Short (6-mm) Nonsubmerged Dental Implants: Results of a Multicenter Clinical Trial of 1 to 7 Years

Chris M. ten Bruggenkate, DMD, MD, PhD*/Pekka Asikainen, DMD**/
Christian Foitzik, DMD, MD, Dr phil nat***/Gisbert Krekeler, DMD, PhD****/
Franz Sutter, Dr H C, Dr H C*****

Limited bone height restricts the use of long dental implants, so short implants may be selected in these situations. Recent reports on clinical results with short implants have been negative, however, and have suggested that indications for the use of these implants are limited. To verify these findings, a multicenter study of short ITI implants was carried out. In a 6-year period 253 short implants with a length of 6 mm were placed into 126 patients, who were followed up from 1 to 7 years. Altogether 7 implants were removed; 6 of these were located in the maxilla and 1 in the mandible. The quality of survival was comparable with the clinical results of longer implants from the same implant system. Although the clinical results of these short implants were favorable, it is recommended that they be used in combination with longer implants, especially when used in the less dense bone that is often seen in the maxilla.
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Key words: atrophy, clinical results, nonsubmerged, short dental implants

Anatomic conditions may limit the use of oral implants. Reduced alveolar bone height is one limitation, especially when observed in the lateral parts of the mandible and the maxilla, where the mandibular nerve and the maxillary sinus, respectively, are to be avoided. Therefore, there has been a demand from clinicians for shorter implants, despite the risk that extremely reduced implant lengths may overload the surrounding bone and lead to implant failure. From recent publications on clinical results of implants, it can be concluded that short implants (7 and 10 mm) in several systems show unfavorable results when compared to longer implants within the same system.1–13

The type of bone at the implant site also plays a major role in the distribution of forces on short implants.[2] Experience with short implants from other groups[1,3] has confirmed the fact that loose spongy bone, as in the maxilla, appears to not withstand the same forces as the dense bone that is often found in the interforaminal region of the mandible. Consequently, the use of short implants should be guided by the intraoral location, the type of bone present, and the type of superstructure required.

Within the ITI Dental Implant System (Institut Straumann AG, Waldenburg, Switzerland), 2 types of 6-mm (length) implants (a hollow-screw implant with 4.1-mm root diameter and a solid-screw implant with 4.1-mm root diameter) are currently available for patients with reduced alveolar bone height (a hollow-cylinder implant with 3.5 mm root diameter was only available as an experimental implant) (Fig 1).[14–17] The 6-mm implants were originally intended to be

*Oral and Maxillofacial Surgeon, Hospital of the Free University, Amsterdam and Rijnland Hospital, Leiderdorp, The Netherlands.
**Oral and Maxillofacial Surgeon, Kuopio and Helsinki, Finland.
***Oral and Maxillofacial Surgeon, Klinik für Mund-, Kiefer- und Gesichtschirurgie, Darmstadt, Germany.
****Professor and Head of Periodontal Surgery, Department of Oral and Maxillofacial Surgery, University of Freiburg, Freiburg, Germany.
*****Former Head, Department for Design and Development, Straumann Research Institute, Niederdorf, Switzerland.

Reprint requests: *Dr C. M. ten Bruggenkate, Hospital of the Free University, Amsterdam and Rijnland Hospital, Postbus 4220, NL-2350 CC Leiderdorp, The Netherlands. Fax: 31-71-5418836.*

supporting implants. According to the ITI protocol, they were meant to be coupled with longer implants within the desired suprastructure.[18] For instance, a 6-mm implant could be of great value in a severely atrophic mandible with 4 implants planned, where the medial portion of the mandible could accept only 8-mm implants, and where 8-mm implants, if used in lateral positions, would cause perforations. Following the successful use of 6-mm implants for this indication, other categories were subsequently treated with these implants. The authors' clinical experience with 6-mm implants has been documented and is reported in this article.

