# One-Year Outcome of Implants Strategically Placed in the Retrocanine Bone Triangle

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## ABSTRACT

*Background:* Implant treatment in the partially edentulous maxilla is often challenging because of minimum bone volumes in distal direction.

*Purpose:* The aim of this study was to evaluate, after 1 year of loading, the outcome of three-unit fixed partial dentures supported by two implants in the retrocanine triangle.

*Materials and Methods:* Twenty patients with atrophic posterior maxillae participated in the study. A total of 40 implants were placed in residual bone anterior to the sinus wall and posterior to the canine. Implant angulations and lengths were chosen to match as much as possible boundaries of the available bone. After a 6-month healing period, three-unit, screw-retained, fixed partial dentures were delivered. The patients were clinically and radiographically reexamined after 1 year of loading.

*Results:* All the implants survived at the end of the follow-up. No differences in bone level changes resulted between axial and tilted implants. No biological or mechanical complications were recorded.

*Conclusions:* Within the limitations of this short-term study on relatively few patients, a positive outcome was seen for three-unit fixed partial dentures supported by two implants. Retrocanine placement of implants with carefully planned lengths and angulations might be an alternative to grafting procedures for restoration of atrophic posterior maxillae.

KEY WORDS: Atrophic posterior maxillas, minimal intervention, short implants, tilted implants

Implant treatment in posterior edentulous maxillae is often complicated by lack of minimum bone volumes in distal direction and presence of soft bone.[1] These conditions have been historically regarded as risk factors for increased implant failure rates.[2] Bone grafting techniques might be used to recreate volumes that allow for ideal implant placement.[1,2] These procedures involve an increased morbidity while, according to a recent literature review,[3] survival rates are more variable for implants placed in grafted sinuses as compared to those placed in pristine bone. Placement of short implants in residual bone volumes has been described in the most recent literature as a valuable alternative to sinus grafting.[1,4–8] Obviously, short implants might not solve cases where the available bone height is still insufficient for any implant placement. A second option to avoid grafting is the use of cantilevers. While correctly designed cantilevers have been shown not to jeopardize implant survival,[9,10] they nonetheless increase stresses at the implant site.[11,12] As a further alternative to sinus grafting, some publications described positive outcome for tilted implants.[13–18] This surgical technique takes full advantage of the residual bone located anterior to the sinus border, and it is useful to extend implant support distally and reduce cantilever length. Two publications dealt specifically with the partially edentulous posterior maxilla. Aparicio and colleagues[13] used a combination of three or more axial and tilted implants to support fixed partial dentures in atrophic posterior maxillae otherwise necessitating of bone grafting procedures. Success rates of tilted implants were comparable to those of axial implants. More recently, Calandriello and Tomatis[14]

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reported 1-year positive results for 12 immediately loaded three-unit fixed bridges supported by two implants, an axial and a tilted one, in atrophic posterior maxillae. Most often, a discrete bone volume residues posterior to the canine and anterior to the sinus wall; this volume can be referred to as the retrocanine triangle. It has been suggested that two implants can be placed in this area if no less than 14 mm is present between the canine root and the segment of alveolar crest with a residual height of 7 mm.[19] In many cases, when it is possible to carefully tilt the two implants, implant support is provided up to the first molar area. In a recent finite element analysis for two splinted implants, it appeared that tilting of the posterior implant does not increase stresses of the peri-implant bone as compared to the axial anterior implant.[12] It was also shown that tilted distal implants are biomechanically more advantageous than distal cantilever units. With regard to the reduced implant number, although three implants are biomechanically advantageous,[11] some clinical studies seem to suggest that two implants could be sufficient to support three-unit fixed partial dentures.[20,21] Therefore, in severely resorbed partially edentulous posterior maxillae, two opportunely tilted implants of various lengths could be the least invasive alternative for substitution of two premolars and the first molar with a prosthesis bearing little or no cantilever at all.

The aim of the present study was to describe and evaluate, after the first year of loading, the outcome of implants strategically placed in the retrocanine triangle and supporting three-unit fixed partial dentures.

## MATERIALS AND METHODS

Twenty patients (14 women and 6 men) with edentulous posterior maxillae seeking fixed restorations were included in the study. Their mean age was 51 years (range 38–63). The criterion for inclusion was missing first and second premolars, and first molar. An additional criterion was the lack of bone available for placement of short implants under the sinus floor, but presence of a residual retrocanine triangle of bone. This residual bone volume had to allow placement of two implants behind the canine and anterior to the mesial wall of the sinus. No limitation to the minimum implant length was established. Treatment planning was made on panoramic and intraoral x-rays. All the patients had to be free from any sign of unhealed bone pathology.

