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Clinical Study

Fixed Dental Prosthesis on 4.2 mm Length Rough Implants: A Case Series Report after an Average Loading Time of 33 Months

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Aim. Several limiting factors encourage the clinician to use short implants. Among those, the presence of limiting anatomical elements and the simplification of surgical procedures are particularly significant. The goal of this study is to analyse the opportunity to extend the use of short implants to extrashort implants with a length less than 5 mm (ESI). *Materials and Methods*. Seven patients (3 women, 4 men; mean age 60.4 years) received extrashort implants (Straumann Implant, Palatal Orthosystem, length 4.2 mm, diameter 4.1 or 4.8 mm) in severe resorbed edentulous posterior areas. The implants were incorporated in partially fixed dentures. The osseous stability and the attachment level were recorded after a loading period of 22 to 54 months. *Results*. The results demonstrated a success rate of 100%, stability in the osseous level surrounding implants (mean annual mesial and distal loss of 0.026 mm and 0.105 mm, resp.), and no significant differences in the mean attachment depth between extrashort implants and contralateral teeth or implants (3.7 mm *versus* 3.55 mm, SD = 0.87). Splinting ESI with natural teeth resulted in significantly more bone resorption than with other implants ($P = 0.001$). *Conclusion*. This exploratory study on the use of extrashort implants demonstrated good reliability over a loading period of 22 to 54 months.

1. Introduction

Compliance with the strict rules laid down by the pioneers of modern endosseous implantology offers hope for implant survival rate above 90% [1, 2]. Breaches of these rules have been proposed by different authors, some suggesting fewer surgical procedures [3] and others seeking to reduce healing time [4] and even proposing immediate loading [5]. New materials and techniques have been designed to simplify surgical and prosthetic procedures and to benefit both practitioners and patients. In this light, the authors started using so-called short implants [6–9], in order to avoid preimplant surgeries dedicated to recreating bone volumes after the resorption process that follows every extraction [10, 11]. The clinical results using these implants showed that specific biomechanical constraints facing short implants did not affect their prognosis [12, 13] and even lead to less bone resorption and less complications than longer implants placed in vertically augmented bone graft sites [14]. This may extend indications for implant sites with reduced bone height. The objective of the present study was to evaluate <5 mm implants. These were termed "extrashort implants" (ESI) in order to distinguish them from 5–10 mm "short" implants [15].

2. Materials and Methods

Seven patients (3 men and 4 women, mean age 60.4 years) received 11 palatal implants (Straumann) between November 2006 and May 2010. These implants have been proposed as palatal orthodontic anchorage devices (Palatal Orthosystem, Straumann). It must be noted that, in 2006, those palatal implants were the only oral endosseous implants with such a short size that gave us the opportunity to do this feasibility study. These implants had an intraosseous length of 4.2 mm and two diameters, 4.1 mm and 4.8 mm (Figure 1).

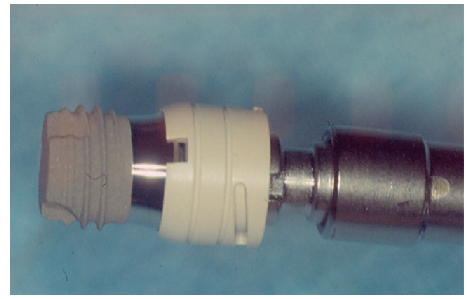


Figure 1: Palatal implant (4.2 mm length, 4.1 mm diameter).