Table 1 Participating Clinics and Numbers of Patients and Implants

Clinic	No. of patients	No. of implants
Leiden, The Netherlands	42	120
Kuopio, Finland	51	94
Darmstadt, Germany	30	32
Freiburg, Germany	3	7
Total	126	253

Materials and Methods

Over a 6-year period in 4 clinics, 253 straight, 2-part, grade IV, pure titanium, plasma-sprayed ITI dental implants with a 6-mm root length were placed into 126 patients (Table 1, Fig 2). The maximum follow-up was 7 years, with a minimum of 1 year of follow-up time (Tables 2 and 3). The first implant sites were prepared with standard burs and depth gauges, which are used for other implant lengths, while the more recent implant sites were prepared with instruments designed specifically for the 6-mm implant. Three different types of titanium plasma-sprayed implants were used: hollow cylinder (root diameter, 3.5 mm), hollow screw, and solid screw (root diameter outside of the thread, 4.1 mm) (Table 2, Fig 1). The 253 implants were placed in 126 patients aged 24 to 80 years (mean age, 59 years). The male-to-female ratio was 1:4.5.

The 6-mm implants were used with several types of suprastructures. They were placed to support overdentures on bars connected to two 6-mm implants in combination with longer implants in the atrophic mandible and maxilla, and on four 6-mm implants in extremely atrophic mandibles (Figs 3 and 4).[19] Two 6-mm implants with retentive anchors were

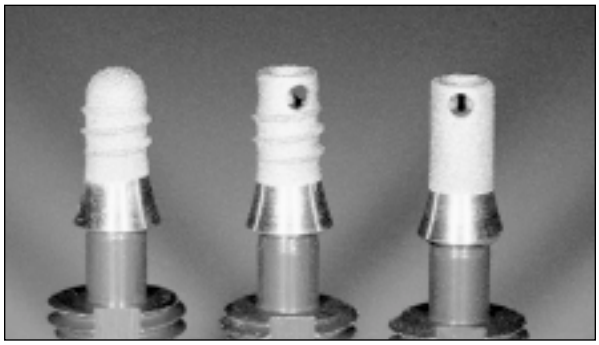


Fig 1 The 3 types of 6-mm ITI implants that were investigated: *(left)* the solid screw, *(center)* the hollow screw, and *(right)* the hollow cylinder.

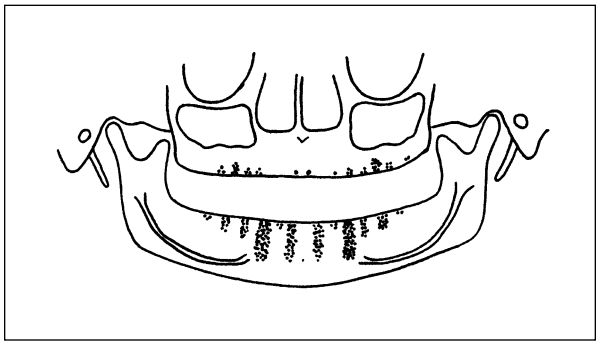
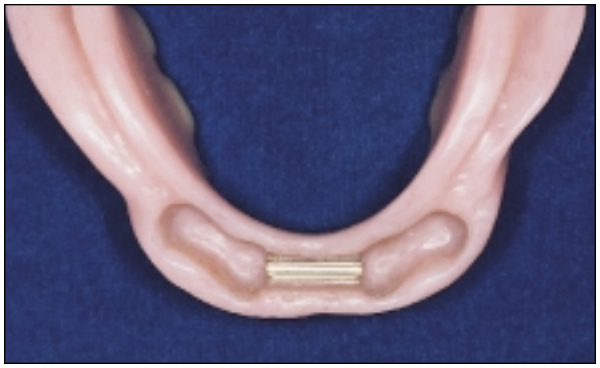


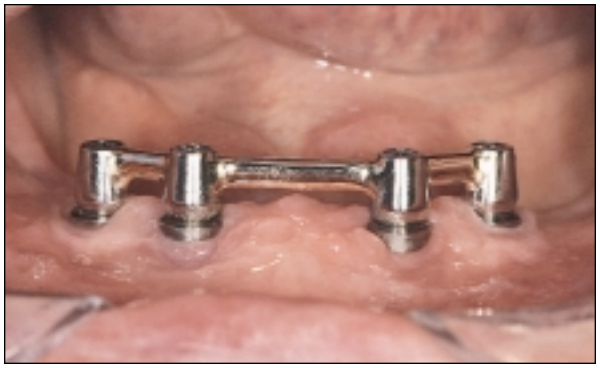
Fig 2 Schematic drawing of the maxilla and mandible with 6-mm implant sites indicated (shaded areas).

