Immediate Functional and Non-Functional Loading of Dental Implants: A 2- to 60-Month Follow-Up Study of 646 Titanium Implants

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Background: The aim of this study was the evaluation, from a clinical point of view, of implants subjected to immediate functional loading (IFL) and to immediate non-functional loading (INFL) in various anatomical configurations.

Methods: The study included 152 patients who had given their informed consent. A total of 646 implants were inserted. The implants were placed in 39 totally edentulous mandibles, 14 edentulous maxillae, 23 edentulous posterior mandibles, 16 edentulous anterior mandibles, 16 edentulous anterior maxillae, and 15 edentulous posterior maxillae. Fifty-eight implants were used to replace single missing teeth. In 65 cases, IFL was carried out for 422 implants. INFL was carried out in 116 cases, (224 implants).

Results: In the IFL group 6 of 422 implants failed (1.4%); in the INFL group 2 of 224 implants failed (0.9%). All the other implants appeared, from clinical and radiographic observations, to have successfully osseointegrated and have been functioning satisfactorily since insertion. All failures were observed in the first few months after implant loading.

Conclusion: Immediate functional and non-functional loading seems to be a technique that gives satisfactory results in selected cases. *J Periodontol 2003;74:225-241.*

KEY WORDS

Comparison studies; dental implants; dental implants, failure; loading; titanium.

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A healing period of about 4 to 6 months without loading is necessary to obtain mineralized bone tissue at the dental implant interface.[1] It is, however, important to emphasize that these time periods have been set up empirically and never verified experimentally.[2] Furthermore, it is also important to define whether these time limits are essential to obtain osseointegration of dental implants, or if they are merely treatment practice, as has been recently suggested.[2] It should also be remembered that the principle of a healing period without loading was proposed by Brånemark at a time when patients frequently presented with poor quality or limited quantities of bone; implant designs had not reached perfection; short implants were frequently used; surgical procedures were not ideal; and implants often had problems of a biomechanical nature.[3]

Today, the high level of predictability in implant dentistry has been well proven and documented. Consequently, some conventional implant protocols require reappraisal.[3]

It has been suggested that early loading could lead to the formation of fibrous connective tissue rather than bone at the implant-bone interface. In fact, a capsule of fibrous tissue was found around the implants that were not kept immobile during the healing process.[4] A similar effect has been reported to occur in bone fractures that had been immobilized inadequately resulting in a non-union.[4]

Microscopy of retrieved implants from man and experimental animals showed the presence of highly mineralized compact mature bone with many Haversian canals.[5-11] No connective tissue was present at the interface in any of the cases. At greater magnification, mature bone could be observed in close connection with the implant with no interface gaps. A Von Kossa silver nitrate stain showed the peri-implant bone to be highly mineralized in most cases.

Questions that may be important to clinicians include: 1) Can osseointegration be obtained for implants subjected to immediate loading? 2) Can osseointegration be obtained for immediately loaded implants placed not only in completely edentulous patients but also in partially edentulous cases including single teeth? 3) Is there an optimal surface for implants to be immediately loaded? The aim of the present study was a clinical evaluation of a large number of immediately loaded implants.

MATERIALS AND METHODS

Definitions of the loading modes used are given in Table 1.

Immediate Functional Loading (IFL)

The advantage of this method, besides surgery taking place in one stage, is the immediate delivery of the final prosthesis. The patient does not have to experience any functional and psychological discomfort associated with being edentulous (with or without removable prosthesis). The 6 implant systems and number of implants placed with this technique are shown in Table 2.

Primary Implants (PI)/Secondary Implants (SI)

A variant of IFL consists in what can be referred to for simplicity's sake as primary implant (PI)/secondary implant (SI). After placement of all the necessary implants, some (usually 3 or 4) are used to support the fixed prosthesis during the healing period. These implants, called secondary implants (SI), are considered disposable; i.e., they are meant to support the temporary prosthesis until the other implants (primary implants) have completely osseointegrated. If the excessive loading applied to these implants during the healing phase impairs osseointegration they are simply eliminated. If not, an assessment will be made as to whether to include them in the final prosthesis. The technique is most commonly used in totally edentulous jaws.[12-15]

Immediate Non-Functional Loading (INFL)

This technique combines the advantages of 1-stage implants with immediate loading. The provisional prostheses are not in occlusion and, therefore, serve only esthetic and soft tissue growth purposes.[16] The 6 implant systems and number of implants placed with this technique are shown in Table 3.

Both methods were monitored with intraoral radiographs at months 1, 6, 12, 18, 24, 36, 48, and 60 after loading. Periapical x-rays were taken following the Rinn parallel cone technique. The marginal bone height was measured from an individually selected reference point on the mesial and the distal surface of each implant. The distance from this reference point to the uppermost point of the interproximal bone level judged to be in contact with the implant surface was measured to the closest 0.5 mm. Clinical implant mobility was checked after 6 months, when the temporary restoration was first removed. At this recall, peri-implant probing depth measurement was also performed. However, these findings were not considered statistically relevant because of the controversy about the correlation between probing and implant success rate.[17-19] All patients had given their prior informed consent and the protocol was approved by the ethical committee of Cheti University. The medical status including current and previous disease history and medications was recorded. Exclusion criteria included: systemic disease; insufficient amount of bone; severe parafunctions; drug or alcohol abuse; heavy smokers (>20 cigarettes per day); antiblastic chemotherapy; chronic renal disease; chronic liver disease; uncontrolled diabetes; hemophilia, bleeding disorders or anticoagulant therapy; immunocompromised conditions, including HIV; poor oral hygiene; mucosal diseases such as lichen planus; uncooperative patients with unrealistic expectations.

Fully and partially edentulous patients were treated with immediate functional loading in the first year of this study. A change of protocol was necessary because of failures and to avoid occlusal contact which may have jeopardized

Table 1.

Loading Mode Definitions

Loading Mode	Definition
Submerged	Flush with bone level, covered by the gingiva
Nonsubmerged	Nonsubmerged, flush or within 1 to 2 mm of gingival level
Immediate functional loading	Temporaries same day of the surgery; in occlusion
Immediate non-functional loading	Temporaries same day of the surgery; not in occlusion
Early loading	Final crowns within 3 weeks from surgery; in occlusion
Anticipated loading	Temporaries within 8 to 10 weeks from surgery

Table 2.

