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Case Report

Unconventional implant treatment: I. Implant placement in contact with ankylosed root fragments. A series of five case reports

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Abstract

Objective: Implant treatment presumes that implants are placed in bone, without any contact with root. At ankylosed teeth, complete root removal is often invasive; subsequently, the sites require additional augmentation procedures to complete the treatment. The aim of this paper is to report on a series of five cases that have been treated with an approach that avoided extractive invasive surgery and bone damage.

Material and methods: The procedure consisted of preparing the osteotomy site by drilling through the root. At the end of the drilling sequence, the root fragments that were not removed were deliberately left at the osteotomy site. Their mobility was checked with a dental pick and when stable an implant was placed in contact with them. The sites were required to be asymptomatic and inflammation free. Ankylosed teeth were replaced with 13–15-mm-long Osseotite implants, four in the anterior maxilla and one in the anterior mandible.

Results: All implants healed uneventfully; they have been now loaded for a period of 12–42 months. On peri-apical radiographs, appearance of the bone–implant interface was similar to osseointegrated implants. The remaining root fragments were visible, in contact with the implants; no specific pathological sign could be detected. A limited resorption of dentine was found at one site after 4 years.

Conclusion: This series of cases suggests that implants placed in contact with ankylosed root fragments might not interfere with implant integration or harm occlusal function, at least in the mid-term. More cases are warranted before this procedure might be considered as a reliable clinical option when, at ankylosed teeth, one wishes to avoid an invasive extraction surgery.

Proper clinical practice in dental implantology rules out leaving any root fragment at the osteotomy site that comes in contact with an implant (Gray & Vernino 2004). The reason is that it is assumed that a durable osseointegration can be gained only through a direct bone–implant contact (Brånemark 1983), without interposition of fibrous tissue or any other root material.

In the experimental literature, some animal studies described implant placement in contact with dental roots (Buser et al. 1990a, 1990b; Warrer et al. 1993). But the aim of these experiments was to investigate the possibility of creating a periodontal ligament (PDL) around the inserted implants.

While dealing with ankylosed teeth, clinicians may be facing complex root extractions. Complete removal of the dental

tissue before placing an implant is frequently invasive (Schwartz-Arad & Levin 2004). The bone volume requested to host an implant is damaged and a bone augmentation procedure is further required. When the ankylosed teeth are situated in the anterior maxilla, aesthetic rehabilitation of the anterior damaged sites often requires soft tissue surgery on top of bone augmentation. All these surgical procedures are making implant treatment complex, lengthy and less affordable; patients are often seeking an alternative. Leaving some root fragment in the osteotomy site would avoid the invasive character of the surgery and the subsequent augmentation procedures. Unfortunately, little is known about the possibilities of obtaining a lasting and functioning bone–implant interface when a root fragment is left in contact with an implant.

The aim of the present paper is to report on a series of five cases in which implant placement has been performed in contact with root fragments, deliberately left at the osteotomy site in order to avoid an invasive and protracted treatment. Their respective follow-up and the relevance of this type of unconventional implant placement are discussed.

Material and methods

Inclusion criteria and general requirements

To undergo this surgical protocol, the following conditions had to be met:

(1) Patients had to be healthy, without general metabolic trouble and able to maintain good hygiene.
(2) Implant therapy was indicated after tooth or root extraction.
(3) The sites receiving the implants had to be asymptomatic and free of inflammation.
(4) When treatment planning was discussed with the patient, it was explained that the extraction might be complex and invasive; it might require additional augmentation procedures to complete the implant treatment.
(5) The patient had to require an alternative option, less invasive and less postponing the delivery of the implant-supported prosthesis.
(6) After explanation of the protocol and its deviation from standard care, the patient had to accept the risk of implant failure. In case of failure, the classical treatment with augmentation procedures was warranted at no additional cost.
(7) An informed consent had to be signed.