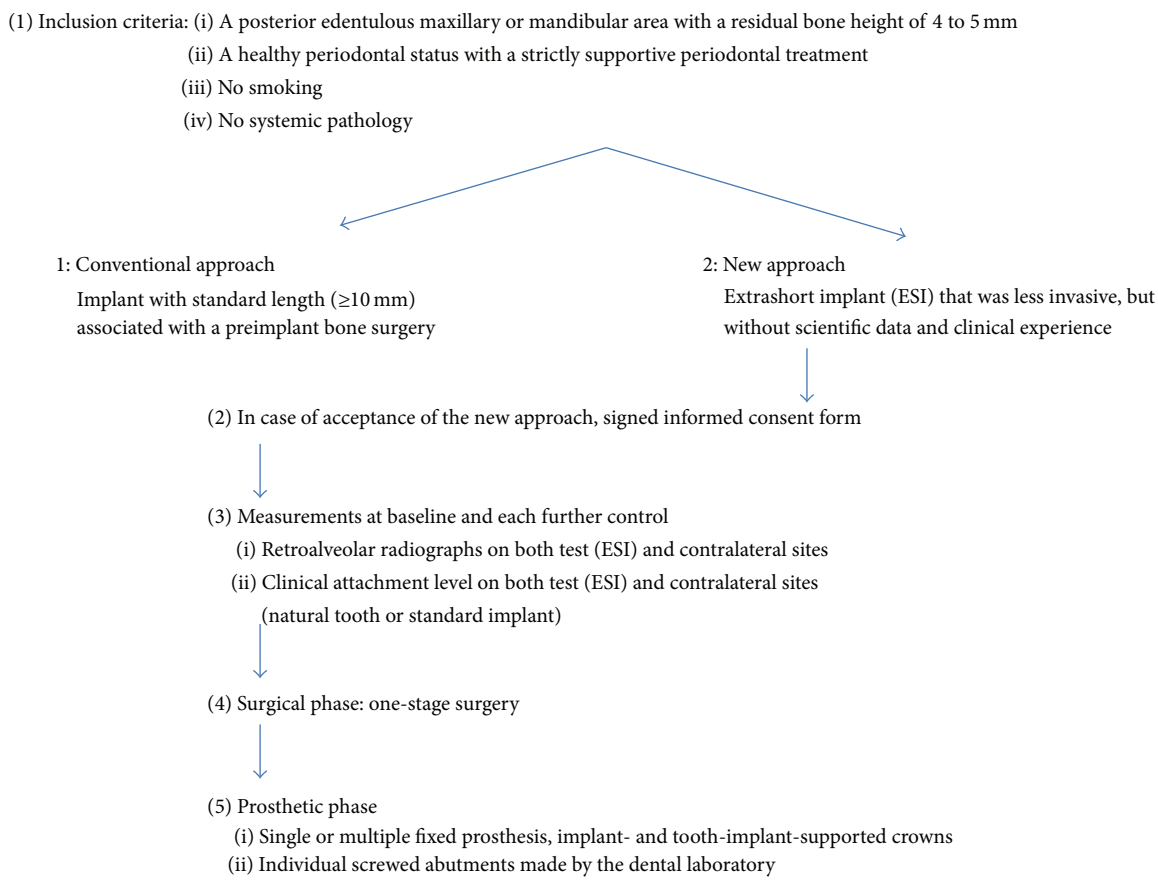


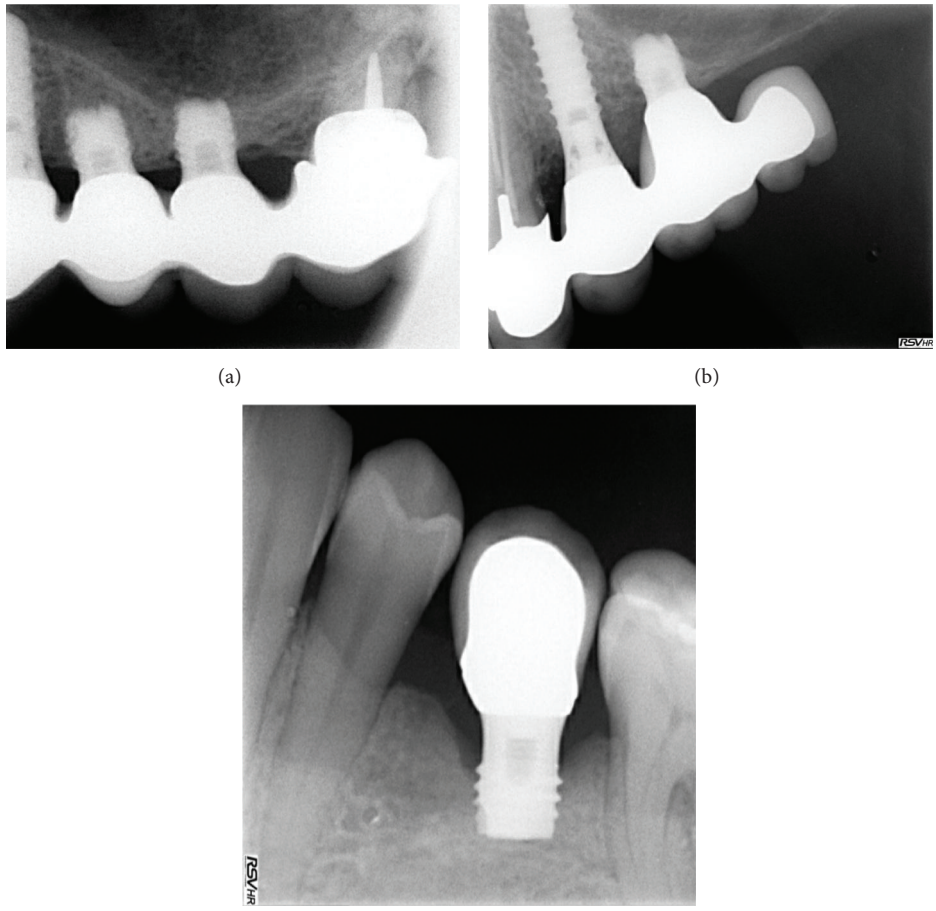
Figure 2: Flow chart.