IFL Implants

Implant	N Implants	N Failures	% Implant Survival	% Prostheses Survival
Frialit 2*	82	6	94.7	93.7
IMZ*	44	0	100	100
Frialoc*	37	0	100	100
Brånemark†	63	0	100	100
Restore‡	70	0	100	100
Maestro§	126	0	100	100
Total	422	6	98.6	98.5

* Friadent, Mannheim, Germany.
† Nobel Biocare, Göteborg, Sweden.
‡ Lifecore Biomedical, Chaska, MN.
§ Biohorizons, Birmingham, AL.

Table 3.

INFL Implants

Implant	N Implants	N Failures	% Implant Survival	% Prostheses Survival
Frialit 2*	62	2	96.6	95
IMZ*	7	0	100	100
Restore†	27	0	100	100
Maestro‡	116	0	100	100
Brånemark§	10	0	100	100
31‖	2	0	100	100
Total	224	2	99.1	98.3

* Friadent, Mannheim, Germany.
† LifeCore Biomedical, Chaska, MN.
‡ Biohorizons, Birmingham, AL.
§ Nobel Biocare, Göteborg, Sweden.
‖ Implant Innovations, Inc., West Palm Beach, FL.

the implants. Subsequently, only the totally edentulous patients were treated with IFL while all other anatomical configurations were treated with INFL.

Success Criteria

An implant was considered to be successful if the following criteria were met:[20] 1) The implant was clinically stable (i.e., no mobility or sign of mobility was found when the prosthesis was manually examined). 2) There was no sign of pain, infection, or other pathologic reaction in the hard or soft peri-implant tissue. 3) Radiographs showed no sign of peri-implant radiolucency. 4) The mean marginal bone loss did not exceed 1.5 mm in total after 3 years, as measured from the baseline radiograph reference point.

An implant was considered to have osseointegrated successfully if it was still in function without complications, but the marginal bone loss was in excess of what was stated in the success rate requirements, or evidence to verify success was lacking.

An implant was considered to have failed if it was removed for any reason; it had fractured beyond repair and could no longer function as support for the prosthesis; or it did not fit any of the success or survival criteria.

Marginal Bone Loss

The marginal bone level was read from periapical radiographs taken at the time of surgery and at each annual recall. A conventional radiograph Rinn holder was used (long cone technique). For IMZ TwinPlus and FRIALIT-2 implants, the marginal bone level was measured as the distance from the implant crown border to the most coronal point where the marginal bone met the implant.[21] A peak scale loupe with a 7-fold magnification factor and a scale graduated in 0.1 mm was used. The measurements were taken at the mesial and distal surfaces by a single examiner.

Surgical and Prosthetic Techniques

For the IFL technique, surgery was started with a crestal bone incision or sulcular incision in case of fresh extraction sockets.

When not indicated for specific anatomical reasons, separation beyond the mucogingival junction was avoided and, if necessary, an osteoplasty was carried out. Implant sites were prepared using surgical templates according to the protocols of the implant manufacturer. Implants with platforms were placed supracrestally in the same manner as the implants with a collar. The impression of bar-supported overdentures was taken preferably with the pick-up method. The healing screws were inserted, then the retainer bar was mounted. The prosthesis and the bar were placed late in the afternoon of the same day. The provisional abutments were positioned for a fixed provisional temporary. Subsequently, the previously prepared provisional template was relined with acrylic, allowed to cure, trimmed, and finally cemented or screwed in place a few hours later. A soft diet was recommended for a few weeks and a nightguard provided (Figs. 1 through 11).

For the INFL technique, the surgical technique was exactly the same as for IFL. The provisional prosthesis was adapted (generally just a few units) to the abutments of the different implant systems, keeping it about 1 or 2 mm shorter centrally and laterally, out of occlusion (Figs. 12 through 17).

RESULTS

Between April 1996 and April 2001 the authors placed 422 immediately functional loaded (IFL) implants, 224 immediately non-functional loaded (INFL) implants

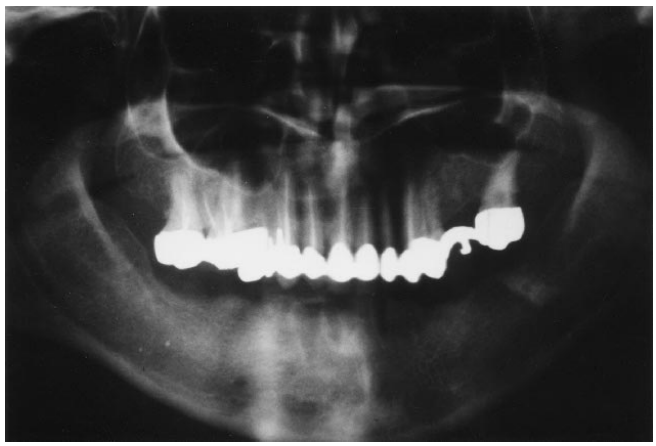

Figure 1.
Presurgical x-ray.

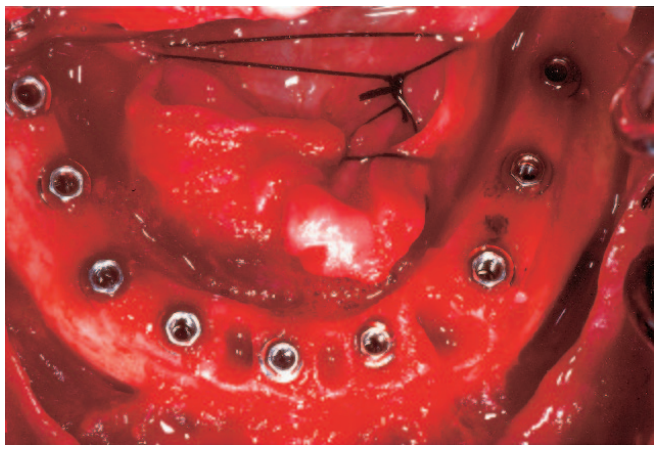

Figure 2.
Implants in place (occlusal view).

Figure 3.
Empty shell (acrylic only).

Figure 4.
Immediate provisionalization (cemented).

Figure 5.
Postsurgical x-ray.

Figure 6.
Six months postsurgery.

Figure 7.
Final abutments (occlusal view).

Figure 8.
Final restoration (occlusal view).

Figure 9.
Final restoration (facial view).