Case presentation and surgical procedures

In five patients, one ankylosed tooth required implant therapy; they were four in the anterior maxilla and one in the anterior mandible (Figs 1–5). Tooth ankylosis with advanced crown and root resorption was found at two upper centrals (Figs 1a and 5a). Another upper central displayed internal resorption (Fig. 4a) with a pink colouration of the crown. One upper central displayed a root fracture and the retained part showed signs of ankylosis (Fig. 2a). On a lower lateral incisive root, the dental ligament on the distal side was not visible (Fig. 3a). In all these cases, extraction of the tooth or the root was not attempted because it was anticipated that complete removal of the root substance would severely damage the bone volume of the treated site. Two crowns were seized with an extraction forceps and were separated from the root (patients 1 and 5). During treatment planning, the implant diameter and its length were selected to meet the classical principles of implant placement.

The osteotomy sites were prepared by drilling through the long axis of the roots; the three-dimensional implant axes were

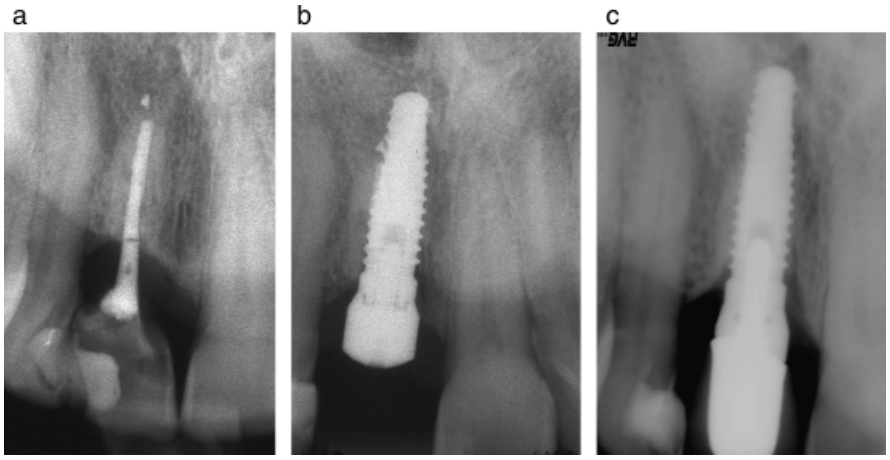

Fig. 1. Radiographs of the upper right central incisor of patient # 1. (a) Before implant treatment. Note the advanced resorption of the crown and the lack of an evident PDL. (b) Immediately after implant placement. Note the large root fragment left on the distal side of the implant. (c) After 49 months. The crestal bone loss features on the mesial and distal sides are related to local occlusal overload. The root fragment is still present; it is involved in local crestal remodelling. PDL, periodontal ligament.

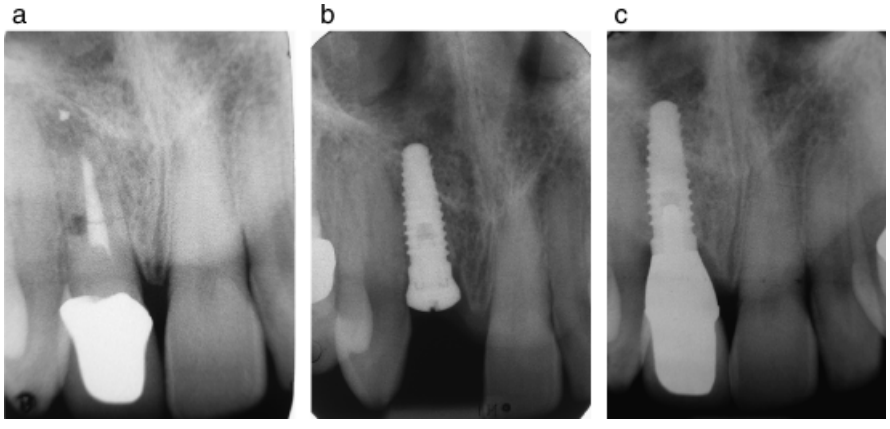

Fig. 2. Radiographs of the upper right central incisor of patient # 2. (a) Before implant treatment. Note the tooth fracture and the lack of an evident PDL at the apical third of the root. (b) Immediately after implant placement. Note the root remaining on the mesial side close to the implant neck. (c) After 45 months. The root fragment is still visible and the implant is asymptomatic. PDL, periodontal ligament.