The intraosseous part was pure titanium, sandblasted and large-grit acid-etched. We suggested extending the indication of these implants to edentulous areas with residual bone height <5 mm. The reduced height was due to anatomical barriers: maxillary sinus (9 cases) and mandibular alveolar nerve (2 cases).

Each patient was offered a choice between an extrashort implant and a longer implant that required preimplant or peri-implant surgery to recreate adequate bone height. Patients were informed of the advantages of extrashort implants (less invasive surgery) but were also informed that palatal anchorage was so far the only way in which this type of implants was clinically used. Written consent was obtained from each patient. After having both treatment options explained to them, all patients chose the former. Only patients with sufficient plaque control (periodontal disease treated and stabilized and patients included in supportive periodontal treatment) were offered this type of implants (Figure 2). The procedures followed were in accordance with the Declaration of Helsinki (1975, revised in 2000).

The surgical procedure was as follows.

After local anaesthesia, a full-thickness flap was elevated before making a 3 mm pilot hole, followed by drills of increasing diameters, 2.2, 2.8, 3.5 mm (for implant diameter 4.1 mm; implants numbers 1 to 10), and 4.2 mm (for 4.8 mm implant diameter: implant number 11). Control of



(a) (b) (c)

Figure 3: Extrashort implants as intermediates (a), as distal with cantilever extension (b), and as single (c).

the temperature during drilling was obtained by applying a procedure described previously [16, 17]. In short, the drilling was performed by successive thirds at low speed (200–400 rpm) in the absence of irrigation. Rinsing with chilled saline was performed between each drilling phase. This approach allowed better drilling precision [18] and the recovery of autogenous bone with osteoinductive properties [19].

The above protocol differed from standard surgical procedures [20]. Specific gauges facilitated proper sizing of holes and allowed for excellent primary stability. Using this new approach facilitated the achievement of a proper angulation and favoured the best dimensioning of the alveolar socket. It is suitable, especially in regard to the difficulties of instrumental and visual access to the maxillary posterior areas as well as the need to obtain an excellent fit between sockets and implant. The intimate contact between bone and implant is an essential condition for gaining primary stability, which is in itself essential for successful extrashort implants.

The prosthetic phase started 4 months after implant placement. No prosthetic abutment was available for this type of implant and the screw-retained abutments were made by the laboratory technician (Pascal Dichert, Parc des Poteries, Strasbourg) after impressions using specific transfers (impression cap, palatal implant, ref 048094). Metal-ceramic crowns were integrated in intermediates ($n = 4$, Figure 3(a)) and mesial or distal positions ($n = 6$, Figure 3(b)) of fixed dental prostheses. One single crown was also performed (Figure 3(c)).

For the 10 extrashort implants that were abutments for fixed partial dentures, the nature of the nearest abutment was recorded as implant, natural tooth, or both (Table 1).