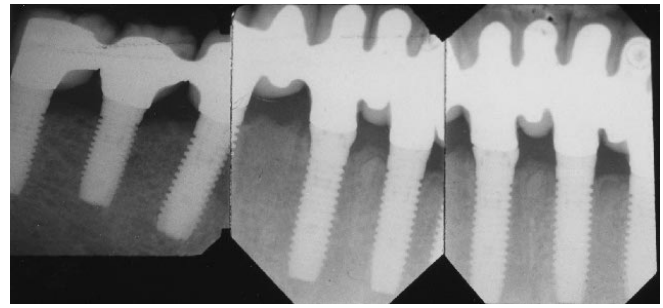

Figure 10.
Control periapical x-rays (after delivery of the final restoration).

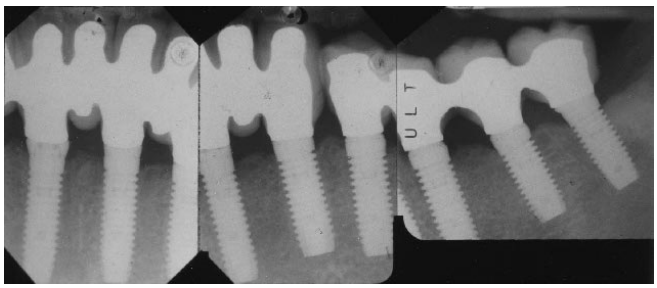

Figure 11.
Control periapical x-rays (after delivery of the final restoration).

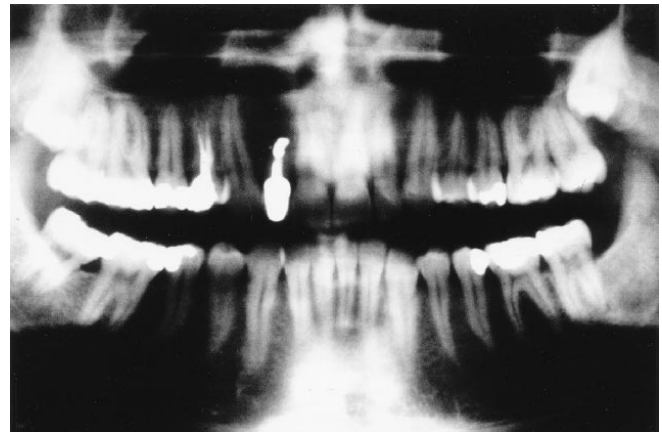

Figure 12.
Presurgical x-ray of a hopeless lateral incisor.

and 24 implants using the primary/secondary method. A total of 152 patients were treated, 68 males and 84 females aged between 18 and 75 years.

Immediate Functional Loading (IFL)

IFL was used in 65 patients: 39 edentulous mandibles, 14 edentulous upper jaws, 2 edentulous posterior maxillae, 4 edentulous anterior maxillae, 1 edentulous anterior mandible, and 5 edentulous posterior mandibles (Table 4). Of the 422 implants placed, 187 were positioned in post-extraction sites and 235 in healed sites.

The prosthetic restorations were a bar-retained overdenture in 17 cases and a fixed provisional prosthesis in 48 cases.

Figure 13.
Immediate implantation and provisionalization.

Figure 15.
Six months postsurgery.

Implant failures. After 3 months, one patient complained of pain in the implant region. The bridge was removed and 2 of the 3 implants were found to be mobile. They could be easily removed. On removal of the fixed provisional prosthesis at the 6-month recall, a second patient presented 2 maxillary implants with a vertical bone loss of more than 50%. The implants were removed. In a third case, an implant was lost as the bridge came off due to cement failure, while another one was removed because it had not osseointegrated. All the failures were observed in the first year of loading, and also within the first year of the research. No additional implants failed in the following 4 years. Analysis of the implant failures is shown in Table 5. The failures were not specifically related to bone quantity, bone quality, implant type, diameter, length, position in the arch, patient's general health, type of prosthesis, patient's age and gender, type of abutment used, intraoperative complications, extraction sites, and dental history. All the other implants seemed to have osseointegrated well from a clinical and radiographic point of view. The cumulative implant survival rate was 98.6% while the prostheses survival rate was 98.5% (Table 4). Table 4 shows the distribution of the IFL cases according to the anatomic configurations.

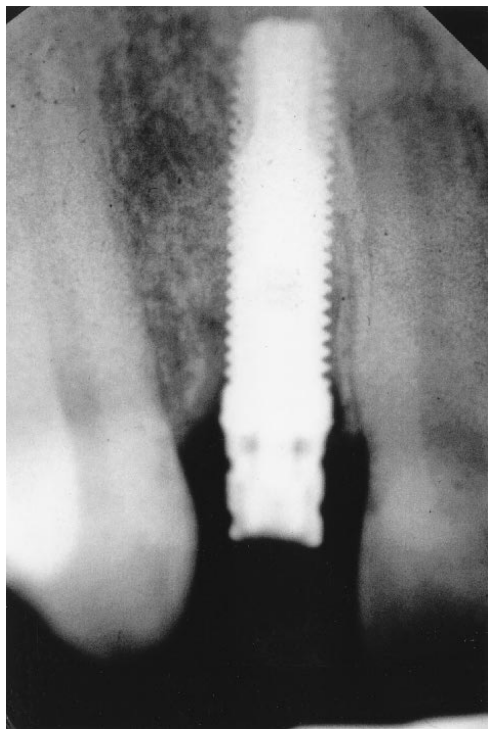

Figure 14.
Postsurgical x-ray.

Figure 16.
Final restoration.

Marginal bone loss. The data have been recorded for all implants placed over the past 5 years. However, only the results of the first group of 93 implants placed in 1996 and followed up to 5 years are presented here

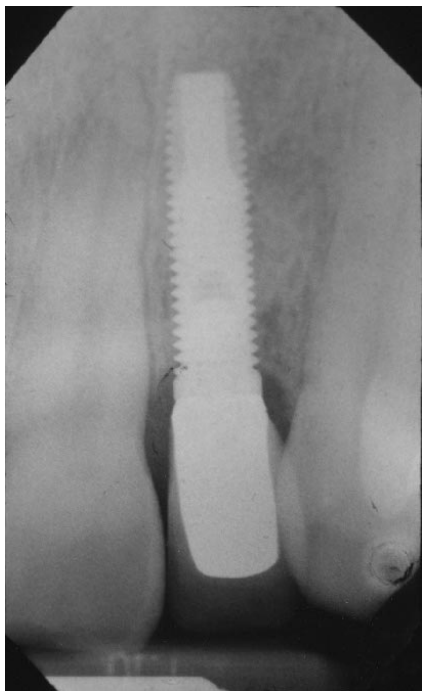

Figure 17.
Control x-ray (after delivery of the final restoration).

(Table 6). The data on the other implants will be considered in a second study, after a longer follow-up period.