Table 2 Number and Types of 6-mm ITI Implants and Observation Time Since Placement

Type of 6-mm ITI implant	Follow-up (y)						Total no. of implants
	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	
Hollow cylinders	14	12	3	5	34	0	68
Hollow screws	16	24	25	14	6	9	94
Solid screws	21	36	17	11	5	1	91
Total	51	72	45	30	45	10	253

*The 6-mm hollow cylinder implant is and was not available commercially.





Figs 3a and 3b Clinical photographs of overdenture and bar construction on 6-mm implants in the interforaminal region of the mandible.

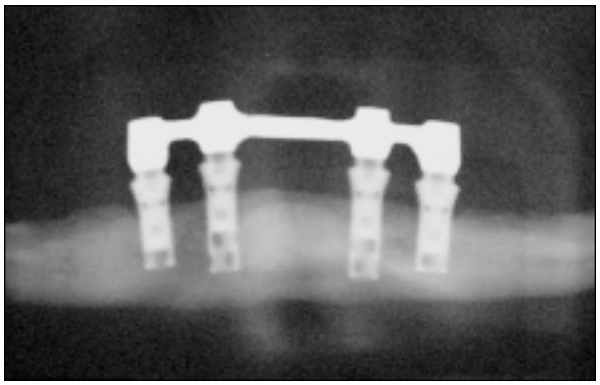


Fig 3c Orthopantomogram of two 8-mm hollow-cylinder implants in the medial positions and two supporting 6-mm hollow-cylinder implants in the interforaminal region of the mandible. Because of the slanted lingual aspect of the mandible, longer implants would have led to perforation of the lingual cortical bone.

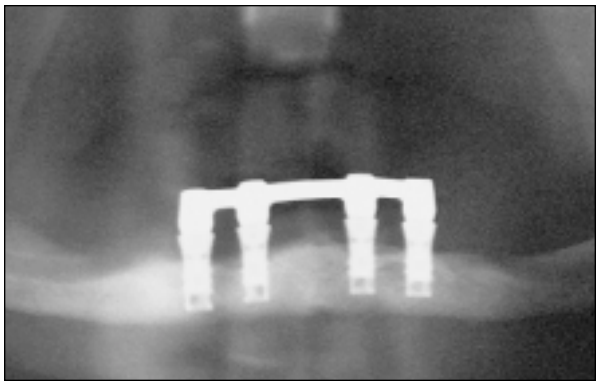
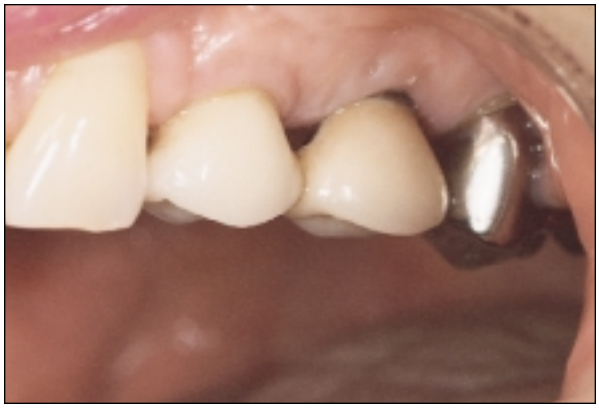
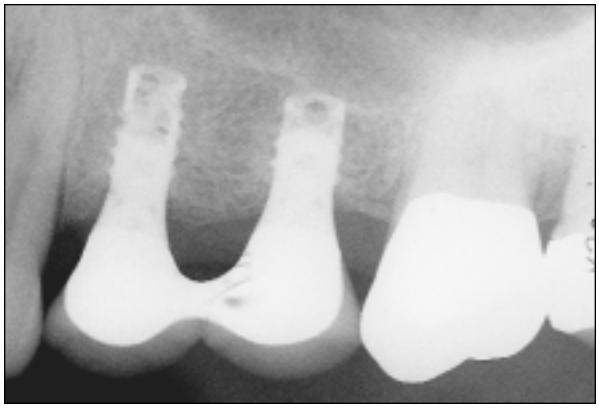


Fig 4 Orthopantomogram of bar construction on four 6-mm hollow-screw implants in the interforaminal region of an extremely atrophic mandible.