The following measurements for the 11 implants were performed after an average loading time of 33 months (22–54 months):

(i) Measurements of the bone level were performed at mesial and distal aspects of each implant, using non-standardised intraoral radiographs taken at baseline (implant placement) and the last control visit. Bone loss equivalent to the height of one implant thread corresponds to bone loss of 0.8 mm. For each thread exposed, a score of 0.8 mm was recorded (Figure 4).

(ii) The anatomical crown-to-implant ratio was registered for every implant. The distances were calculated from the shoulder of the implant and not from the alveolar crest [21].

Table 1: Line 5: *bone resorption* (mesial and distal measurements) around each implant; line 4: *time of loading* goes from 54 months (implants numbers 1 and 2) up to 22 months (implants numbers 10 and 11). Lines 1 and 2: *implants are located* in intermediate (Int., number 3-4-7-8), mesial (Mes., number 10), and distal (Dis., number 1-2-5-6-9) positions; one implant is a single-unit implant (S, number 11). Line 3: element(s) with which the extrashort implants are directly *connected*: implant (I), natural tooth (T), or both (I + T); in those cases, the teeth are always located distally. Line 6: *C/I ratio*: crown-to-implant ratio; measurement concerns the anatomic ratio (fulcrum located at the implant shoulder). Line 7: *pocket depth*: mean pocket depths around the ESI (test group, in bold) or around the contralateral teeth or implants (control group, in italic).

Line 1 Number and position of each implant	1 Dis.	2 Dis.	3 Int.	4 Int.	5 Dis.	6 Dis.	7 Int.	8 Int.	9 Dis.	10 Mes.	11 S
Line 2 Localisation of each implant	26	27	25	26	17	27	16	27	26	45	35
Line 3 Connection with implant (I), natural tooth (T), or both (I + T)	I	I	I + T	I + T	I	I	I + T	I + T	I	T	Nonsplinted
Line 4 Time of loading (months)	54	54	33	33	26	26	30	29	29	22	22
Line 5 Bone resorption (mm)											
Mes.	0	0	0	0	0	0	0	0	0	0.8	0
Dist.	0	0	0	0.8	0	0	1.6	0.8	0	0	0
Line 6 C/I ratio	2.07	1.73	2.14	1.96	3.4	3.57	3.13	2.51	2.95	1.58	2.92
Line 7 Pocket depth (mm)											
Test	**2.83**	**2.83**	**3.66**	**4**	**3.5**	**4.5**	**6.33**	**2.83**	**3**	**2.66**	**2.83**
Control	*3.33*	*3.83*	*3.33*	*3.16*	*4.66*	*4*	*4.33*	*3.16*	*4.16*	*2.66*	*3*

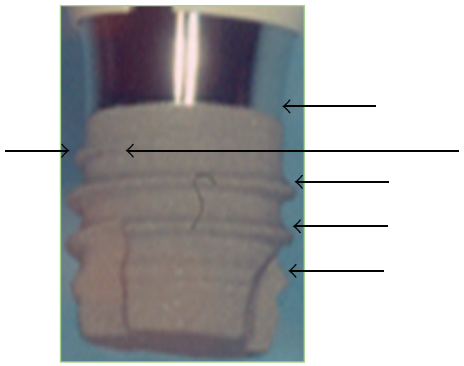


Figure 4: The distance between 2 threads of ESI (arrows) was 0.8 mm. Bone loss between 2 threads, whatever it is, is assessed as a loss of all the distance between 2 threads.

(iii) Pocket depths were measured on 6 aspects (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, and distolingual) of each test implant and contralateral tooth or standard implant, using a Williams probe. The surgeries and the different measurements were performed by the same operator (YR). Duplicate readings of the radiographs at two different times were performed and had similar results.

2.1. Statistical Analysis. Statistical differences of attachment level between the test and the control groups were calculated using the Student t-test. The significance level was set at $P < 0.05$. Statistical differences of bone resorption between splinted and nonsplinted short implants were calculated using the Mann-Whitney test with XLSTAT (Microsoft, Redmond, WA, USA). The significance level was set at $P < 0.05$.