At the 5-year examination, the 87 original implants remaining in place were evaluated. Because there were no significant differences between measurements on the distal and mesial aspects, only mean values are presented. The mean marginal bone loss value is the difference between the rough part of the implant that is no longer in contact with bone and the distance from the reference point. After the first year, the mean marginal bone loss was 0.6 ± 0.2 mm and 1.1 ± 0.2 mm at the 5-year evaluation (Table 7). No patient showed any progressive marginal bone loss over time (Figs. 18 through 27).

Immediate Non-Functional Loading (INFL)

INFL was the treatment of choice in 15 edentulous anterior mandibles, 18 edentulous posterior mandibles, 12 edentulous anterior maxillae, 13 edentulous posterior maxillae; 58 implants were single-tooth restorations (Table 8, 116 patients). Of the 224 implants, 97 were positioned in post-extraction sites and 127 in healed sites. The final prosthesis was cemented in all cases.

Implant failures. In one case, an upper central incisor, restored with an unloaded provisional implant-supported crown immediately after extraction, presented mobility of the implant and of the provisional restoration just a few weeks after placement. The whole assembly had to be removed. Besides being a smoker, the patient had an habitual tongue movement, exerting continuous pressure on the recently placed restoration. A second patient lost his upper central incisor implant 2 months after immediate loading. In both cases, the bone condensing technique (with osteotomes) was used to shape the implant site and both implants were positioned into immediately extracted sites (Table 9). All the other implants appeared to have osseointegrated well, clinically and radiographically. The cumulative implant survival rate was 99.1% while the prostheses survival rate was 98.3% (Tables 3 and 10).

Primary Implants (PI)/Secondary Implants (SI)

Two totally edentulous mandibles were restored, 1 with 13 implants and the other with 11 implants; 9 were SI and 15 PI. In one case, 3 of the 5 secondary implants were mobile when the fixed prosthesis was removed. In the second case, 3 of the 4 secondary implants had not integrated. These implants were easily removed.

DISCUSSION

Ledermann[23,24] used titanium plasma-sprayed threaded implants to support mandibular overdentures in a

Table 4.

IFL Implants by Placement Site

Site	Patients (N)	Implants (N)	Failures (N)	Survival (%)	Prostheses Failures (N)	Prostheses Survival (%)
Mandible, full	39	241	0	100	0	100
Maxilla, full	14	133	2	98.5	0	100
Mandible, anterior	1	4	0	100	0	100
Mandible, posterior	5	22	2	91	1	80
Maxilla, anterior	4	16	2	87.5	0	100
Maxilla, posterior	2	6	0	100	0	100
Total	65	422	6	98.6	1	98.5

Table 5.

IFL Failures

Patient	Age	Gender	Smoker	Bone Quality[22]	Bone Quantity[22]	Implant Type	Implant		Location	Restoration Type	Abutment	Complications	Extraction Site	Months Since Loading
							Diameter	Length						
1	57	M	No	D3	C-h	Frialit2	5.5	10	4	FTB Cemented	Acrylic*	Sinus penetration	No	6
1	57	M	No	D3	C-h	Frialit2	5.5	10	13	FTB Cemented	Acrylic*	Sinus penetration	No	6
2	37	F	No	D1	B	Frialit2	3.8	8	19	FTB Cemented	Acrylic*	None	No	3
2	37	F	No	D1	B	Frialit2	4.5	10	18	FTB Cemented	Acrylic*	None	No	3
3	44	F	No	D2	B	Frialit2	4.5	15	8	FTB Cemented	Acrylic*	No primary stability	No	6
3	44	F	No	D3	B	Frialit2	4.5	15	12	FTB Cemented	Acrylic*	No primary stability	No	6

FTB = Fixed temporary bridge.
* Protect, Friadent, Mannheim, Germany.

Table 6.

Life-Table Analysis (IFL implants)

	Months Loaded									
Outcome	0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60
Success	422	317	244	172	142	126	118	114	105	93
Failure	6	–	–	–	–	–	–	–	–	–

Table 7.

Marginal Bone Loss (IFL implants)

	Baseline-1 Year	Baseline-5 Years
N implants	87	87
Mean bone resorption (mm)	0.6	1.1
SD	0.2	0.2

follow-up study from 1 to 81 months. A total of 476 implants were placed in 138 patients with a success rate of 91.2%. In the studies by Schroeder et al.,[25-27] 53 implants were inserted to support a mandibular overdenture: the success rate was 98.1% (follow-up 5 to 48 months). Babbush et al.[28] followed the Ledermann protocol for mandibular overdentures. A total of 129 patients were treated with 514 implants and followed up for 5.5 years. During this period 20 implants failed, resulting in a success rate of 96.1%. All the failures occurred in the first year, of which 80% in the first 6 months. In the Dietrich et al. study,[29] 2 different implant systems were used to fabricate implant-retained overdentures in the mandible. The IMZ TwinPlus implants were placed according to the conventional 2-stage technique, while the TPS implants were splinted and loaded immediately. Six months after surgery, the success rate for the TPS implants was 92.5% and 99.3% for IMZ. After 5 years, 83.6% of the TPS implants were still in function, as were 94.6% of the IMZ. The authors concluded that immediate loading caused a higher failure rate. Spiekermann et al.[30] reported on cases of mandibular overdentures fixed to 3 implants splinted

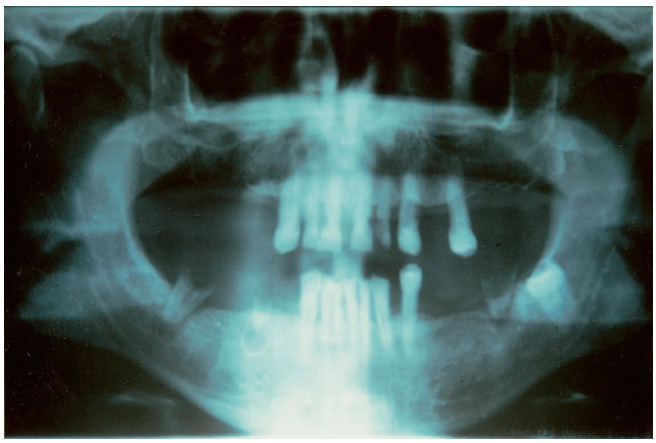

Figure 18.
Presurgical x-ray.