Table 3 Number of 6-mm ITI Implants Placed at Different Locations

Location	No. of implants	Location	No. of implants
Maxillary right third molar	0	Mandibular left third molar	0
Maxillary right second molar	3	Mandibular left second molar	2
Maxillary right first molar	8	Mandibular left first molar	13
Maxillary right second premolar	3	Mandibular left second premolar	11
Maxillary right first premolar	3	Mandibular left first premolar	47
Maxillary right canine	0	Mandibular left canine	3
Maxillary right lateral incisor	0	Mandibular left lateral incisor	28
Maxillary right central incisor	1	Mandibular left central incisor	0
Maxillary left central incisor	1	Mandibular right central incisor	0
Maxillary left lateral incisor	0	Mandibular right lateral incisor	28
Maxillary left canine	1	Mandibular right canine	3
Maxillary left first premolar	4	Mandibular right first premolar	48
Maxillary left second premolar	3	Mandibular right second premolar	13
Maxillary left first molar	12	Mandibular right first molar	9
Maxillary left second molar	4	Mandibular right second molar	3
Maxillary left third molar	2	Mandibular right third molar	0
Total no. maxillary implants placed	45	Total no. mandibular implants placed	208





Figs 5a and 5b Two crowns supported by 8-mm and 6-mm ITI implants in the maxillary left premolar region.

Table 4 Type of Suprastructure Supported by 6-mm ITI Implants

Suprastructure type	No. supported
Bar construction for overdentures	62
Retentive anchors for overdentures	2
Full fixed prosthesis	10
Partial fixed prosthesis	48
Single crown	13
Total no. of suprastructures	135

Table 5 Failing 6-mm ITI Implants Removed

Time of failure (time since placement)	No. of patients	No. of implants
Early failure (< 4 mo)	3	4
Delayed early failure (4 mo to 2 y)	2	2
Late failure (> 2 y)	1	1
Total	6	7

also used for overdenture support in the interforaminal region. Furthermore, 6-mm implants were used to support complete arch prostheses and partial prostheses, all in combination with longer implants. Single crowns were also placed on 6-mm implants (Fig 5). The different types of prostheses used are listed in Table 4.

Patient Selection. As far as known, no patients suffered from serious internal diseases, such as endocrine or hemopoetic systemic diseases or immune system disturbances. None of the patients had irradiated arches. Patients with previous endocarditis or heart valve or metallic joint prostheses were excluded from implantation. None of the patients in this review were known to be alcoholics or drug abusers.

Preoperative and Postoperative Measurements. Treatment planning consisted of initial consultation and evaluation by the surgeon and prosthodontist to analyze individual patient requirements and clinical and radiologic findings. Preoperative bone height measurements were calculated from orthopantomograms. However, because of the slanted configuration of the lingual aspect of the mandible, an orthopantomogram may suggest more bone height than actually exists. For patients with atrophic edentulous mandibles, in the absence of attached, keratinized mucosa, a palatal mucosa transplantation was provided in preparation for implant surgery.[20]

Prophylactic antibiotic medication was routinely administered for implant surgery. Second-stage abutment connection was routinely performed after 4 months. Abutment selection was based on individual requirements and prosthetic planning. Only original ITI abutments were used. Patients returned for recall examinations twice per year.

Criteria for Evaluation. To evaluate the quantity and quality of implant survival, the following data were gathered. For the quality of implant survival, subjective data such as implant-related pain or discomfort and sensory disturbances were registered. Objective implant and peri-implant data consisted of the Plaque Index and Gingival Index according to Mombelli et al,[21] probing depth, and implant mobility tests (mobility test according to Lindhe,[22] percussion test, torque test at abutment connection,[17] and Periotest according to Schulte[23,24]). Peri-implant bone loss was determined based on orthopantomograms and periapical radiographs. Bone loss was calculated from radiographs taken at the time of abutment connection and the time of clinical investigation. Finally, complications during implantation, healing, and follow-up were recorded.