3. Results

Implant survival and success rates were 100% after a mean of 33 months. The success criteria of Albrektsson et al. (1986) were used for evaluation of osteointegration [22]. No clinically detectable mobility, pain, infection symptoms, or presence of radiolucency around implants was recorded. The proximal average annual bone loss was, respectively, 0.026 mm at the mesial aspect and 0.105 mm at the distal aspect. Significant bone loss was observed around implants connected to natural teeth (implants numbers 4-7-8 and 10), $P = 0.001$ (Table 1).

The crown-to-implant ratio ranged from 1.58 to 3.57 with an average value of 2.54. Due to the limited number of patients, no correlation could be shown between the crown-to-implant ratio and bone loss. No significant differences were observed between probing depth measurements performed on extrashort implants (mean test group: 3.7 mm)

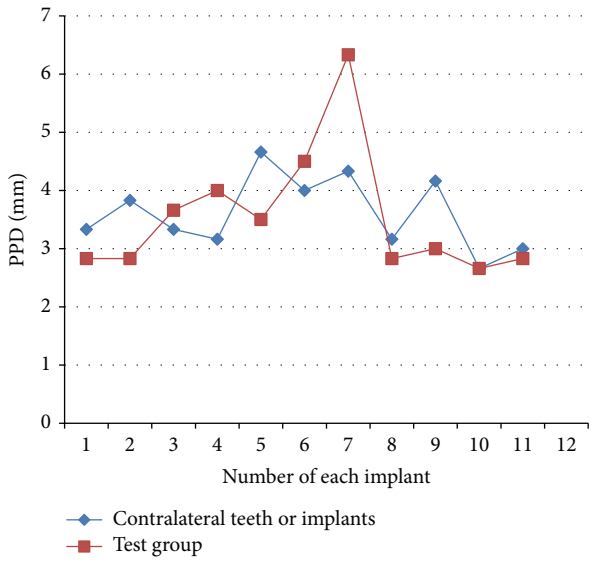


FIGURE 5: Pocket probing depth (PPD) around each implant (test group, red line) and around contralateral teeth or implants (blue line). No statistical significant difference appeared between test and control groups (Student's t-test: $P > 0.05$).

and contralateral standard implants or natural teeth (mean test group: 3.55 mm) (standard deviation: 0.87) (Figure 5).

4. Discussion

The 11 patients who participated in this study were offered two different approaches: a less invasive one, consisting in a one-step and one-surgical-site procedure using ESI implants in areas with a poor residual bone height, or a more invasive approach which required either an autograft from a second operative site or an allograft or a xenograft whose absolute safety has never been established [23]. This latter solution was to be followed by the placing of conventional length implants (≥10 mm) which is a well-established clinical protocol. Every patient opted for the less invasive solution. Perhaps this choice means that patients fear invasive surgical treatments, as concluded by Goodson et al. [24]. Indeed, when comparing different treatments of periodontitis, Goodson et al. observed that when the group treated firstly by root planing was scheduled to receive surgical treatment afterwards, 68% missed the second appointment.

With a success rate of 100%, our results are close to those obtained by Slotte et al. [12] who analysed 87 4 mm long implants after a loading time of 24 months. To get a success rate of 95.7% after 1 year and of 92.3% after 2 years, Slotte et al. insisted on the need to obtain a high initial stability, the latter being related to a very strict operative procedure and a high bone implant contact (BIC). In our study, the first point was achieved by following a protocol whose results have shown a high rate of success and reproducibility [17–19]. To facilitate a high BIC, Slotte et al. placed the implants only in bone types 1 and 2 (posterior mandible). This condition was not retained in our study; implantation in bone of type 2 was performed in only two cases (numbers 10 and 11), whereas all other cases were performed in the posterior maxilla with type 4 bone. In our study, the indications for ESI were situations associated with a limited residual bone height and a risk of damaging sensitive anatomic structures, such as the maxillary sinus (the first nine implants), the inferior dental nerve, or the mental foramen (the last two implants).