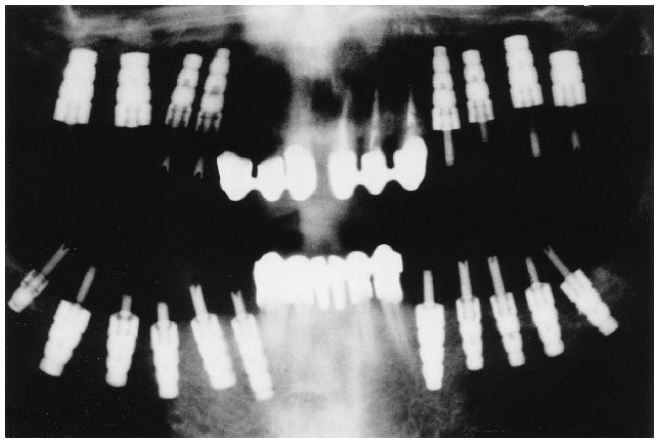

Figure 19.
Postsurgical x-ray showing immediate provisionalization by means of temporary abutments and acrylic screw-retained temporaries.

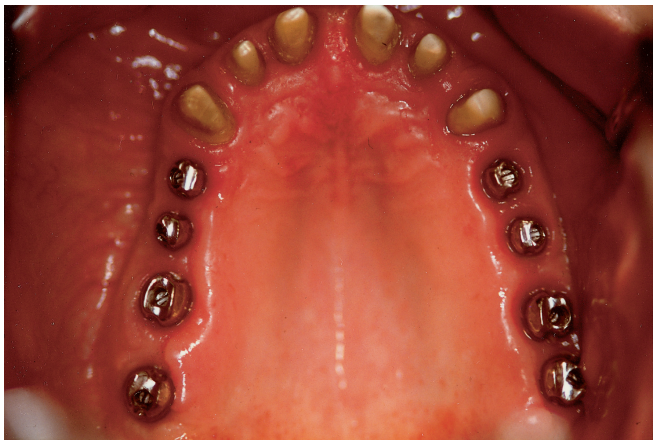

Figure 20.
The final abutments in place (maxilla).

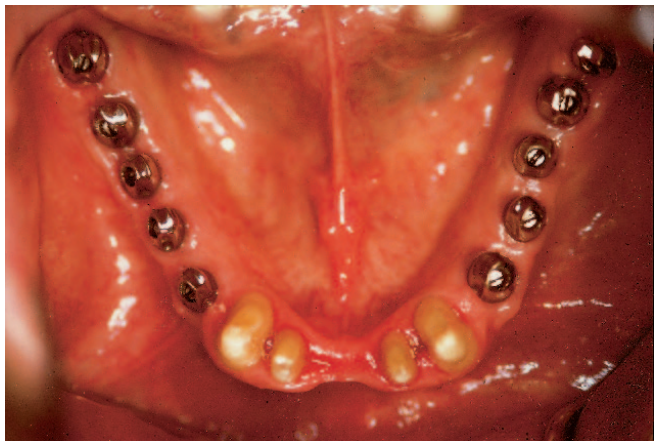

Figure 21.
The final abutments in place (mandible).

Figure 22.
The final restoration (maxilla).

Figure 23.
The final restoration (mandible).

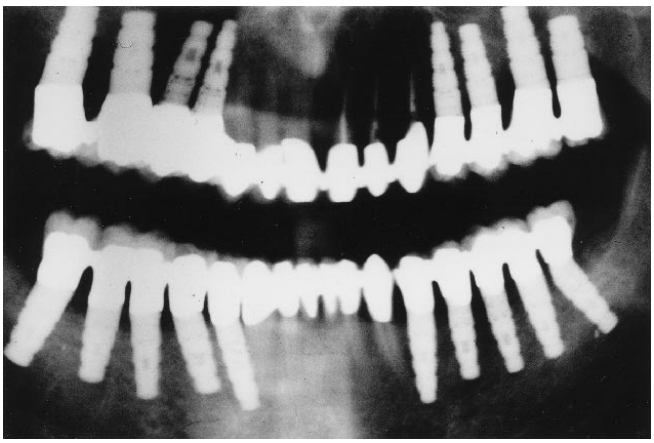

Figure 24.
Control x-ray (at prosthetic delivery).

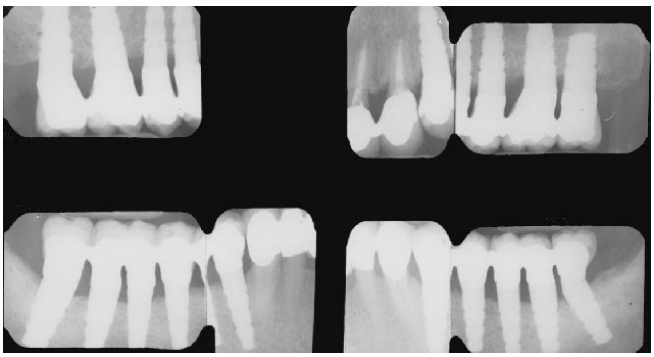

Figure 26.
Periapical x-rays at 3-year follow-up (1999).

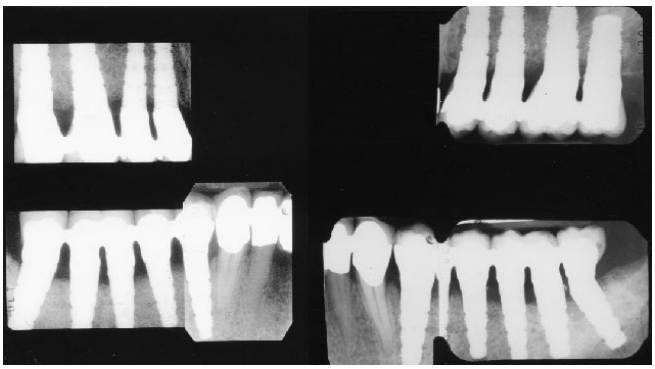

Figure 25.
Periapical x-rays at 1-year follow-up (1997).