**TABLE 1 Implant Length Distribution**

| | Anterior | Posterior |
|---|---|---|
| 8 | 4 | 3 |
| 9 | — | 3 |
| 11 | 5 | 9 |
| 13 | 8 | 4 |
| 15 | 2 | 1 |
| 17 | 1 | — |

All the implants were 4 mm in diameter except for a 4.5 × 15 mm anteriorly placed implant.

The exclusion criteria were as follows: a compromised medical status contraindicating any surgical intervention and smoking more than 10 cigarettes a day.

### Surgical Treatment

All the patients were treated between May 2004 and March 2007 by an experienced surgeon. Forty implants were placed, two for each patient. Fourteen implants were Astra Tech Microthread® (Astra Tech, Mölndal, Sweden), while the remaining 26 were Astra Tech Osseospeed® (Astra Tech). Distribution of implant dimensions is shown in Table 1. Implants with length of 8 and 9 mm were considered short. All the implants were placed according to a two-stage procedure. A full-thickness mucoperiostal flap was elevated. The anterior border of the maxillary sinus and the outline of the canine root were identified. The distal site was prepared parallel to the anterior sinus wall, and therefore, the implant was tilted mesiodistally. The anterior implant was placed in an axial direction or with slight distomesial inclination. Site preparation was adapted aiming at the best primary stability possible. Flaps were then sutured, and the patients were given a prescription of analgesics. Two weeks later, the patients were reviewed and sutures were removed.

### Prosthetic Procedures

After 6 months of healing, all the patients had the second surgery performed and healing abutments were connected. All the patients were rehabilitated with three-unit, screw-retained, fixed partial dentures with acrylic veneers (Figure 1). Six patients received conventional bridges connected to either Angled Abutments or UniAbutments (Astra Tech). The remaining patients received bridges fabricated with the Cresco™ method

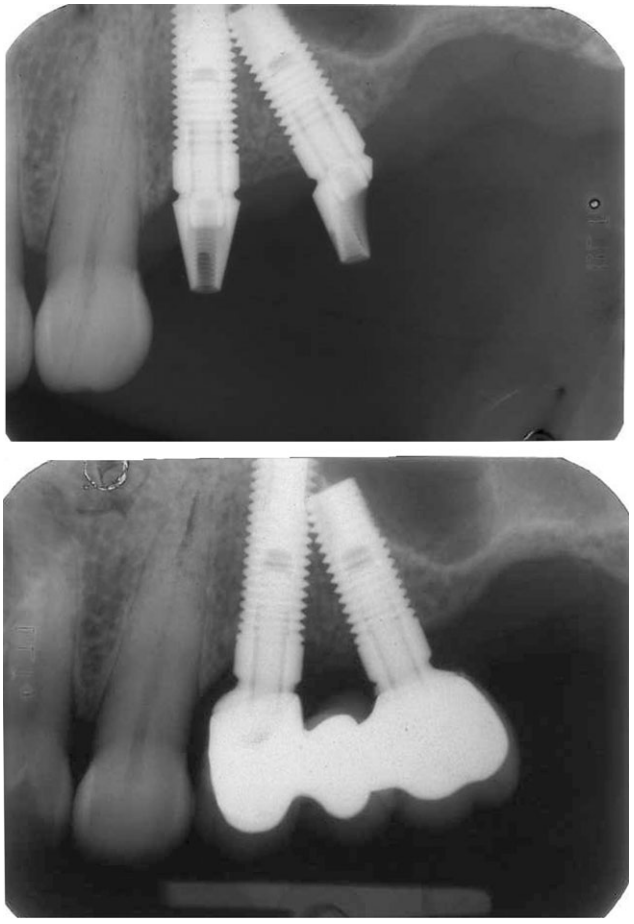

**Figure 1** X-rays at abutment connection and at 1 year of loading. Angled abutments were used for this patient.

(Astra Tech). In six cases, a small cantilever was required to completely restore the occlusal table (Figure 2). Seventeen of the patients had their own teeth or fixed partial dentures in the mandibular arch; the remaining patients had removable partial dentures.