Table 6 Failing or Removed Implants, and Their Types, Locations, Suprastructures, and Possible Causes of Failures

Implant type	Location	Suprastructure	Cause of failure
Solid screw	Maxillary right first molar	None—healing phase	Infection
Hollow screw	Maxillary left second molar	None—healing phase	Infection
Hollow screw	Maxillary right second premolar	None—healing phase	Infection
Hollow screw	Maxillary right first molar	None—healing phase	Infection
Solid screw	Maxillary left first molar	Single crown	Mobility
Hollow screw	Mandibular left first molar	Single crown	Mobility
Solid screw	Maxillary left first premolar	Bar construction	Infection

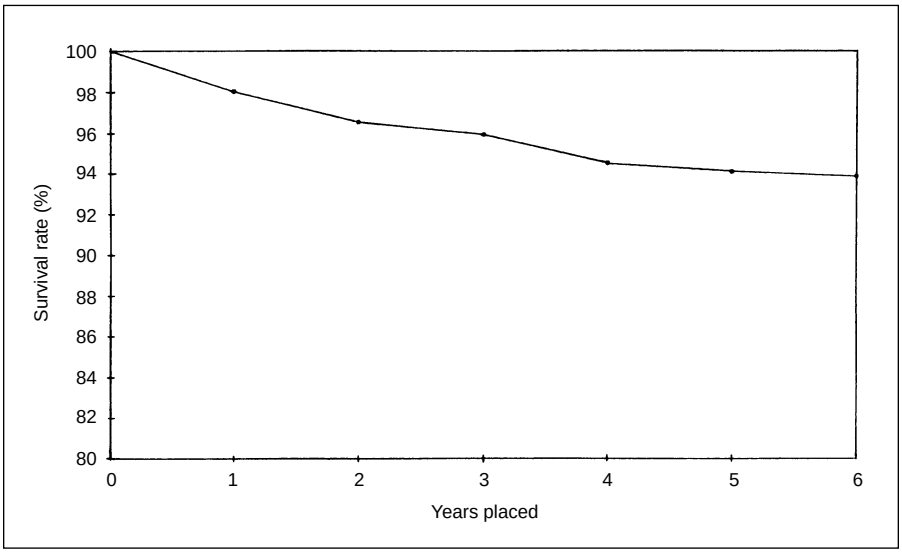


Fig 6 Life analysis of the cumulative survival rate of 6-mm ITI dental implants.

Results

Implant Survival. Altogether, 7 of the 253 implants placed were removed, for an absolute survival rate of 97% (Table 5). Five implants were removed because of inflammation. All of these were located in the maxilla (at the maxillary right and left molar and premolar sites). Four of these 5 implants were lost at a very early stage (during the healing phase). The fifth implant was lost after 2 years. The patient with this implant did not appear for regular recall visits; when she was finally examined, the implant was covered with calculus buildup and showed inflamed periimplant tissue. Two more implants were lost because of bone loss, without clear signs of inflammation. Both implants were carrying single crowns (at molar sites in the mandible and maxilla, respectively) (Table 6).

Of the 246 remaining implants, 28 were lost to follow-up for various reasons. Therefore, 218 implants could be investigated relative to quality of survival. The cumulative survival rate was 94% after 6 years (Fig 6).[25]

Quality of Survival. The quality of survival was determined in clinical evaluations. Clinically there were no signs of immediate failure. No patients exhibited sensory disturbances. However, at the time of the investigation, 2 patients (who had 2 implants each) complained of painful or sensitive mucosa around their 2 implants, with various degrees of periimplant inflammation. Around 12 implants, some degree of implantitis could be noticed at the time of examination. Plaque Index readings according to Mombelli et al[21] showed 74% grade 0, 24% grade 1, and 2% grade 3. The Gingival Index according to Mombelli et al[21] measured during the investigation was 81% grade 0, 26% grade 1, and 3% grade 2. Sulcus probing revealed a probing depth of 1 mm in 12% of the subjects, 2 mm in 43% of the subjects, 3 mm in 40% of the subjects, 4 mm in 3% of the subjects, 5 mm in 1% of the subjects, and more than 5 mm in 1% of the subjects.