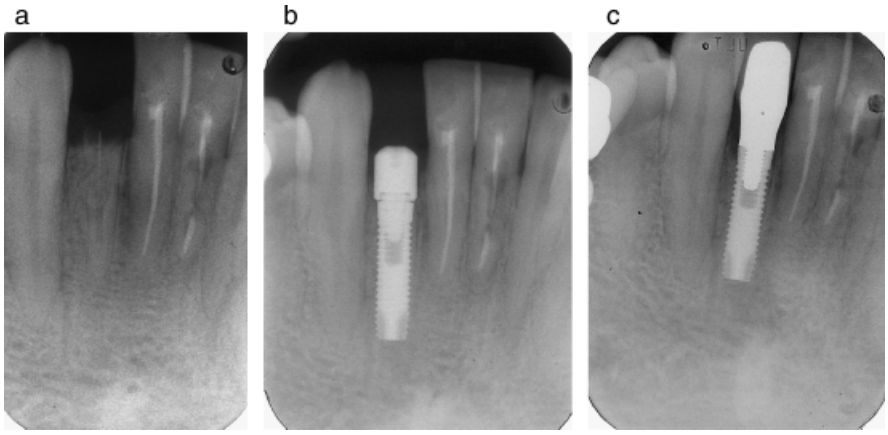

Fig. 3. Radiographs of the lower right central incisor of patient # 3. (a) Before implant treatment. Note the absence of ligament on the distal side. (b) Immediately after implant placement. The root fragment with its visible PDL has been left in contact with the mesial side of the implant. (c) After 27 months. There is no significant change compared with the post-operative situation. PDL, periodontal ligament.

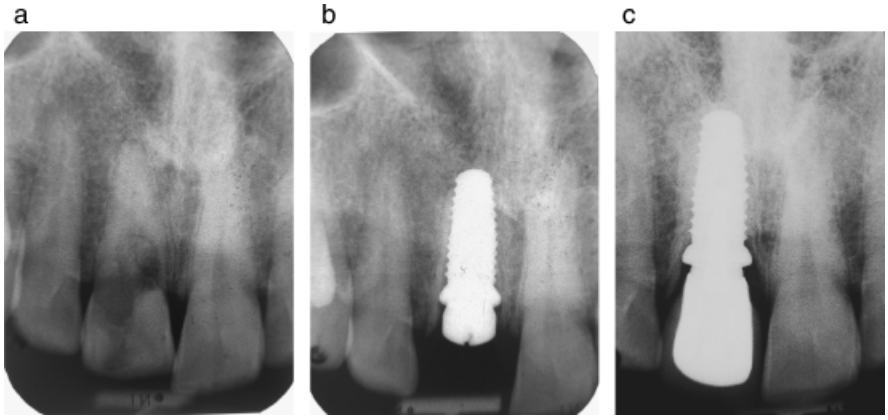

Fig. 4. Radiographs of the upper right central incisor of patient # 4. (a) Before implant treatment. Note the internal resorption of both the crown and the root. (b) Immediately after implant placement. The root fragment covers most of the distal side, up to the crest. (c) After 27 months. The root fragment is present and the bone level adjacent to the crestal part did not move apically.