## Follow-Up

Patient recall was planned after 1 year of loading, although they were advised to refer as soon as possible any disturbance associated with the restoration. At follow-up visit, the following clinical variables were recorded: absence of pain, discomfort, or infection associated with the implants. A surviving implant was defined as an implant that was stable, in function, and symptom free. The prostheses were not removed at the follow-up visit to check individual implant stability.

## Radiographic Examination

Using a paralleling technique, intraoral radiographs were taken at abutment connection or framework try-in (baseline), and then 1 year later. Radiographs were digitized to 600 dpi and analyzed using ImageJ, a freeware software (National Institutes of Health, Bethesda, MD, USA; http://rsb.info.nih.gov/ij/). The mean bone volume of patient's retrocanine triangles was measured according to a previously published scheme[19] (Figure 3). *X* is the point where the residual alveolar crest has a 7 mm of height, *A* is the distance between the canine root and *X*, *Y* is the crest height at the point of most posterior implant support, and *B* is the distance between the canine root and *Y*. In addition, the mesiodistal inclination in relation to a vertical axis perpendicular to the occlusal plane was calculated for each implant. Crestal bone levels were measured as the vertical distance of a fixture reference point from the bone level. Such a reference point was the most coronal point of the vertical part of the fixture.[22] Measurements were made at the distal and mesial sides of each implant, and a mean value

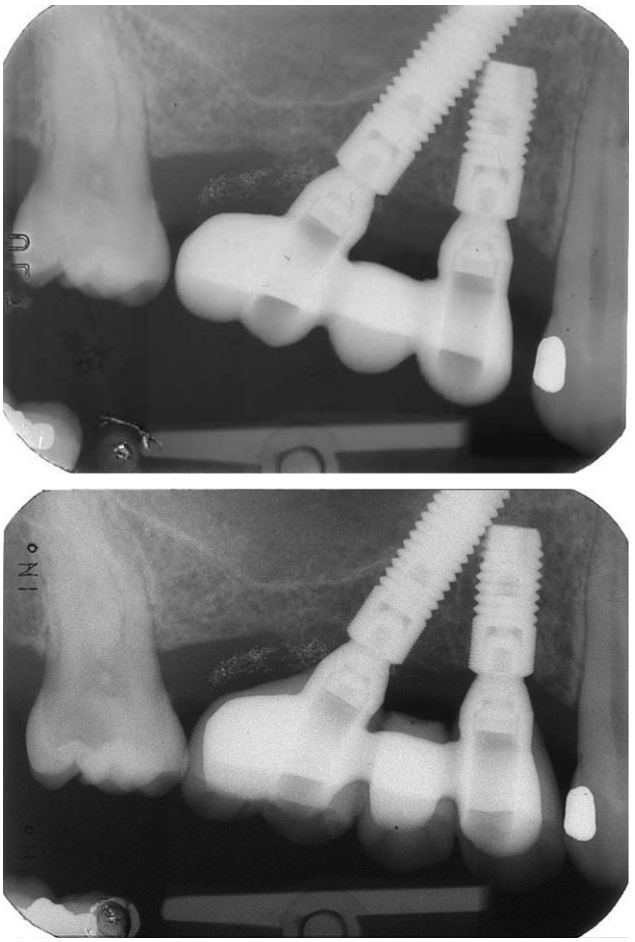

**Figure 2** X-rays at try-in of the Cresco framework and after 1 year of loading. A cantilever was used to create the contact point with the second molar.

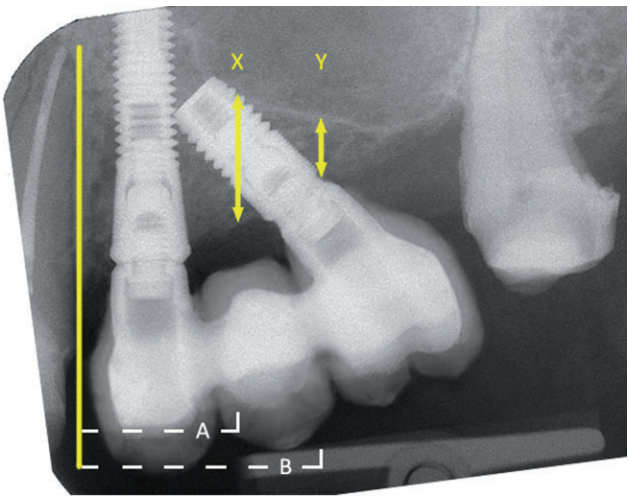


**Figure 3** Suggested minimum bone dimension for two implants posterior to the canine: X = 7 mm, A = 14 mm.[19] The patients included in the study had mean A = 11.2 mm (SD 1.4; range 9.18–13.2 mm); mean Y = 4 mm (SD 0.7; range 3.3–5.4); mean B = 14.1 mm (SD 0.8; range 13.2–15.4).

per implant was then calculated. Bone loss during the study period was obtained by subtracting, for each implant, the bone level registered at the baseline from the level registered a year later. In addition, x-rays were used to measure the cantilever length where present.

