# Stability of implants as anchorage for orthopedic traction

G.A.M. De Pauw, DDS; L. Dermaut, DDS, PhD; H. De Bruyn, DDS, PhD; C. Johansson, PhD

**Abstract:** The aim of this animal study was to investigate the stability of osseointegrated fixtures when used as anchorage for orthopedic traction with extreme force magnitude. Three Brånemark fixtures were placed in the left zygomatic arch and three in the right of five adult dogs. An orthopedic nonaxial force of 5 N was applied using an intraoral coil system. The initial displacement immediately after force application was measured by means of speckle interferometry. After 2 months of continuous loading, bone adaptation and mineralization around all implants were analyzed. All the loaded implants were immobile. Significant marginal bone loss at the abutment-fixture interface (<1 mm) was observed around each loaded fixture implant. Bone remodeling was significantly more pronounced at the tension side of the implants, irrespective of fixture length. Radiographical and histological analyses showed bone with normal trabecular pattern around the implants.

**Key Words:** Titanium implants, Orthopedic force, Initial displacement.

In orthodontics, external force systems, such as face masks and reverse headgears, apply forces through tooth structures.[1-6] Unfortunately, this indirect application of force causes undesirable tooth movements and limits orthopedic effects. To avoid these dental side effects, anchorage to ankylosed teeth[7-8] or oral implants[9-10] is preferable. Even after oral implants have achieved osseointegration, overloading or bacterial infection in the surrounding tissues may lead to failures.[11] Axial and nonaxial loading of dental implants have been investigated extensively.[12-19] However, an extreme nonaxial force of 5 N, normally used in dentofacial orthopedics in order to induce changes in skeletal growth, has not yet been studied.

Double exposure holography and speckle interferometry techniques are noninvasive techniques used in orthodontics to describe bone or tooth displacement after force application.[20-31] This technique is based on the superimposition of two exposures. The object (tooth or bone) is photographically registered twice, once before and once after force application. An initial displacement of the object due to force application results in the creation of a fringe pattern that can be observed on the double-exposed photographic plate. The amount and orientation of the fringes permit calculation of the magnitude and direction of the initial displacement compared with a stable reference line.

The aims of this animal study were (1) to evaluate by means of laser measuring techniques the initial displacement of the implants immediately after loading, and (2) to evaluate bone remodeling and osseointegration after 2 months' application of a nonaxial force of 5 N magnitude.

## Materials and methods

The sample consisted of five healthy adult dogs, each with a full set of permanent teeth. Pre- and postoperative care of the five dogs was controlled by a veterinarian to ensure all necessary treatments.

All operations were performed under general anesthesia. The animals were premedicated intramuscularly (Thalamonal[R], Janssens-Cilag), anesthetized with thiopental sodium (pentothal, Abbott), and

**Author Address**
Guy De Pauw
Department of Orthodontics
P8, De Pintelaan 185
9000 Gent, Belgium

*G.A.M. De Pauw, assistant professor, Department of Orthodontics, University of Gent, Belgium.*

*L. Dermaut, professor and chairman, Department of Orthodontics, University of Gent, Belgium.*

*H. De Bruyn, associate professor, Department of Periodontology, Center for Oral Health Sciences, Lund University, Sweden, and Center for Periodontology and Implantology Brussels, Belgium.*

*C. Johansson, associate professor, Department Handicapped Research, University of Gothenburg, Sweden.*

**Submitted:** July 1998, **Revised and accepted:** March 1999
Angle Orthod 1999;68(5):401-407.

intubated. General anesthesia was maintained using halothane (Fluothane, Zeneca).

The skin of the zygomatic arch was shaved in full circumference and prepared and draped in a sterile fashion. A 3 cm incision was made 2 cm above the bone area chosen for placement of the fixtures. The dissection was carried through skin, subcutaneous tissue, and periosteum. A subperiosteal dissection exposed an area of the temporal bone adequate for fixture placement.