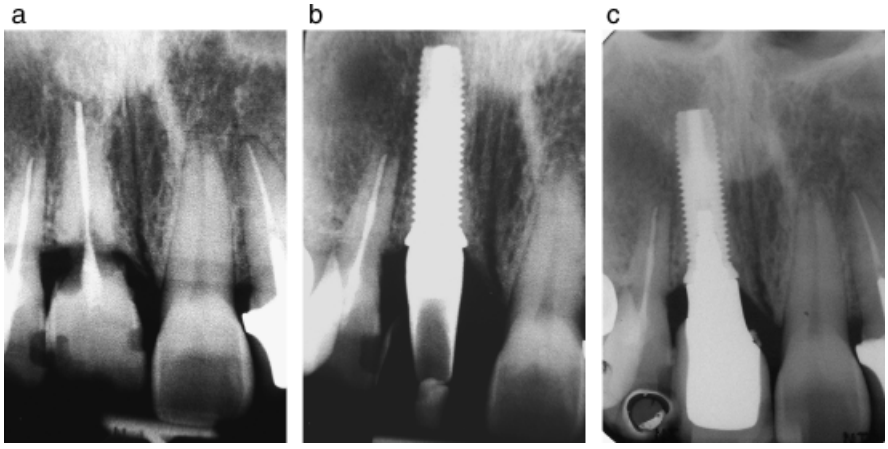

Fig. 5. Radiographs of the upper right central incisor of patient # 5. (a) Before implant treatment. Note the advanced resorption of the crown and the apparent lack of PDL. (b) Immediately after implant placement. Note that the root remains on the mesial and distal sides. The implant was also immediately loaded. (c) After 12 months of loading. The root fragment is still present and the bone level adjacent to the root remains has been maintained at its original level. PDL, periodontal ligament.

prescribed by the surgical guides. For each implant type, the drilling sequence was performed according to the manufacturer's recommendations. When the root canal was filled, attention was paid to remove all the filling material (patients 1, 2 and 5). Because of the dimensions of the selected implants, a dentine fragment was expected to remain at the osteotomy site. A larger implant diameter, with the aim of reducing the extent of the residual dentine, was not selected to avoid the risk of injuring the adjacent teeth. Mobility of the root fragments was tested with a dental pick; only sites with stable fragments were further treated with the present protocol. The root fragments remained either in communication with the crest (Figs 1b, 4b and 5b) or were more apical (Figs 2b and 3b).

Drilling through the dentine of the root gave the feeling of drilling through a harder material than dense bone of type I, without, however, any specific difficulty. The drilling axes could be kept despite the presence of the internal canal; implant insertion was also uneventful. Two implants were left to heal in a submerged way (patient 2), a one-stage protocol was followed for three implants (patients 1, 3 and 4) and one implant was immediately loaded (patient 5). In the latter, an impression was taken immediately after surgery and a laboratory-made provisional cement-retained single crown was delivered the next day (Fig. 5b). The prosthesis was carefully placed in under-occlusion.

Data related to the patients, implant location, types and dimensions are given in Table 1. In addition, each root fragment was characterized according to its position, either crestal or sub-crestal, location and extent.

Clinical and radiographic evaluation of the implants

Implants were clinically and radiographically evaluated at the end of the healing period, at 6 months and at the annual recall. The success criteria of Buser et al. (1997) and Cochran et al. (2002) listed below were applied.

Clinical evaluation

Clinical evaluation included (1) absence of clinically detectable implant mobility, (2) absence of pain or any subjective sensation

Table 1. **Details about the ankylosed teeth, implant type and remaining root fragments**

