, Glauser R, Blomback U, et al: A computed tomographic scan-derived customized surgical template and fixed prosthesis for flapless surgery and immediate loading of implants in fully edentulous maxillae: a prospective multicenter study. Clin Implant Dent Relat Res 2005;7(Suppl 1):S111-S120
16. van Steenberghe D, Naert I, Andersson M, et al: A custom template and definitive prosthesis allowing immediate implant loading in the maxilla: a clinical report. Int J Oral Maxillofac Implants 2002;17:663-670
17. Marchack CB, Moy PK: The use of a custom template for immediate loading with the definitive prosthesis: a clinical report. J Calif Dent Assoc 2003;31:925-929
18. Marchack CB: An immediately loaded CAD/CAM-guided definitive prosthesis: a clinical report. J Prosthet Dent 2005;93:8-12
19. Kan JY, Rungcharassaeng K, Oyama K, et al: Computer guided immediate provisionalization of anterior multiple adjacent implants: surgical and prosthodontic rationale. Pract Proced Aesthet Dent 2006;18:A-G
20. Oyama K, Kan JYK, Kleinman AS, et al: Misfit of implant fixed complete denture following computer-guided surgery. Int J Oral Maxillofac Implants 2009;24:124-130
21. Yong LT, Moy PK: Complications of computer-aided-design/computer-aided-machining-guided (NobelGuide) surgical

implant placement: an evaluation of early clinical results. Clin Implant Dent Relat Res 2008;10:123-127
22. Branemark PI: Osseointegration and its experimental background. J Prosthet Dent 1983;50:399-410
23. Carr AB, Stewart RB: Full-arch implant framework casting accuracy: preliminary in vitro observation for in vivo testing. J Prosthodont 1993;2:2-8
24. Kan JY, Rungcharassaeng K, Bohsali K, et al: Clinical methods for evaluating implant framework fit. J Prosthet Dent 1999;81:7-13
25. Jemt T, Book K: Prosthesis misfit and marginal bone loss in edentulous implant patients. Int J Oral Maxillofac Implants 1996;11:620-625
26. Jemt T, Lekholm U, Johansson CB: Bone response to implant-supported frameworks with differing degrees of misfit preload: in vivo study in rabbits. Clin Implant Dent Relat Res 2000;2:129-137
27. Michaels GC, Carr AB, Larsen PE: Effect of prosthetic superstructure accuracy on the osteointegrated implant bone interface. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:198-205
28. McGarry TJ, Nimmo A, Skiba JF, et al: Classification system for complete edentulism. J Prosthodont 1999;8:27-39
29. Esposito M, Hirsch JM, Lekholm U, et al: Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. Eur J Oral Sci 1998;106:721-764
30. Jemt T, Lekholm U: Measurements of bone and framework deformations induced by misfit of implant superstructures: a pilot study in rabbits. Clin Oral Implants Res 1998;9: 272-280
31. Carr AB, Gerard DA, Larsen PE: The response of bone in primates around unloaded dental implants supporting prostheses with different levels of fit. J Prosthet Dent 1996;76: 500-509
32. Huwiler MA, Pjetursson BE, Bosshardt DD, et al: Resonance frequency analysis in relation to jawbone characteristics and during early healing of implant installation. Clin Oral Implants Res 2007;18:275-280
33. Balshi SF, Allen FD, Wolfinger GJ, et al: A resonance frequency analysis assessment of maxillary and mandibular immediately loaded implants. Int J Oral Maxillofac Implants 2005;20:584-594
34. Duyck J, Vrielinck L, Lambrichts I, et al: Biologic response of immediately versus delayed loaded implants supporting ill-fitting prostheses: an animal study. Clin Implant Dent Relat Res 2005;7:150-158
35. Goodacre CJ, Kan JY, Rungcharassaeng K: Clinical complications of osseointegrated implants. J Prosthet Dent 1999;81:537-552
36. Duyck J, Ronald HJ, van Oosterwyck H, et al: The influence of static and dynamic loading on marginal bone reactions around osseointegrated implants: an animal experimental study. Clin Oral Implants Res 2001;12:207-218
37. Testori T, Del Fabbro M, Szmukler-Moncler S, et al: Immediate occlusal loading of Osseotite implants in the completely edentulous mandible. Int J Oral Maxillofac Implants 2003;18:544-551
38. Collaert B, De Bruyn H: Immediate functional loading of TiOblast dental implants in full-arch edentulous maxillae: a 3-year prospective study. Clin Oral Implants Res 2008;19:1254-1260
39. Sanna AM, Molly L, van Steenberghe D: Immediately loaded CAD-CAM manufactured fixed complete dentures using flapless implant placement procedures: a cohort study of consecutive patients. J Prosthet Dent 2007;97:331-339
40. Berdougo M, Fortin T, Blanchet E, et al: Flapless implant surgery using an image-guided system. A 1- to 4-year retrospective multicenter comparative clinical study. Clin Implant Dent Relat Res 2010;12:142-152