### Experimental setup

Three standard Brånemark fixtures (Nobel Biocare AB), 3.75 mm diameter and 15, 10, or 7 mm long, were installed in the posterior part of both zygomatic arches of the temporal bone (Figure 1). Standard titanium abutments 3 to 5.5 mm long were connected to the fixtures during the surgery, and an impression of the fixtures and abutments was taken using a polyether material. Surgical placement of fixtures and abutments and technical construction of the splint were performed according to a protocol,[11] using original equipment and components provided by the manufacturer (Nobel Biocare AB, Göthenburg, Sweden). After the impression was removed, healing caps were screwed on top of the abutments to avoid connective tissue ingrowth. The surgical site was disinfected and local antibiotic treatment was initiated before suturing the skin periosteal flap. The implants were re-exposed after a healing period of 8 weeks. At the time of exposure, a splint connecting the two longest implants was screwed onto the abutments. A coil system was connected between each splint and a maxillary splint on the teeth. The chromium-cobalt splint was bonded onto the crowns of six teeth by means of an orthodontic composite material (Concise, 3M, Monrovia, Calif).

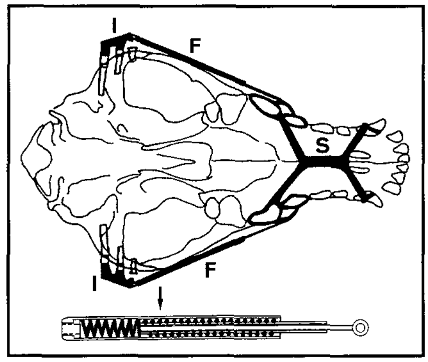


Figure 1
Occlusal view of skull with applied force system (F) between implants (I) and the maxillary splint (S).

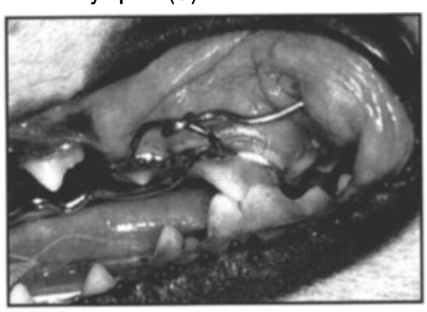

Figure 2
Entrance of the coil system into the oral cavity in the area of the second molar and the connection with the maxillary splint.

The entire coil system was underneath the skin and entered the oral cavity in the second molar area (Figure 2). The skin-periosteal flap was meticulously sutured and the animals were kept 2 weeks before the actual experiment started.

### Initial displacement

The animals were anesthetized and the frontal bone of each dog was clamped between four pins screwed against the skull.[30-31] Measuring plates (small pieces of metal that reflect the laser light beam) were fixed on both the bridge connecting the two implants and the temporal bone. The amount of the initial displacement of the bridge was compared with the initial displacement of the temporal bone. In the case of perfect osseointegration, both parts react as one unit.

The photographic plate was exposed twice in 10 seconds: once before and once after a force application of 5 N.

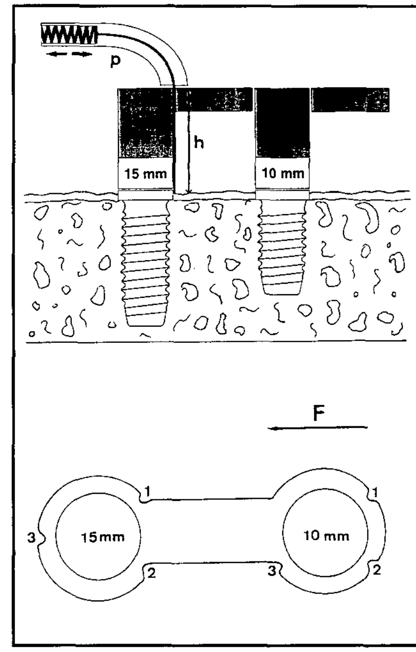


Figure 3A-B
A: Procedure for measuring bone height (h) before and after loading by means of a perio-probe (p), sagittal view.
B: Bone height was measured along each implant at three standardized places—two leading grooves on the tension side (1,2) and one on the pressure side (3), occlusal view.

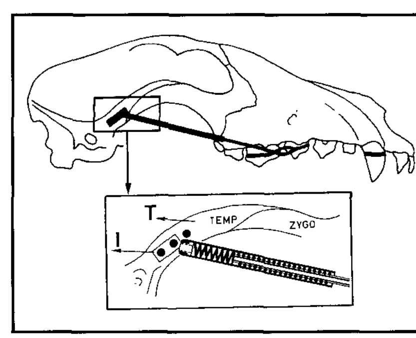


Figure 4
Initial displacement vectors I and T of both implants and the temporal bone after loading in one experimental animal.