Two studies have put forward solutions to compensate for the reduced BIC of the extrashort implants. The first one consisted of using rough surface implants where the odds ratio was more favourable than machined implants [25]. Both this report and our own study used rough implant surfaces: SLActive (Straumann) surface by Slotte et al. and an acid-etched sandblasted surface for the Palatal Orthosystem (Straumann). The second solution that has been proposed is the use of large diameter implants. This solution led to a higher rate of failure, mostly in bone type 4 in the posterior region of the maxilla. This may be due firstly to the use of large diameter drills. Bone injury did result not only from the speed of the drill, but also from the linear speed ($ls = r \times as$, where r is radius of the drill and as is angular speed). The other reason was related to the limited bone volume at the periphery of a large diameter implant. The poorly vascularised layer associated with type 4 bone may present a higher risk of local bone resorption. For those reasons, we only used a 4.8 mm diameter implant in one case (implant number 11, bone type 2) whilst all other implants (9 in the posterior maxilla and 1 in the mandible) had a diameter of 4.1 mm.

Reluctance to using extrashort implants could be related to more unfavourable biomechanical constraints at the coronal part of implants [26, 27]. However a >1 crown-root ratio does not preclude reliable clinical outcomes that are comparable to those obtained with longer implants [15, 28]. This is in accordance with the results of our study and the 2.54 average crown-to-implant ratio. It may seem odd to find in the category of ≤10 mm short implants [29] much shorter implants that are twice as short (<5 mm). To distinguish between these two types of implants, we propose to call these less than 5 mm-long implants extrashort implants (ESI).

Our study demonstrated a stable bone level with a mean mesial annual bone loss of 0.026 mm and a mean distal annual bone loss of 0.105 mm. Interestingly, the 4 sites where bone resorption appeared corresponded to prosthetic situations where extrashort implants were splinted to natural teeth. In 3 of these cases, ESI were located in an intermediate position relative to the tooth located distally. This observation may be explained by the presence of maximal stress applied to crestal peri-implant tissues as revealed by finite element modelling [30]. Bone destruction in the periphery of implants occurred when they were associated with natural teeth [31]. This was also the case in the presence of rigid connectors (that corresponded to the prosthetic situations in our study), as opposed to the lower resorption level observed in the presence of nonrigid connections between teeth and implants. These *in vitro* and radiographic results were confirmed by the literature reviews reporting higher rates of complications after 5 to 10 years when implants were connected to natural teeth [32].

The attachment level measured at ESI and their contralateral side teeth or implants showed no significant differences.

However, we noted an average probing depth of 6.33 mm on implant number 7, located in the maxillary second molar position, that appeared to be associated with a lack of keratinized gingiva on the buccal aspect of this implant. For some authors, a sufficient height of attached gingiva at the periphery of the implant could reduce inflammatory risk. For other authors, the presence of inflammation was related to difficulty in ensuring adequate quality of oral hygiene around an implant [33]. Success with extrashort implants requires reducing the risks of loss of attachment. One of the main criteria for inclusion in this study, after anatomical factors, was the level of oral hygiene achieved according to the periodontal health status. This preventive approach [34, 35] included, in addition to strict oral hygiene procedures, no smoking and limited systemic risk factors (uncontrolled diabetes). Regarding the latter, and unlike Felice et al. [36], a patient treated by bisphosphonates was included in the study (implant number 9, Figure 3(b)) since ESI need only minimally invasive surgical procedures.

5. Conclusion

The results provided by this study on the behaviour of 11 extrashort implants (ESI) evaluated between 22 and 54 months after loading achieved a survival rate of 100%. Bone resorption was observed in fixed dental prostheses where ESI were splinted to natural teeth, suggesting that ESI may be contraindicated in these combined reconstructions. Comparison of attachment levels at ESI and contralateral teeth and implants shows no significant differences. The choice of this therapeutic approach avoids the need for pre- or peri-implant bone augmentation techniques. Nevertheless, a strict selection of patients especially on their ability to achieve high quality of oral hygiene is required. There is a need for other long-term studies using this protocol on a larger population before this therapeutic choice can be validated.

Conflict of Interests

The authors declare that they do not have any conflict of interests. Part of the materials (11 palatal implants) dedicated to the study has been provided by Straumann (Basel, Switzerland).

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