Patient no.	Sex	Age	Site	Reason for treatment	Local situation	Characterization of the remaining root fragment	Inserted implant	Healing unloaded period (months)	Loading period (months)	Total follow-up (months)	Bone–implant interface	Root–implant interface	Modification of dentine fragment
Patient 1	M	52	11	Crown and root resorption	Ankylosis, no apparent PDL	2/3 of the distal side of the implant, starting from crestal	NT Ø 4.1 × 15	7	42	49	Normal	Normal	Partial resorption
Patient 2	F	40	11	Fractured tooth extraction	Ankylosis, no apparent PDL	1/2 of the distal side of the implant, in the middle	NT Ø 4.1 × 13	7	38	45	Normal	Normal	No visible change
Patient 3	M	59	42	Root extraction	Ankylosis, PDL apparent	1/2 of the mesial side of the implant, starting from crestal	Micro Ø 3.25 × 13	3	24	27	Normal	Normal	No visible change
Patient 4	M	34	11	Crown internal resorption	Ankylosis, PDL apparent	3/4 of the distal side of the implant, starting from crestal	Prevail 4/5 × 13	6	21	27	Normal	Normal	No visible change
Patient 5	F	40	11	Crown and root resorption	Ankylosis, no apparent PDL	1/3 of mesial and distal sides of the implants, starting from crestal	Prevail 4/5 × 13	–	12	12	Normal	Normal	No visible change

PDL, periodontal ligament.

and (3) absence of recurrent peri-implant infection.

Radiographic evaluation

Radiographic evaluation was performed on peri-apical radiographs. It included (1) absence of continuous radiolucency around the implant, (2) observation of any abnormal reaction at the bone–implant interface, (3) observation of any specific reaction at the root–implant interface and (4) evaluation of the resorption of the remaining root fragments.

Results

All implants, whatever the healing mode was, i.e. submerged, non-submerged or immediately loaded, healed uneventfully. Clinical stability was achieved at the end of the 3–7-month integration period (Table 1). Afterwards, the classical prosthetic steps were undertaken and the prostheses were delivered within 1 month. The immediately loaded implant was in function during 6 months; then the final prosthesis was prepared following the classical prosthetic steps. All implants have now been followed for 12–49 months and have been loaded for 12–42 months.

The root fragments were clearly identified on the peri-apical radiographs (Figs 1c–5c). Neither the bone–implant interface nor the root–implant interface displayed any specific feature. Signs of limited dentine resorption were noticed at one implant. The most coronal portion of the remaining dentine seemed to be involved in a remodelling process, similar to the one occurring at the opposite mesial side with a bony interface (Fig. 1c); this was attributed to local implant overload (Szmukler-Moncler et al. 2008).

Discussion

In dental implantology, standards of care cover a large span of clinical situations; sometimes, however, specific circumstances may challenge the clinician and application of a non-recognized technique might find certain relevance. The decision to embark or not on an unconventional route depends on the potential risks and the expected benefits.

The standard approach to remove an ankylosed tooth requires invasive surgery; subsequently, several surgical procedures may be required to complete the implant treatment. This increases the treatment cost substantially, prosthesis delivery is delayed and patient acceptance of implant treatment is decreased. The benefit of this alternative approach was to meet the patient requirements for a non-invasive, simpler and more effective implant treatment.

The risk involved in this unconventional approach was to leave root remains coming in contact with the implant surface. In this patient pool, the root fragments were either completely ankylosed, undergoing extensive resorption without any visible PDL (patients 1 and 5) or partially ankylosed (patients 2, 3 and 4) with remains of the dental ligament. Deviation from the standard implant procedure might have created up to three distinct implant interfaces instead of a single one: (1) a classical bone–implant interface, (2) a dentine–implant interface and (3) a PDL–implant interface (Buser et al. 1990a, 1990b; Warrer et al. 1993; Gray & Vernino 2004).