A bilateral anteroposterior force of 5 N on the maxilla was exerted through a coil system (Figure 1) pushing between the connected implants in the zygomatic arch (anchorage) and the maxillary splint.

After loading, the initial displacement of the bridge connecting the two implants and the displacement of the temporal bone were measured by speckle interferometry.[30-31]

The direction of the displacement vector of the bridge as well as of the temporal bone was expressed relative to a stable reference line (occlusal plane) in each dog. Differences in the magnitude and direction of the displacement between the temporal bone and the inserted implants were calculated and compared by means of the Student's *t*-test.

### Evaluation of bone loss

The distance between the marginal bone level adjacent to the implant and the reference point on the bridge (Figure 3A) was measured immediately after abutment connection (first measurement) and after 8 weeks of loading (second measurement). This allowed bone loss to be measured after loading. The bone height around each implant was measured with an automatic pressure-controlled periodontal probe (Peri Probe) before and 2 months after the force application at three standardized places. Two measurements were made on the anterior (tension) side and one on the posterior (pressure) side. Leading grooves for the probe (Figure 3B) were made on the constructed bridge to measure bone height at the same place and parallel to the implant direction. The measurement in each groove was repeated five times.

At both experimental times, the error of the method was randomly determined in each dog by taking the first and fifth values of the measurements in each groove. The error of the method was tested by 24 paired measurements in each dog, according to the Dahlberg formula (Table 1).

Differences in bone loss were determined on the tension side as well as on the pressure side for each implant. This measurement was carried out on each implant in each dog, and the overall difference in bone loss between sides was calculated. The influence of implant length on bone loss was examined as well. A two-factor ANOVA analysis with replicate tests on both factors (length of implant and side) was used to compare the bone loss measurements.

At the end of the experiment, the animals were sacrificed and radiographical and histological analyses were performed. In this part of the study, the unloaded implant served as a control.

**Table 1**
**Error of the method for bone loss measurements**

| | Dog 1 | Dog 2 | Dog 3 | Dog. 4 | Dog 5 |
|---|---|---|---|---|---|
| n | 24 | 24 | 24 | 24 | 24 |
| s | 0.12 | 0.08 | 0.16 | 0.15 | 0.11 |
| Error percentage = $\frac{100\,d}{l}$ | 1.3% | 1.1% | 1.9% | 1.7% | 1.2% |

Error of measurement: $s = \frac{\sqrt{\Sigma d^2}}{2n}$ (formula of Dahlberg)

l = distance between the marginal bone level and the reference point on the bridge (see also Figure 3A)
d = difference between a pair of repeated measurements
n = number of measured pairs

**Table 2**
**Average values for the direction (α) and magnitude (number of fringes) of initial displacement in five dogs ($D_1$ - $D_5$)**

| | n | Direction: Temporal bone α (SD) | Direction: Implants α (SD) | t | Magnitude: Temporal bone $\bar{x}$ (SD) | Magnitude: Implants $\bar{x}$ (SD) | t |
|---|---|---|---|---|---|---|---|
| $D_1$ | 12 | -0.4 | -1.9 | | 13.1 | 13.4 | |
| $D_2$ | 13 | 10 | 10.9 | | 12.8 | 13.1 | |
| $D_3$ | 14 | 5.6 | 4.5 | | 9.8 | 10.1 | |
| $D_4$ | 14 | 8.7 | 9.1 | | 12.6 | 12.9 | |
| $D_5$ | 13 | 2.3 | 1.5 | | 14.5 | 14.6 | |
| All dogs | | 5.2 (4.3) | 4.8 (5.3) | NS | 12.6 (1.7) | 12.8 (1.7) | NS |

n = number of measurements of initial displacement
t = comparison of displacement from temporal bone and implants at 0.05 level
NS = not significant

## Results

At the time of connection of the splints (2 months after fixture installation) all implants were clinically immobile.

After loading, an initial displacement of the temporal bone, including the bridge connecting the two implants, was noticed in all dogs. Speckle interferometry measurements revealed that both the temporal bone and the implants were translated backward with some small upward rotation (Figure 4). There was no significant difference between the direction or magnitude of the initial displacement of the temporal bone and the implants in each dog (Table 2). The implants did not move in a way different from the temporal bone, indicating perfect osseointegration.