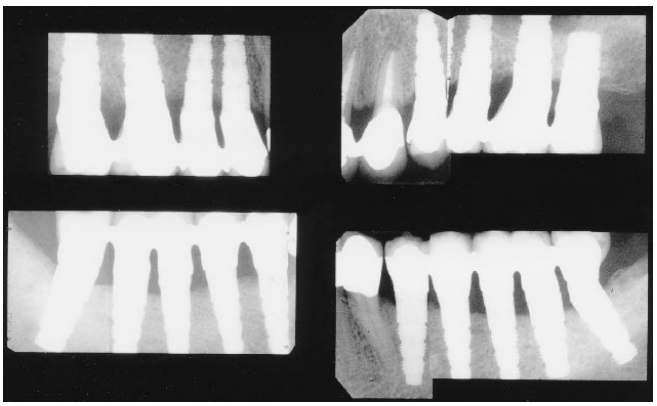

Figure 27.
Periapical x-rays at 5-year follow-up (2001).

with bar retainers and loaded immediately. The implant survival rate was 97.3% after a follow-up period of 5 years. Chiapasco et al.[31] published a retrospective multicenter study on 226 edentulous patients rehabilitated with overdentures on 904 immediately loaded implants. The reported success rate was 96.9%. Schnitman et al.[12,13] inserted 63 implants in 10 patients who did not wish to wear provisional prostheses during the healing period. Twenty-eight implants were loaded at the time of placement to support a provisional fixed prosthesis. The assumption was that the implants loaded immediately were likely to fail and were thus considered to be "disposable" implants to some extent. Surprisingly, on reopening, most of the implants were not mobile, and so they were incorporated in the construction of the final fixed prosthesis. At 10 years follow-up, 4 of the immediately loaded implants had failed. Most of the failures occurred in the first 6 months, while one implant failed after 21 months. The authors concluded that the submerged healing gave statistically better results than the immediately loaded implants. In the study of Salama et al.,[14] 2 patients were treated with (immediately loaded) secondary implants and primary implants (left submerged). No failures were reported after 2 years. In the study of Tarnow et al.,[32] 10 patients were subjected to immediate loading. The follow-up period was between 1 and 5 years. Sixty-seven of the 69 immediately loaded implants appeared to have osseointegrated clinically, as did 37 of the 38 submerged implants. Balshi and Wolfinger[15] reported on immediately loaded mandibular implants with a follow-up of 12 to 18 months. In total, 130 implants were placed in 10 patients (minimum 10 implants per patient). At the end of the follow-up period, 32 of the 40 immediately loaded implants (80%) and 86 of the 90 submerged implants (95.6%) were still clinically stable. The authors concluded that premature loading of the implants led to a lower than average implant survival rate. Randow et al.[33] treated 16 completely edentulous patients with 88 implants inserted in the mandible, using a 1-stage procedure. Fixed rigid prosthetic reconstructions were placed within 20 days after implant surgery. These patients were compared to a control group consisting of 11 patients

Table 8.

INFL Implants by Placement Site

	Patients (N)	Implants (N)	Failures (N)	Survival (%)	Prostheses Failures (N)	Prostheses Success (%)
Single	58	58	2	96.6	2	98.5
Mandible, anterior	15	42	0	100	0	100
Mandible, posterior	18	56	0	100	0	100
Maxilla, anterior	12	32	0	100	0	100
Maxilla, posterior	13	36	0	100	0	100
Total	116	224	2	99.1	2	98.3

Table 9.

INFL Failures

Patient	Age	Gender	Smoker	Bone Quality[22]	Bone Quantity[22]	Implant Type	Implant Diameter	Implant Length	Location	Bone Condensing	Type of Restoration	Abutment	Parafunction Habits	Extraction Site	Months Since Loading
4	24	M	Yes	D2	A	Frialit2	6.5	15	9	Yes	FTB Cemented	Acrylic*	Tongue thrust	Yes	2
5	28	M	No	D2	A	Frialit2	5.5	15	9	Yes	FTB Cemented	Acrylic*	Hard food	Yes	2

FTB = Fixed temporary bridge.
* Protect, Friadent, Mannheim, Germany.

Table 10.

Life-Table Analysis (INFL implants)

	Months Loaded								
Outcome	0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54
Success	220	174	137	90	54	22	15	1	–
Failure	2	–	–	–	–	–	–	–	–

treated in the mandible with a 2-stage procedure in which the implants were loaded after 4 months of healing. At 18 months follow up, no implants were lost in either patient group. Gatti and coworkers inserted 84 implants in the mandibular intraforaminal area, reporting an overall failure rate of 4% after a mean follow-up of 37 months.[34] In a study of Horiuchi et al., 140 implants were inserted in edentulous patients. After an 8- to 24-month follow-up, 136 implants (97.2%) had osseointegrated.[35] Malò et al. found a cumulative survival rate of 96% at 1 and 2 years in 94 immediately loaded Brånemark implants.[36] The present study is the first one analyzing IFL also in partially edentulous patients (Table 4) with a radiographic follow-up of up to 5 years. The study shows that IFL and INFL techniques can be used with a high degree of reliability, based on the authors' observation period of 60 months. However, both methods require adequate training: lack of such training may lead to much higher failure rates.[32]

Analysis of Failures

IFL. As shown by other authors[13,32] and confirmed by our experience, almost all of the failures presented in the initial stages of the study when the bony interface

Table 11.

Implant Surfaces

Surface	IFL	INFL	Failures		Implant Survival (%)		Prostheses Survival (%)	
			IFL	INFL	IFL	INFL	IFL	INFL
RBM	122	42	0	0	100	100	100	100
SLA	119	62	6	2	94	97	98	97
Titanium plasma sprayed	60	25	0	0	100	100	100	100
Hydroxyapatite	58	83	0	0	100	100	100	100
Machined	63	12	0	0	100	100	100	100

RBM = Resorbable blast medium; SLA = sandblasted large grit acid-attacked.

starts remodeling. All failures occurred in the first year of the study, at the beginning of the authors' learning curve (Table 5). They should therefore not be attributed to the quality of the implant. In the following years, no other failures were registered (Table 6). In one case, there was a prosthetic cement failure on 2 occasions during the first few months of healing. Unfortunately, the patient did not promptly return to have it put back into place.

In a second case, it was difficult to achieve primary stability during surgery. In a third case, both implants projected into the sinus floor bilaterally. No signs or symptoms of failure were present. At the 6-month reevaluation, when the temporary prothesis was removed, a pocket greater than 50% of the implant length was noted. The implants were considered failures and removed. A series of other data were considered in the implant failure analysis and they are listed in Table 5.

Four out of the 6 failures were found in immediately loaded bridges in partially edentulous patients. After the first year of clinical trial, the implants of the partially edentulous patients were no longer immediately loaded. Instead, they were subjected to immediate nonfunctional loading; i.e., temporaries out of occlusion. The excessive load applied on these small bridges could have been the reason for the high failure rate. As soon as the partially edentulous patients were restored with same day temporaries out of occlusion, no more failures were experienced.