During the integration period, the risk that a deleterious reaction may originate from the root–implant interface must be taken into consideration. However, since the early 1990s, the few experimental papers that have been published on this topic have shown that this is not likely to occur because the root–implant interface is not related to any sign of pathology (Buser et al. 1990a, 1990b; Warrer et al. 1993; Gray & Vernino 2004). Instead, in places of close contact between the implant and the dentine, a newly formed cementum is deposited (Warrer et al. 1993; Gray & Vernino 2004). When the contact is looser with a wider space left (Buser et al. 1990b; Warrer et al. 1993) and when the ligament of the remaining root is close to the implant surface (Warrer et al. 1993), a new PDL is formed with cement deposited against the implant surface. Collagen fibres are running towards the alveolar bone perpendicularly (Buser et al. 1990a, 1990b; Warrer et al. 1993) or according to a random pattern (Gray & Vernino 2004). The screw implant surface placed in contact with bone at a distance from the ligament always showed osseointegration (Warrer et al. 1993; Gray & Vernino 2004). The stability of this mix of interfaces has been documented in the monkey model over a healing period of 3 months (Warrer et al. 1993) and 12 months (Buser et al. 1990b). Thus, the hazard of lack of implant integration and clinical stability can be estimated to be rather low.

The second point to consider is that a deleterious reaction might take place after a successful integration period, i.e. after function has started. In the monkey model, Gray & Vernino (2004) reported that implants in contact with roots have been successfully loaded for 3 months. A newly formed PDL structure was found at the implant interface, while collagen fibres were following a random pattern; this new PDL was circumscribed to the immediate vicinity of the root PDL.

A single case report has so far provided the histology of a human root–implant interface after being loaded in the mandible (Guarnieri et al. 2002). The impacted cylindrical implant placed in contact with the root was removed after 1 year because of peri-implantitis but not because of a deleterious reaction at the root–implant interface. This supposes a loading period of 6–9 months, after which the root was strongly adhering to the implant; indeed, direct apposition of cementum was found at the porous titanium plasma-sprayed implant interface. The cementum was hypertrophic, devoid of inflammation and without trace of a PDL. The authors questioned whether neo-formation of a ligament could occur in humans as well or might be specific to the animal model (Guarnieri et al. 2002).

In the longer term, one might take into consideration a possible fatigue of the osseointegrated portion because of the presence of a ligament or a possible disuse and calcification of the newly created PDL. But fatigue of the osseointegrated part is not likely to occur because the ligament covers only a limited percentage of the implant surface. In the same way, should ossification of the neo-formed ligament occur in the course of time, it should be similar to what occurs when an avulsed tooth is splinted for too long after placing it back in the injured socket (Mine et al. 2005). The latter would not be deleterious; it would only result in a bone–implant interface.

The fate of the remaining root fragment can also be a source of possible concern. It can be anticipated that the interface either remains asymptomatic or that the dentine is resorbed with time and substituted by bone (Trope 2002; Malmgren et al. 2007). The latter was expected to occur at the resorbing roots of patients 1 and 5 but the exact time that this would take was unknown. It is well documented that ankylosed roots become involved in local bone turn-over (Hammarstrom et al. 1986); resorption in children is more rapid, down to 3 months (Majorana et al. 2003), and slower in adults, up to 10 years and more (Tsukiboshi 2000; Moffat et al. 2002).

The positive results of the present series of cases showed no deleterious reaction either during the healing period or loading for up to 27 months in average (12–42 months). A late reaction centred on the root fragment might still occur, and may be attributed to this unconventional implant placement. Should it occur, the implant site would be treated at no additional cost for the patient.

On the radiographs, the bone–implant interface did not show any abnormal characteristics. Partial resorption of the dentine was identified in a 52-year-old patient. Dentine resorption was part of a V-shaped feature at the crestal part of the implant (Fig. 1c). It was evoking a bone remodelling process due to occlusal overloading (Testori et al. 2002; Szmukler-Moncler et al. 2008). The resorption feature at the dentine fragment was similar to the one occurring on the opposite mesial side, fully in contact with bone.

Clinically, the reason for these positive results may be attributed to the fact that the sites were asymptomatic and free of inflammation before treatment. Otherwise, peri-apical inflammation can occur and endanger the implant (Quirynen et al. 2005). When drilling through the root, all the endodontic filling material was carefully removed to avoid any local source of irritation. Attention was also paid to remove dentine and leave at least half of the implant surface in contact with bone.