An initial amount of bone loss after a nonaxial force application of 5 N was obvious almost all the way around the loaded implants. Since the constructed bridge was carried only by the implants to be loaded, measurement of the control implants was not involved in this part of the study. In the loaded implants, the average bone loss in each dog was about 0.5 mm (Table 3). After loading, bone loss appeared to be more pronounced at the tension side ($\bar{x}$ = 0.6 mm) than at the pressure side ($\bar{x}$ = 0.3 mm). This was substantiated by a two-factor ANOVA of the bone loss measurements with replicate tests on length of the implant and side (pressure and tension). The analysis showed that there was no difference between short and long implants for the whole group of dogs ($p$ = 0.9673), with no interaction between length and the side of the loaded implants ($p$ = 0.4886). However, the difference in bone loss between the pressure and tension side of the loaded implants was highly significant ($p$ = 0.0001).

Radiographic analysis revealed bone tissue with a normal trabecular pattern and no obvious radiolucencies around or beneath the implants (including the control areas, Figure 5). No marginal bone loss was seen around the unloaded control implants, whereas a small dip at the bone level up to 1.5 mm could be seen on the tension side of the loaded implants. On the pressure side, however, the bone level was more horizontal. This was confirmed by histological sections in which intimate, well-organized, vital bone contact with the loaded implants was seen. No evidence of connective tissue capsules or inflammatory reaction at the interface was observed (Figure 6). The unloaded control implants had mature bone tissue along the entire titanium surface, whereas the loaded implants had bone contact only starting from the first thread. So, compared with the control implants, there was some marginal bone loss around the loaded implants after the experimental period.

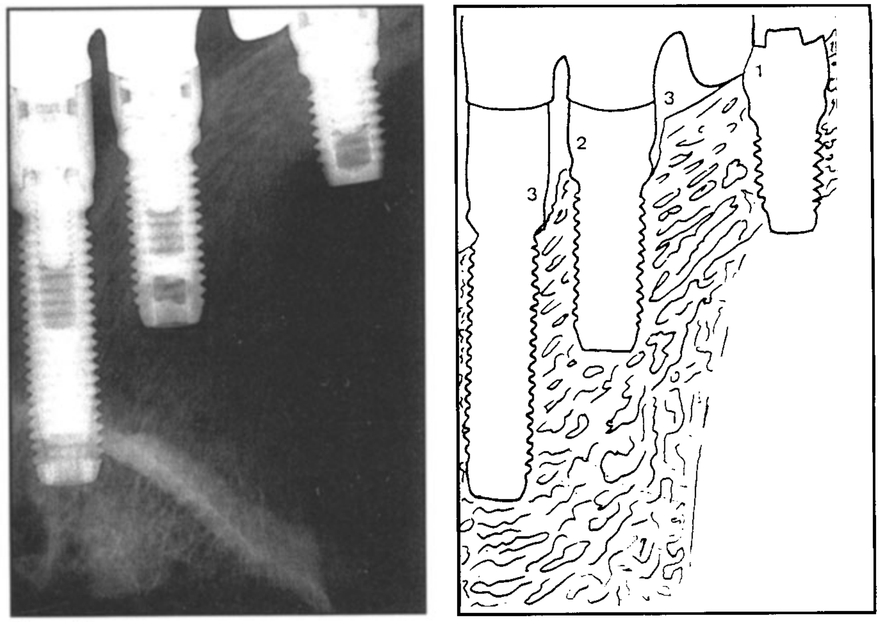


Figure 5
Radiograph and tracing of implant area. No marginal bone loss was observed around the unloaded control implant (1) or on the pressure side of the loaded implant (2). A small dip of bone loss can be observed on the tension side (3) of two loaded implants.

## Discussion

Osseointegrated implants of commercially pure titanium are used for the fixation of dental prostheses. Specific criteria for placement of the implants are advocated (see introduction) and adequate statistical methods to analyze implant success have been reported.[32-34] The indications for use of implants have been gradually extended to regions of vital bone outside the oral cavity.[35-36]

The absence of a sufficient number of anchor teeth in adults can be a limiting factor in orthodontic treatment planning. In these cases, the rigidity and stability of implants can help resist reaction forces.[9-10] The possibility of permanently changing the relationship between the maxillary and mandibular jaws using conventional orthopedic appliances can still be questioned.[37] According to Smalley et al.,[9] the use of implants as abutments for extraoral traction can limit undesirable tooth movements and enlarge the orthopedic effects.