### Statistical Analysis

Having checked that the data distribution was normal (Kolmogorov-Smirnov test, $p > .05$) and group variances were homogeneous (Levene test, $p > .05$), a *t*-test was applied to evaluate if bone level changes after 1 year of loading varied among the axial and tilted implants. In addition, the same analysis was used to evaluate bone level changes at prostheses with and without cantilevers. This latter evaluation was repeated at prosthesis and at implant level. Statistical significance was set at $\alpha = .05$.

## RESULTS

All the patients received the planned restoration and they all attended the planned annual recall. The survival rate was 100%, and all the prostheses were found stable, in function, and symptom free. The mean dimension of retrocanine triangles is illustrated in Figure 3. Data regarding implant inclination are shown in Table 2. No differences in bone level changes resulted between axial and tilted implants (Table 3). The mean cantilever length was 3.9 mm (range 3.6–4.4 mm). No differences in bone levels were found at implants and prostheses regardless of the presence of cantilevers (see Table 3). No biological or mechanical complications were recorded.

**TABLE 2 Distribution and Degrees of Angulations for the Investigated Implants**

| | <30° | >30° | Mean Inclination | Range |
|---|---|---|---|---|
| Anterior | 20 | 0 | 7.8° | 0–18.6° |
| Posterior | 12 | 8 | 23.4° | 8.4–38.3° |

## DISCUSSION

Posterior edentulous maxillae are often very atrophic because of possible periodontal or endodontic infections, or because of sinus pneumatization. Frequently, bone grafting is advocated, although this procedure seems to affect in some measure implant survival rates.[3] However, a useful residual bone volume often remains posterior to the canine and anterior to the sinus wall. The present investigation dealt with optimized implant placement in this residual volume. The patients included in this study had two opportunely tilted implants placed in their residual retrocanine bone to support a three-unit fixed partial denture. The treatment outcome after 1 year of loading was very satisfactory with a 100% survival rate.

The minimum bone dimension suggested for placement of two implants to rehabilitate the posterior maxilla is 14 mm between the canine and a residual alveolar crest height of 7 mm.[19] With a mean bone dimension of 11 mm, the majority of the patients of the present study did not satisfy the above-mentioned criterion and therefore were in need of grafting procedures. Nevertheless, they were all treated with fixed partial dentures supported by implants in residual bone volumes. Four concepts have been combined to

**TABLE 3 Data on Bone Level Changes According to Implant Position and Presence of Cantilevers**

| | Mean Bone Change |
|---|---|
| Anterior implants | –.4 |
| Posterior implants | –.35 |
| Implants not adjacent to cantilever | –.38 |
| Implants adjacent to cantilever | –.32 |
| Prostheses without cantilever | –.37 |
| Prostheses with cantilever | –.33 |

No significant difference resulted.

optimize treatment of such little bone volumes: implant tilting, short implants (8 and 9 mm long), reduced implant number, and a decreased number of dental units. Implant tilting is a technique supported by a number of publications.[13–18] Described advantages are: placement of longer implants, reduced cantilever length, and increased posterior implant support with avoidance of anatomical structures. Two studies dealt specifically with tilting in the case of posterior maxillae; however, included patients had bone volumes that were slightly greater than in the present study. In fact, Aparicio and colleagues[13] placed approximately a mean of three implants per patient to withstand four to five units fixed partial dentures, while Calandriello and Tomatis,[14] although inserting two implants, excluded situations where it was not possible to use at least 10-mm-long implants. In the present study, two implants were placed to support three-unit fixed partial dentures, and no minimum implant length was established; instead, lengths were selected with the aim to accommodate two implants in the residual bone volume. Similarly, degrees of tilting were decided with the same final aim. As a result, six patients received short posterior implants and four patients received short anterior implants. Short implants traditionally showed success rates somewhat lower[1] than conventional implants; however, better results were described more recently.[4–8] This might be caused by improvements in the surgical techniques aiming at high primary stability also in reduced volumes of soft bone.[6,7] Medium roughness surfaces might also play a role in the increased success rate of short implants.[6,7] Another aspect to be considered is that in the present study, many anteriorly placed implants, previously referred to as the axial implants,[14,16] showed some degree of disto-mesial inclination as well. This inclination allows for complete utilization of the existing bone volume with the two implants matching as much as possible the boundary of the available bone.