Gray and Vernino (2004) stated that the lack of deleterious interaction at the root–implant interface should not be misunderstood as a recommendation that root tip/implant contact is an acceptable outcome in humans. However, the present positive clinical outcome, although limited in numbers, encourages us to further apply this unconventional implant placement

protocol when requested under these strict conditions.

Tooth ankylosis is related to dental trauma (Andreasen & Vestergaard Pedersen 1985; Andreasen & Andreasen 2005) or iatrogenic orthodontic treatment (Bergenholz & Hasselgren 1998; Trope 2002). Epidemiologic studies are showing that one out of two children in the 8–12-year-old age group undergo dental trauma (Naulin-Ifi 2005). Males contribute from 2/3 to 3/4 of the traumas (Majorana et al. 2003; Naulin-Ifi 2005), and anterior maxillary teeth are involved in 75% or more of the cases (Trope 2002; Zuhal et al. 2005). The occurrence of tooth trauma that leads to tooth ankylosis is not negligible; dental intrusion and avulsion have been rated 9.5% and 20.4% among dental traumas (Rezende do Carmo et al. 2007). In a 5-year survey on avulsed permanent teeth, partial root resorption affected 49.3% of the teeth (Trope 2002). This means that permanent tooth ankylosis in the anterior maxilla is not so uncommon; therefore, an alternative approach that avoids the invasive nature of extraction of ankylosed teeth is of interest. It should be the focus of more clinical investigation.

Conclusion

In this limited series of five cases, implant placement in contact with root fragments of ankylosed teeth was helpful to replace ankylosed teeth. It was considered as a possible alternative approach to the standard invasive procedure that requires removal of every root fragment. The treated sites showed no adverse events; implants in contact with the dentine fragments have functioned successfully for an average of 27 months (12–42 months). The bone–implant interface resembled standard implants. Partial resorption of dentine was observed at one implant and this did not lead to a deleterious reaction. More cases are warranted to document this unconventional implant placement in contact with dentine, but it provides intriguing possibilities to meet the need for a simpler treatment in this indication.

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References

Andreasen, F.M. & Vestergaard Pedersen, B. (1985) Prognosis of luxated permanent teeth – the development of pulp necrosis. *Endodontics and Dental Traumatology* **1**: 207–220.

Andreasen, J.O. & Andreasen, F.M. (2005) *Essentials of Traumatic Injuries to the Teeth*. Copenhagen: Munksgaard.

Bergenholz, G. & Hasselgren, G. (1998) Endodontics and periodontics. In: Lindhe, J., Karring, T. & Lang, N.P., eds. *Clinical Periodontology and Implant Dentistry*. 3rd edition, 297–331. Copenhagen: Munksgaard.

Brånemark, P-I. (1983) Osseointegration and its experimental background. *Journal of Prosthetic Dentistry* **50**: 399–410.

Buser, D., Mericske-Stern, R., Bernard, J.-P., Behneke, A., Behneke, N., Hirt, H.-P., Belser, U.C. & Lang, N.P. (1997) Long-term evaluation of non submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-centre study with 2359 implants. *Clinical Oral Implants Research* **8**: 161–172.

Buser, D., Warrer, K. & Karring, T. (1990a) Formation of a periodontal ligament around titanium implants. *Journal of Periodontology* **61**: 597–601.

Buser, D., Warrer, K., Karring, T. & Stich, H. (1990b) Titanium implants with a true periodontal ligament: an alternative to osseointegrated implants? *International Journal of Oral & Maxillofacial Implants* **5**: 113–116.

Cochran, D.L., Buser, D., ten Bruggenkate, C., Weingart, D., Taylor, T., Bernard, J.-P., Simpson, J.P. & Peters, F. (2002) The use of reduced healing times on ITI implants with a sandblasted and etched (SLA) surface: early results from clinical trials on ITI SLA implants. *Clinical Oral Implants Research* **13**: 144–153.