All surviving implants withstood the torque forces (35 Ncm) necessary for abutment connection at the end of the postplacement integration period (3 to 4 months).[17] Mobility was 0, and the percussion test

Table 7 List of Problems and Adjustments of the Observed Implants During Follow-up

	No. of patients	No. of implants	Treatment	Treatment result
Inflammation	3	6	Antibiotics	Successful
Hyperplasia	8	28	Gingivectomy	Successful
Peri-implant bone loss	1	1	Repair—surgery	Successful
Peri-implant bone loss	2	3	Repair—surgery	Unsuccessful
Tension on bar when opening mouth	1	4	Cutting the bar in midline	Successful
Total	15	42		

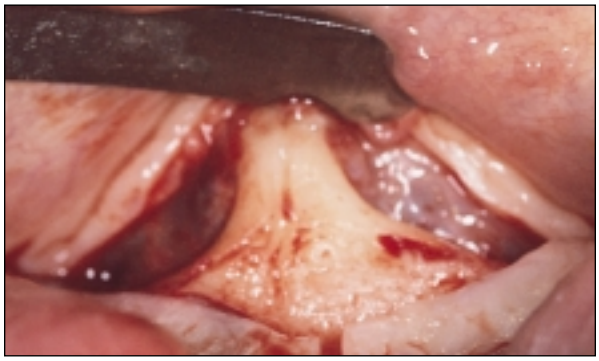


Fig 7 Perioperative photograph of a prominent genial tubercle.

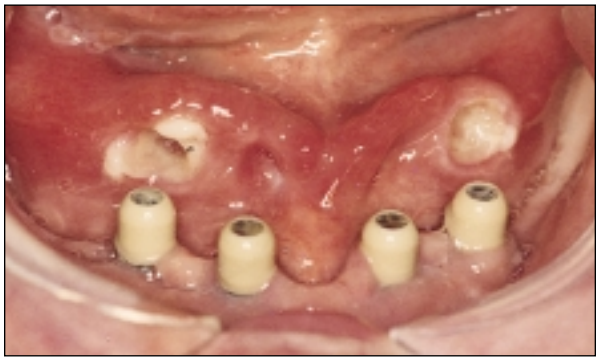


Fig 8 Extremely atrophic mandible with dental implants in combination with a protruding floor of the mouth causing lingual pressure ulcers, after abutment connection.

Table 8 Success Rate of Investigated 6-mm ITI Dental Implants[26]

No. placed	253
Implants lost during healing phase	4
No. of implants loaded	249
Implants lost after loading	3
Unable to monitor	28
Implants at risk	225
Monitored implants	218
Subjective complaints	4
Various degrees of peri-implantitis	12
Implant mobility	0
Radiolucency	7
Success rate (%)	93.8

was "metallic" in all patients. In one clinic, Periotest measurements were registered on a total of 105 functioning implants. All but one implant measured negative Periotest values. In fact, 90% of the implants showed values under –4. Bone levels around implants were compared with bone levels at the time of abutment connection. Radiologic findings of peri-implant bone loss since abutment connection showed no bone loss in 72% of the patients, 1 mm of bone loss in 16%, 2 mm of bone loss in 9%, and more than 3 mm of peri-implant bone loss in 3%.

Complications. During the follow-up period, 3 patients with peri-implantitis around 6 implants were successfully treated with antibiotics. Eight patients with 28 implants in the interforaminal region of severely atrophic mandibles showed gingival hyperplasia underneath the bar and required surgical correction (Table 7). After correction, the peri-implant conditions were normal. Three patients with bone loss of more than 3 mm and peri-implantitis symptoms underwent "repair" surgery. Of those 4 implants, 1 seemed to be successful, while the other 3 implants, although functioning, appeared to have a bad prognosis. Taking all these factors into consideration, a survival rate of 93.8% was achieved (Table 8).[16,26] One patient with four 6-mm implants in the interforaminal region complained about feelings of tension when opening the mouth. The problem was alleviated by cutting the bar in the midline.