Also of interest with regard to this protocol of treatment is the need to reduce the number of implants from three to two. Placement of three implants, possibly not on straight line, has been recommended to reduce bending moments at implants and their possible associated complications.[11] However, there is some evidence that two implants used to support three-unit fixed partial dentures are an effective solution.[20,21,23] Although this evidence is still weak to be generalized in all situations, it might be of special utility when small bone volumes preclude placement of more implants.[24] Accordingly, in the present study, three-unit fixed partial dentures supported by two implants in small bone volumes had a very good outcome, although in the short term only.

With regard to the number of replaced dental units, the lack of the second molar does not jeopardize the restoration of patient's functional demands as stated by Käyser,[25] who estimated that the presence of all teeth up to the first molar satisfies aesthetics, phonetics, biting, mastication, and mandibular stability. Conversely, because of the little bone volume in posterior maxillae, replacement of the second molar would have lead to an overtreatment with increased morbidity and treatment cost.

One last consideration is needed on the presence of cantilevers. Traditionally, it was recommended to avoid their use because of the possibility of increased biomechanical complications because of higher bending moments developed.[11] Conversely, some clinical literature shows that they can be accepted[9,10] and they can be especially helpful in cases of little bone to avoid grafting procedures. In the present study, optimized implant placement in the residual triangle of bone posterior to the canine allowed for replacement of three prosthetic units with almost no need for cantilevers. In six cases, cantilevers were used mainly to create a contact point with the second molar; however, the average cantilever length of approximately 4 mm was very short as compared with previous publications.[9,10] The possibility to reduce or eliminate cantilevers was already reported as a main advantage of implant tilting.[13,14] This is translated in a biomechanical improvement as it has been demonstrated that in the case of partial dentures connected to two implants, tilting is more advantageous than a cantilever unit.[12]

It is obvious that data obtained from these patients need to be confirmed in longer follow-up studies on greater numbers of patients. However, in light of the satisfactory clinical results achieved here, it might be suggested that careful treatment planning considerations have to be spent for patients with atrophic edentulous posterior maxillae and endodontically treated premolar teeth still present. In fact, the morbidity of grafting techniques and the prevalence of vertical root fractures of endodontically treated premolars[26] should be weighted against the good outcome here observed

and achieved with strategic implant placement in the retrocanine triangle. It might be the case that extraction of an endodontically treated premolar and implants in the bone that becomes available might be for some patients the least invasive choice for restoration of posterior maxillae. However, it is still controversial which alternative is the most effective in the above-mentioned clinical scenario, and comparative studies are needed to help orienting clinical decisions.[27]

In conclusion, within the limitations of this short-term study on relatively few patients, three-unit fixed partial dentures supported by two implants in residual bone volumes had a satisfactory outcome. Implants of carefully planned lengths and angulations might be placed in the retrocanine triangle for restoration of atrophic posterior maxillae as an alternative to grafting procedures.