Gray, J.L. & Vernino, A.R. (2004) The interface between retained roots and dental implants. A histologic study in baboons. *Journal of Periodontology* **75**: 1102–1106.

Guarnieri, R., Giardino, L., Crespi, R. & Romagnoli, R. (2002) Cementum formation around a titanium implant: a case report. *International Journal of Oral & Maxillofacial Implants* **17**: 729–732.

Hammarstrom, L.E., Blomlof, L.B., Feiglin, B. & Lindskog, S.F. (1986) Effect of calcium hydroxide treatment on periodontal repair and root resorption. *Endodontics and Dental Traumatology* **2**: 184–189.

Majorana, A., Bardellini, E., Conti, G., Keller, E. & Pasini, S. (2003) Root resorption in dental trauma: 45 cases followed for 5 years. *Dental Traumatology* **19**: 262–265.

Malmgren, B., Malmgren, O. & Andreasen, J.O. (2007) Alveolar bone development after decoronation of ankylosed teeth. *Endotontic Topics* **14**: 35–40.

Mine, K., Kanno, Z., Muramoto, T. & Soma, K. (2005) Occlusal forces promote periodontal healing of transplanted teeth and prevent dentoalveolar ankylosis: an experimental study in rats. *Angle Orthodontics* **75**: 637–644.

Moffat, M.A., Smart, C.M., Fung, D.E. & Welbury, R.R. (2002) Intentional surgical reposition of an ankylosed permanent maxillary incisor. *Dental Traumatology* **18**: 222–226.

Naulin-Ifi, C. (2005) *Traumatismes dentaires. Du diagnostic au traitement*. Paris: CdP Editions.

Quirynen, M., Vogels, R., Alsaadi, G., Naert, I., Jacobs, R. & van Steenberghe, D. (2005) Predisposing conditions for retrograde peri-implantitis and treatment suggestions. *Clinical Oral Implants Research* **16**: 599–608.

Rezende do Carmo, F.M., Guajac, C., Racha, A.C. & Peres, M.P.S. (2007) A retrospective study of dentoalveolar trauma at the hospital das Clinicas, Sao Paulo university medical school. *Clinics* **62**: 133–138.

Schwartz-Arad, D. & Levin, L. (2004) Post-traumatic use of dental implants to rehabilitate anterior maxillary teeth. *Dental Traumatology* **20**: 344–347.

Szmukler-Moncler, S., Davarpanah, M., Bernard, J-P., Jakubowicz-Kohen, B. & Khoury, P.M. (2008) Réponse des tissus durs et mous à l'implantation. In: Davarpanah, M., Szmukler-Moncler, S., Khoury, P.M., Jakubowicz-Kohen, B. & Martinez, M., eds. *Manuel d'implantologie Clinique, 2nd édition. Concepts, protocoles et innovations récentes*, 25–57. Paris: Editions CdP.

Testori, T., Szmukler-Moncler, S., Francetti, L., Del Fabbro, M., Trisi, P. & Weinstein, R.L. (2002) Healing of Osseotite implants under submerged and immediate loading conditions in a single patient: a case report and interface analysis after 2 months. *International Journal of Periodontics and Restorative Dentistry* **22**: 345–353.

Trope, M. (2002) Root resorption due to dental trauma. *Endodontic Topics* **1**: 79–100.

Tsukiboshi, M. (2000) *Treatment Planning for Traumatized Teeth*, 81–97. Chicago: Quintessence books.

Warrer, K., Karring, T. & Gotfredsen, K. (1993) Periodontal ligament formation around different types of dental titanium implants. I. The self-tapping screw type implant system. *Journal of Periodontology* **64**: 29–34.

Zuhal, K., Semra, O.E. & Hüseyin, K. (2005) Traumatic injuries of the permanent incisors in children in southern Turkey: a retrospective study. *Dental Traumatology* **21**: 20–25.