One of the difficulties encountered during surgery was the high position of the floor of the mouth in patients with severely atrophic mandibles. Postoperatively, this sometimes caused a tendency for the mucosa to slip over the large closure screws covering the implants during the first month. Also some difficulties with prostheses at the site of the genial tubercle or with hygiene procedures were experienced later (Fig 7).

Discussion

The 1- to 7-year results from using 6-mm long dental implants are promising within the conditions mentioned earlier in this article. This means that the authors have had little experience with the use of 6-mm implants in situations involving single-tooth replacement, retentive anchors on 6-mm implants, or fixed prostheses supported exclusively by 6-mm implants. These are categories in which, because of unfavorable load-to-anchorage or crown-to-root ratio, the failure ratio may rise to higher levels. The 2 "delayed early" failures with single-tooth replacements might be an indication of that phenomenon.

Buser has defined success criteria as follows[16]: *(1)* absence of subjective complaints; *(2)* absence of implant mobility; *(3)* absence of signs of peri-implant inflammation; and *(4)* absence of continuous peri-implant bone loss (as determined using radiographs). Using these criteria, the success rate would be 93.8% (Table 8).

During the duration of this study, the presently available hollow-screw and solid-screw implants were employed, as well as 68 experimental hollow-cylinder implants. Although the hollow-cylinder implant has no threaded design, its clinical success was similar to that of the hollow screws and solid screws. But because of concerns about good primary stability, only the 2 threaded implants (hollow-screw and solid-screw) have been on the market.

As noted previously and in recent publications, the use of short implants raises the question as to whether the clinical limits of oral implants have been reached or whether for some indications and bone types (particularly type IV) the limits have been overstepped. However, in light of the findings of this investigation, it cannot be concluded that an implant length of less than 8 mm is, in principle, unacceptable. Certainly bone quality seems to be one decisive factor, since 6 of the 7 removed implants were situated in the maxilla. However, if the implants that failed during the integration phase are disregarded, only 2 loaded implants failed in the maxilla.

However, bone quality alone is not the only factor that influences success or failure. In their studies, Jaffin and Berman[2] and Quirynen et al[5] found that implant lengths were directly related to failure rates. However, this phenomenon could not be clearly detected in the clinical results of ITI implants.[27–31] An obvious conclusion would be that implant design and therefore the implant-bone interface also play an important role in this respect.[32,33] The rough (plasma-sprayed) implant surface used in this study may have compensated for the shorter implant length.

As mentioned, under preoperative diagnosis, the orthopantomogram may suggest an inaccurate bone height, because of the possible slanted configuration of the lingual aspect of the mandible. If the surgeon is not aware of this, longer implants and thus deeper preparations might be chosen, which in turn could provoke threatening hemorrhages.[34] CT scanning should be considered in extreme situations. The clinical experience of the surgeon in this situation is a valuable asset.

A problem that needs to be addressed is the previously mentioned unfavorable crown-to-root ratio seen in extremely atrophic arches. This leads not only to high moment forces on short implants but also results in large prosthetic restorations that may be heavy, esthetically unsatisfying, and uncomfortable for the patient. In some situations, short implants that are placed in severely atrophic arches will be positioned deep in a "negative" alveolar crest, along with their suprastructures, making them difficult to clean. For these reasons, surgeons might choose to augment the extremely atrophic mandible rather than placing 6-mm implants.[35–37] Then high position of the floor of the mouth, the extent of the genial tubercle, and the deep position of the suprastructure could be avoided, and the possibility of "spontaneous" fracture of the mandible could be eliminated (Fig 8). In the lateral mandibular area, augmentation would also be favored over the obvious risks of mandibular nerve transposition procedures.[38,39]

In the maxilla, sinus floor augmentation is a possible alternative to the placement of short implants.[40–42] Also, a combination of sinus lift and local augmentation of the total atrophic ridge could solve the lever action problems and eliminate esthetic complications.

Conclusion

It can be concluded that within the conditions described, the results of this trial are promising. These 6-mm implants can be used successfully in patients with minimal bone height, preferably when used in combination with other, longer implants.

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