The criteria for defining the success of implants in orthodontics

Figure 6
Histological section showing well-organized, vital bone contact with the implant after loading.

and orthopedics are not the same as in prosthetic dentistry. To obtain skeletal changes, larger force magnitudes are needed. Osseointegrated implants are aimed at resisting these larger forces during the experimental period. The long-term conditions of osseointegration are less important in orthopedics and orthodontics than in prosthetic dentistry because of the shorter loading period.

The magnitude and duration of force application on the implants are important factors for the conditions of the tissues surrounding the implant surfaces. Force application immediately or shortly after placement of the implants may lead to the development of a fibrous capsule around the implant[38]; furthermore, no osseointegration will take place. In this study, a nonloaded healing period of 8 weeks after implant placement seemed to be sufficient to obtain adequate osseointegration of the implants. In the first part of this study, the stability of implants 2 months after placement was investigated in vivo by means of speckle interferometry. The error of the method has been studied by De Clerck et al.,[31] who found measurement errors of approximately 1° and 1 μ for displacements smaller than 10 μ. As every displacement in each dog was larger than 10 μ, this measuring error was considered within acceptable limits. Nevertheless, to improve accuracy, the double exposure procedure was repeated 10 to 15 times in each dog and average values were compared.

The initial displacement of implants inserted in temporal bone and the initial displacement of the temporal bone itself were compared after loading with a force of 5 N. In all dogs, both the temporal bone and the bridge connecting the inserted implants were equally translated backward with some upward rotation. There was no significant difference between the direction or magnitude of the initial displacement vector of the connected implants and the temporal bone in each dog. The displacement of the implants coincided with that of the other parts of the temporal bone. Both the implants and the temporal bone were displaced as a unit. These findings indicate that the degree of osseointegration was adequate. In other words, the reaction forces exerted by the force system were well translated to the temporal bone through the implants. This displacement of temporal bone was due to opening of the suture between the temporal and the zygomatic bones. Similar findings were reported by Smalley et al.,[9] who noticed a complete disarticulation of the zygomaticotemporal suture after an anteroposterior force application.

In the second part of this study, changes in the tissues surrounding the implants after a continuous force application for 2 months were studied. Mean marginal bone loss was about 0.5 mm. This result was similar to the results of clinical experiments: After implant loading, bone loss of 1 mm to 1.5 mm due to bone remodeling during the first year of function is considered clinically acceptable.[39-41]

Although the experimental period of force application was short, bone loss was not greater, despite the high force magnitude and the nonaxial loading of the implants. Bone loss was more obvious along the tension side of the loaded implants (0.6 ↔ 0.3 mm). It was not correlated with the length of the implant. More bone loss along the tension side can be explained by the excessive nonaxial force application of 5 N during the experimental period. The magnitude and direction of the force probably create an adverse stress distribution around the cervical part of the implant. It can be questioned if the differential bone loss observed in this study will continue over time. If so, this amount of bone loss may have some clinical impact. This would mean that implants initially used as anchorage for orthopedic or orthodontic tooth movement in a nonaxial direction could not be used as fixtures for prosthetic replacement on a long-term basis. This conclusion, however, cannot be deduced from this experiment because of the short experimental time of the study. In a recent comparable study,[42] Akin-Nergiz et al. didn't find a progression of bone loss even after a period of 24

**Table 3**
**Bone loss measurements (mm) in five dogs ($D_1$- $D_5$)**

| | | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | All dogs n = 5 (SD) | |
|---|---|---|---|---|---|---|---|---|
| Total overall bone loss | $\bar{x}$ (SD) | 0.5 (0.2) | 0.6 (0.5) | 0.5 (0.4) | 0.6 (0.2) | 0.5 (0.2) | 0.5 (0.05) | |
| Average bone loss at tension side | $\bar{x}$ | 0.6 | 0.6 | 0.6 | 0.7 | 0.6 | 0.6 (0.04) | S |
| Average bone loss at pressure side | $\bar{x}$ | 0.4 | 0.5 | 0.1 | 0.3 | 0.2 | 0.3 (0.1) | S |
| Average bone loss at short implant (10 mm) | $\bar{x}$ | 0.5 | 0.7 | 0.4 | 0.6 | 0.5 | 0.5 (0.1) | NS |
| Average bone loss at long implant (15 mm) | $\bar{x}$ | 0.5 | 0.4 | 0.6 | 0.6 | 0.5 | 0.5 (0.1) | NS |

$\bar{x}$ = average values, n = number of dogs, SD = standard deviation,
S = significant, NS = not significant (ANOVA analysis with replicate tests)

weeks. This finding suggests that the same amount of loading (5 N) did not cause an increasing amount of bone loss on a long-term basis.