INFL. All anatomical configurations were treated with this technique except totally edentulous jaws (Table 8). The results were encouraging. The 2 failures which occurred are analyzed in Tables 9 and 10. The reason for the failure in the first case can be attributed to the patient's specific tongue movement which caused significant stress to the provisional crown on the upper central incisor during the healing period. This parafunctional habit was not given sufficient importance at the first visit. In the second case, the patient's collaboration was far

Table 12.

Total (IFL and INFL)

	Prosthetic Unit/Implant-Ratio (PU/I)			
	Completely Edentulous*		Partially Edentulous	
	Maxilla	Mandible	Maxilla	Mandible
Prosthetic Units	145	194	158	161
Implants	127	148	139	133
PU/I	1.1	1.3	1.1	1.2

* Overdentures are not included.

from optimal and he chewed heavily on the temporary. In both cases, the bone condensing technique had been used for placing the implants. The authors consider that this procedure, when applied to bone sites other than D4 quality, could lead to a traumatized implant site that could respond negatively if immediately loaded. In addition, the 2 failures were related to immediate extraction sites. Despite the excellent results obtained, even in the cases of partially edentulous patients, the IFL technique should be limited to totally edentulous cases. Even if the quality of the bone is excellent, to immediately load; i.e., put the restoration in full occlusal contact, a single crown or a bridge with few elements, represents an unnecessary risk as compared to the INFL method. This latter method has all the advantages of IFL but eliminates the risk of applying too much load to the implants due to functional and parafunctional activity.

The PI/SI technique merits separate discussion. In the 2 cases carried out in this study there was a 25% failure rate for all implants (IP/IS), a figure which rises to 67% if SI alone is considered. The prosthetic survival rate was however 100%. It should be noted that other authors too, with larger case numbers, have had failure rates of 15%[13] or 20%,[15] which, although better than those of the present study, cannot be consid-

ered as satisfactory. It can be assumed that the heavy loading to which these implants were subjected, together with the flexibility of the spans which tend to be very long, cause the high failure rates. If this is viewed as a method using disposable elements, then such implants carried out their task perfectly well; i.e., the patient not having to wear a removable prosthesis during the healing period.

However, implant loss is an unpleasant experience (even if predicted) both for the patient and the surgeon, and sometimes can lead to complications of the adjacent implant sites. The authors ceased to use this technique, preferring to carry out IFL in the totally edentulous jaw which showed a much lower failure rate, probably due to the fact that load distribution was better.

Implant macrostructure. In this study several different implant geometries were employed, all of them providing high primary stability. The FRIALIT-2, the IMZ TwinPlus and the Restore implants were always used in their self-tapping threaded version. The Maestro implant required the tapping of the site, due to its square threading. Primary stability was more important in single tooth and partially edentulous arches. In totally edentulous cases, bilateral splinting provided primary stability even in those cases where this was lost either wholly or in part due either to the implant design or to poor bone quality. Other factors to be considered in the search for the "ideal implant" include the surface area in relation to size, the design of the crest module, and the manner of transmission of loading to the bone as far as possible by compressive forces.[16]

Implant microstructure. As can be seen in Table 11, almost all the implant surfaces available were used in the study. The search for the best osteophilic microstructure certainly represents an important objective for anyone wishing to use these techniques which are undoubtedly more demanding in terms of their ability to bear early implant loading.

Bone resorption. Analysis of the radiographical data limited to the group of 87 implants followed up to 5 years leads us to the conclusion that peri-implant resorption in IFL is comparable to 2-stage implant placement methods subjected to an equal loading period.[20,37-40] No differences were observed between implants in different anatomical configurations. Minimizing soft tissue surgery appears to reduce initial bone loss.

Soft tissues. As previously reported,[41] due to the minimal elevation of the flap and to the fact that bone resorption was very limited, the soft tissues were not modified. A very good long-term stability of the hard and soft tissues could be noted in single teeth. This could also be due to the strict recall program with reinforced oral hygiene instructions and good patient cooperation.

Implant splints. Micromotion at the bone-implant interface seems to be tolerated up to a certain threshold

Table 13.

INFL Prosthetic Unit/Implant-Ratio (PU/I)

	Maxilla	Mandible
Prosthetic units	136	132
Implants	117	107
PU/I	1.2	1.2

Table 14.

IFL Prosthetic Unit/Implant-Ratio (PU/I)

	Completely Edentulous		Partially Edentulous	
	Maxilla	Mandible	Maxilla	Mandible
Prosthetic units	145	194	22	29
Implants	127	148	22	26
PU/I	1.1	1.3	1.0	1.1

level.[2,42-46] Implants coated with hydroxyapatite tolerate micromotions better than non-coated implants.[2] No critical threshold level has yet been precisely determined, but 50 to 150 microns are recommended.[42-44,46] Splinting seems to be important in conditioning the peri-implant tissue response insofar as the mechanical stress acting on the implants is thereby reduced. Consequently, stability of the prosthesis is significantly increased and micromotion at the interface can be maintained below the critical threshold.[2] In addition, a healing period without loading is not necessary when using threaded implants splinted to each other.[2] The experimental and clinical results of this study are confirmed by several other studies on man carried out on immediately loaded implants.[12-14,31,32]

Primary stability. Primary stability is a very important parameter in achieving osseointegration.[47-51] Several authors[35,38,52] reported that high torque values would provide a better primary stability leading to higher success rates. The optimal torque threshold was first thought to be 45 N,[52] then 35 N,[36] or 42 N.[35]

When this study was started, there was no device available on the market to record the torque value. Consequently, no records were kept of the amount of torque necessary to place the implants. However, all the surgeries were performed by the same surgeon with the same drilling unit. Since the unit‡ used could not exceed the 35 N threshold, no implants were placed with more than 35 N. Whenever the cutting resistance exceeded the unit capacity, the bone was

‡ Osseocare, Nobel Biocore, Göteborg, Sweden.

Table 15.

Days Elapsed Between Implant Surgery and Prosthesis Delivery

Reference	Days
Balshi and Wolfinger[15]	0 to 24
Salama et al.[14]	7
Tarnow[32]	0
Schnitman et al.[12,13]	0
Chiapasco et al.[31]	1
Randow et al.[33]	20
Babbush et al.[28]	2 to 3
Degidi and Piattelli (current study)	0

either tapped or the implant unscrewed and re-seated. The implant should gently engage the bone in order to avoid too much pressure at the bone interface which could jeopardize healing.

Based on our experience, we tried to address the following questions related to immediate loading:

What is the optimal or minimum ratio between the number of prosthetic units and the number of implants (PU/I)?