## REFERENCES


1. Friberg B. The posterior maxilla: clinical considerations and current concepts using Brånemark system implants. Periodontol 2000 2008; 47:67–78.
2. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I) Success criteria and epidemiology. Eur J Oral Sci 1998; 106:527–551.
3. Graziani F, Donos N, Needleman I, Gabriele M, Tonetti M. Comparison of implant survival following sinus floor augmentation procedures with implants placed in pristine posterior maxillary bone: a systematic review. Clin Oral Implants Res 2004; 15:677–682.
4. Fugazzotto PA. Shorter implants in clinical practice: rationale and treatment results. Int J Oral Maxillofac Implants 2008; 23:487–496.
5. Maló P, de Araújo Nobre M, Rangert B. Short implants placed one-stage in maxillae and mandibles: a retrospective clinical study with 1 to 9 years of follow-up. Clin Implant Dent Relat Res 2007; 9:15–21.
6. Renouard F, Nisand D. Impact of implant length and diameter on survival rates. Clin Oral Implants Res 2006; 17:35–51.
7. Renouard F, Nisand D. Short implants in the severely resorbed maxilla: a 2-year retrospective clinical study. Clin Implant Dent Relat Res 2005; 7:S104–S110.
8. Romeo E, Ghisolfi M, Rozza R, Chiapasco M, Lops D. Short (8-mm) dental implants in the rehabilitation of partial and complete edentulism: a 3- to 14-year longitudinal study. Int J Prosthodont 2006; 19:586–592.
9. Wennström J, Zurdo J, Karlsson S, Ekestubbe A, Gröndahl K, Lindhe J. Bone level change at implant-supported fixed partial dentures with and without cantilever extension after 5 years in function. J Clin Periodontol 2004; 31:1077–1083.
10. Romeo E, Lops D, Margutti E, Ghisolfi M, Chiapasco M, Vogel G. Implant-supported fixed cantilever prostheses in partially edentulous arches. A seven-year prospective study. Clin Oral Implants Res 2003; 14:303–311.
11. Rangert B, Sullivan RM, Jemt T. Load factor control for implants in the posterior partially edentulous segment. Int J Oral Maxillofac Implants 1997; 12:360–370.
12. Zampelis A, Rangert B, Heijl L. Tilting of splinted implants for improved prosthodontic support: a two-dimensional finite element analysis. J Prosthet Dent 2007; 97:S35–43.
13. Aparicio C, Perales P, Rangert B. Tilted implants as an alternative to maxillary sinus grafting: a clinical, radiologic, and periotest study. Clin Implant Dent Relat Res 2001; 3:39–49.
14. Calandriello R, Tomatis M. Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: a prospective 1-year clinical study. Clin Implant Dent Relat Res 2005; 7:S1–S12.
15. Krekmanov L, Kahn M, Rangert B, Lindström H. Tilting of posterior mandibular and maxillary implants for improved prosthesis support. Int J Oral Maxillofac Implants 2000; 15:405–414.
16. Koutouzis T, Wennström JL. Bone level changes at axial- and non-axial-positioned implants supporting fixed partial dentures. A 5-year retrospective longitudinal study. Clin Oral Implants Res 2007; 18:585–590.
17. Malo P, Rangert B, Nobre M. All-on-4 immediate-function concept with Brånemark system implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res 2005; 7:S88–S94.
18. Fortin Y, Sullivan RM, Rangert BR. The Marius implant bridge: surgical and prosthetic rehabilitation for the completely edentulous upper jaw with moderate to severe resorption: a 5-year retrospective clinical study. Clin Implant Dent Relat Res 2002; 4:69–77.
19. Lekholm U. The surgical site. In: Lindhe J, Karring T, Lang NP, eds. Clinical periodontology and implant dentistry. 4th ed. Copenhagen, Denmark: Blackwell Munksgaard, 2003:856.
20. Buser D, von Arx T. Surgical procedures in partially edentulous patients with ITI implants. Clin Oral Implants Res 2000; 11:S83–S100.
21. Eliasson A, Eriksson T, Johansson A, Wennerberg A. Fixed partial prostheses supported by 2 or 3 implants: a retrospective study up to 18 years. Int J Oral Maxillofac Implants 2006; 21:567–574.
22. Åstrand P, Engquist B, Dahlgren S, Grondahl K, Engquist E, Feldmann H. Astra Tech and Brånemark system implants: a 5-year prospective study of marginal bone reactions. Clin Oral Implants Res 2004; 15:413–420.

23. Iplikçioğlu H, Akça K. Comparative evaluation of the effect of diameter, length and number of implants supporting three-unit fixed partial prostheses on stress distribution in the bone. J Dent 2002; 30:41–46.
24. Palmer R. Two-implant supported fixed partial prostheses provide a viable treatment alternative to 3-implant designs. J Evid Based Dent Pract 2007; 7:114–115.
25. Käyser AF. Teeth, tooth loss and prosthetic appliances. In: Öwall B, Käyser AF, Carlsson GE, eds. Prosthodontics. Principles and management strategies. London, England: Mosby-Wolfe, 1996:35–48.
26. Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. Int Endod J 1999; 32:283–286.
27. Torabinejad M, Anderson P, Bader J, et al. Outcomes of root canal treatment and restoration, implant-supported single crowns, fixed partial dentures, and extraction without replacement: a systematic review. J Prosthet Dent 2007; 98:285–311.