Continuous excessive force application can change the initially obtained osseointegration.[38] Histological analysis in this study showed good vital bone contact with both the loaded implants as well as the controls. Marginal bone height around the loaded implants was at a lower level on the tension side than on the pressure side. Bone loss measurements were confirmed by radiographic analysis. Somewhat more bone resorption seems to occur on the tension side. This bone loss, however, was within acceptable limits and comparable to bone loss reported after loading of implants in clinical studies.[39-41] No bone loss was observed around the unloaded controls.

Histological examination revealed good osseointegration with well organized vital bone contact although, as in other reports,[10,33] 100% bone contact was not observed (Figure 6).

Based on the results of this study, the use of titanium implants as anchorage for orthopedic force application systems can be recommended.

## Acknowledgments

This study was supported by Nobel Biocare. The authors wish to thank Prof. Dr. P. Boone for his support during the laser experiments, Prof. Dr. R. Verbeeck for the statistical support, the technical team of the dental school (Ing. F. De Bakcer, E. Comhaire, W. Heyndrickx, A. Blondia) for developing the experimental setup, Mrs. B. Jouret for typing the manuscript, and Mr. G. Dermout for the photographic work.

## References

1. Dellinger E. A preliminary study of anterior maxillary displacement. Am J Orthod 1973; 63:509-516.
2. Kambara T. Dentofacial changes produced by extraoral forward force in the Macaca irus. Am J Orthod 1977; 71:249-277.
3. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral forces. Am J Orthod 1978; 74:121-141.
4. Nanda R. Biomechanical and clinical considerations of a modified protraction headgear. Am J Orthod 1980; 78(2):213-226.
5. Nanda R, Hickory W. Zygomaticomaxillary suture adaptations incident to anteriorly directed forces in rhesus monkeys. Angle Orthod 1984; 54:199-210.
6. Jackson GW, Kokich VG, Shapiro PA. Experimental and post-experimental response to anteriorly directed extraoral force in young Macaca nemestrina. Am J Orthod 1979; 75:318-333.
7. Guyman G, Kokich VG, Oswald R. Ankylosed teeth as abutments for palatal expansion in the rhesus monkey. Am J Orthod 1980; 77:486-499.
8. Shapiro PA, Kokich VG. Treatment alternatives for children with severe maxillary hypoplasia. Eur J Orthod 1984; 6:141-147.
9. Smalley W, Shapiro PA, Hohl T, Kokich VG, Brånemark P. Osseointegrated titanium implants for maxillofacial protraction in monkeys. Am J Orthod 1988; 94:285-295.
10. Roberts WE, Helm FR, Marshall KJ, Gangloff RK. Rigid endosseous implants for orthodontic and orthopedic anchorage. Angle Orthod 1989; 59(4):247-256.
11. Brånemark PI, Hansson BO, Adell R. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg 1977; 18-38.
12. Kydd WL, Daly CH. Bone-titanium implant response to mechanical stress. J Prosthet Dent 1976; 35:567-571.
13. Paige S, Clarck AE, Costa P, King GJ, Waldron JM. Orthodontic stress application to bioglass implants in rabbit femurs. J Dent Res 1980; 59A abstract 712:445.
14. Gray JB, Steen ME, King GJ, Clarck AE. Studies on the efficacy of implants as orthodontic anchorage. Am J Orthod 1983; 83:311-317.
15. Roberts WE, Smith RK, Zilberman J, Mozrary PG, Smith RS. Osseous adaption to continuous loading of rigid endosseous implants. Am J Orthod 1984; 86:95-111.
16. Roberts WE, Marshall KJ, Mozrary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. Angle Orthod 1990; 60:135-152.
17. Turley PK, Gray DW, Kean CJ, Roberts WE. Titanium endosseous and vitallium subperiosteal implants as orthodontic anchors for tooth movement in dogs. J Dent Res 1984; 63A:334.
18. Turley PK, Kean C, Schur J, Stefanac J, Gray J, Hermes J, Poon LC. Orthodontics for application to titanium endosseous implants. Angle Orthod 1988; 58:151-162.
19. Odman J, Lekholm U, Jemt T, Brånemark PI, Thilander B. Osseointegrated titanium implants—a new approach in orthodontic treatment. Eur J Orthod 1988; 10:99-105.
20. Kragt G, Ten Bosch JJ, Borsboom PCF. Measurement of bone displacement in a macerated human skull induced by orthodontic forces: a holographic study. J Biomech 1979; 12:305-310.
21. Kragt G, Duterloo HS, Ten Bosch JJ. The initial reaction of a macerated human skull caused by orthodontic cervical traction determined by laser metrology. Am J Orthod 1982; 81:49-56.
22. Kragt G, Duterloo HS. The initial effects of orthopedic forces: A study of alterations in the craniofacial complex of a macerated human skull owing to high-pull headgear traction. Am J Orthod 1982; 81:57-63.
23. Kragt G, Duterloo HS. The initial alterations in the craniofacial complex of Macaca mulatta skull resulting from forces with highpull headgear. J Dent Res 1983; 62:388-394.
24. Burstone CJ, Pryputniewicz RJ. Holographic determination of centers of rotation produced by orthodontic forces. Am J Orthod 1980; 77:396-409.
25. Pryputniewicz RJ, Burstone CJ, Golden B. Reproducibility of tooth displacements using laser holography. J Dent Res 1980; 59A Abstract 368.
26. Dermaut LR, Beerden L. The effects of Class II elastic force on a dry skull measured by holographic interferometry. Am J Orthod 1981; 79:296-304.
27. Kleutghen JP, Dermaut LR, Boone PM, De Caluwe M. The analysis of extraoral orthodontic forces on a macerated skull by means of speckle interferometry: a preliminary report. Proceedings of the Society of Photo-Optical Instrumentation Engineers, Edinburgh 1982; 369:538-550.
28. Duterloo HS, Kragt G, Algra A. Holographic and cephalometric study of the relationship between craniofacial morphology and the initial reactions to high-pull headgear traction. Am J Orthod 1985 88:297-302.
29. Dermaut LR, Kleutghen JP, De Clerck HJ. Experimental determination of the center of resistance of the upper first molar in a macerated dry human skull submitted to horizontal headgear traction. Am J Orthod 1986; 90:29-36.
30. De Clerck H. De waarde van de droge schedel als model voor de studie van de initiële botverplaatsingen na krachtapplicatie (thesis). University of Gent, 1987.
31. De Clerck H, Dermaut L, Timmerman H. The value of the macerated skull as a model used in orthopaedic research. Eur J Orthod 1990; 12:263-271.

32. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants. A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11-25.
33. Albrektsson T, Eriksson AR, Friberg B, Lekholm U, Lindahl L, Wevins M, et al. Histologic investigations on 33 retrieved Nobelpharma implants. Clinical Mat 1993; 12:1-9.
34. Albrektsson T, Sennerby L. State of the art in oral implants. J Period 1991; 18:474-481.
35. Tjellström A, Rosenhall U, Lindström J, Hallen O, Albrektsson T, Brånemark PI. Five year experience with skin-penetrating bone-anchored implants in the temporal bone. Acta Otolaryngol 1983; 95:568-75.
36. Tjellström A, Jacobsson M. The bone-anchored maxillofacial prosthesis. In: Albrektsson T, Zarb GA, eds. The Brånemark osseointegrated implant. Chicago: Quintessence, 1989; 235-244.
37. Aelbers CMF, Dermaut LR. Orthopedics in orthodontics: fiction or reality? Part I: A review of the literature. Am J Orthod Dentofac Orthop 1996; 110:513-515.
38. Brunski JB. The influence of force, motion and related quantities on the response of bone to implants. In: Fitzgerald R Jr, ed. Non-cemented total hip arthroplasty. New York: Raven Press, 1988: 43.
39. Adell R, Lekholm U, Rockler B, Brånemark PI, Lindhe J, Eriksson B, Sbordone L. Marginal tissue reactions at osseointegrated titanium fixtures. Part I: A 3 year longitudinal prospective study. Int J Oral Maxillofac Surg 1986; 15:39-52.
40. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. A long term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990; 5:347-359.
41. Van Steenberghe D, Lekholm U. The applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. Int J Oral Maxillofac Implants 1990; 5:272-281.
42. Akin-Nergiz N, Nergiz I, Schulz A, Arpak N, Niedermeier W. Reactions of peri-implant tissues to continuous loading of osseointegrated implants. Am J Orthod Dentofac Orthop 1998; 114:292-298.