The PU/I ratio should be as close as possible to one. Based upon the authors' experience (Tables 12, 13, and 14) the PU/I value should not exceed 1.4 in the maxilla and 1.5 in the mandible, independently of IFL or INFL implants. The optimal PU/I value is found in the single tooth restoration (PU/I = 1). A high PU/I value could produce bending and flexure of the interim restoration leading to micro-movement at the implant-interface and fibrous encapsulation. Higher clinical failure rates have been reported with PU/I greater than 2.[13,15] A low PU/I ratio improves the long-term prognosis of implants[53-58] and of the prosthetic restorations. This applies even more to demanding situations such as IFL/NFL. The PU/I value is a "safe side" parameter. Modifications in the stress factors (bone quality, implant diameter, peri-implant region, implant design, implant crest module,[59] opposing arch, etc.) can change the PU/I to a higher or smaller value. It is important to fabricate a prosthetic restoration that prevents the transfer of excessive load to the interface.[60] It is therefore necessary to: avoid long bridge spans; use rigid metallic abutments; use metallic reinforcements to the provisional prosthesis; decrease, when possible, the height of the clinical crown; avoid occlusal contacts in parafunctions or wear a night guard; and avoid cantilevers. Other factors that must be kept in mind are implant diameter, bone quality, and implant length.

Table 16.

Loading Mode Analysis in the Current Literature (fixed restorations)

Reference	Cases	Secondary Implants*	IFL Implants	Total	Unloaded Implants
Balshi and Wolfinger[15]	10/10	40	0	40	90
Tarnow et al.[32]	8/10	49	20	69	38
Salama et al.[14]	2/2	7	0	7	11
Schnitman et al.[12,13]	10/10	28	0	28	35
Totals	30/32	124 (86%)	20	144	174

*Immediate overloading.

Table 17.

Loading Mode Analysis in the Current Literature (removable restorations)

Reference	Cases	Implants	Bars
Chiapasco et al.[31]	226	904	All
Babbush et al.[28]	129	514	All
Gatti et al.[34]	21	84	All

What is the optimal time interval between surgery and prosthetic delivery?

Every effort must be made in order to deliver the prosthesis to the patient on the same day of the surgery. Delaying the delivery even only a few days exposes the patient to an unpleasant experience because of postoperative swelling.

Which technique should be used for partial and which for total edentulism?

IFL should be used in totally edentulous patients, and INFL in partially edentulous patients and for single tooth replacements.

Should the immediate fixed provisional prosthesis only be acrylic or should it have a metallic reinforcement? Should the prosthesis be screw-retained or cemented?

A screw-retained prosthesis is preferred for the following reasons: it has a higher rigidity compared to the cemented prosthesis since the quantity of metal is higher. The procedures are easier during the healing period, prosthetic delivery, and recalls. No metallic reinforce-

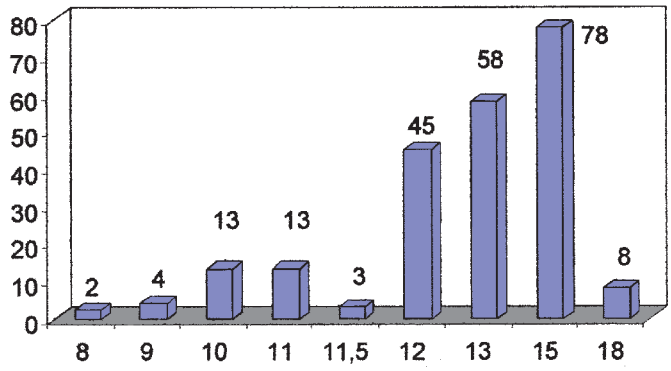

Figure 28.
INFL implant lengths.

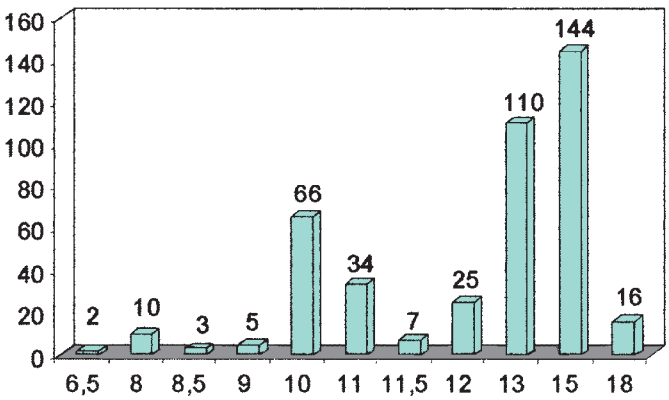

Figure 29.
IFL implant lengths.

ment has been used for this study, contrary to what has been proposed by Tarnow et al.,[32] and no disadvantages were observed. However, it must be pointed out that the low PU/I ratio (close to 1.0) reduced the flexibility of the temporaries. Whenever a greater PU/I ratio is anticipated, a metal reinforcement to decrease bending of the temporary structure could be of some help.

Is there an ideal abutment?

In the authors' opinion, the ideal abutment does not exist. It should present the rigidity of a titanium abutment, but it should be able to be prepared like an acrylic abutment. In addition, it should be cost-effective and have an internal screw of sufficient length or design to prevent loosening during the healing period.

Is there a torque threshold below which IFL/INFL is not indicated?

Different values have been reported for the torque values registered during implant placement. Values between 32 and 40 N have been reported in the literature.[35,36] Lower torque values have also been used to load the implants, and the results have been similar to those of the other implants. When the values were higher than 35 N, the implants were unscrewed and rescrewed until these values decreased significantly. In conclusion, excessive shear and torsion forces at the interface could produce an unfavorable bone response.

What is the long-term outlook for the implant-bone interface?

Clinical and radiographical results have shown that immediately loaded implants remain osseointegrated for long periods (up to 5 years). In the present study, both surgery and prosthetic restoration were performed by the same clinician. This could be one of the reasons for the high success rates.

CONCLUSIONS

Some clinicians load implants the same day, while others wait for 6 weeks (Table 15). The term "immediately loaded implants" should refer only to implants loaded the same day. An analysis of the literature (Table 16) shows that the majority of immediately loaded implants are, in fact, secondary implants. The masticatory load is distributed on a few implants until it is possible to use the primary implants. This is a situation of immediate overloading, and these primary implants should not be compared with real immediately loaded implants. In some studies (Table 17), immediately loaded implants were used in edentulous mandibles, in the interforaminal area, and in association with bars. This last situation is extremely favorable from a biomechanical point of view due to an excellent bone quality, a low profile of the prosthesis, and the possibility of removing it at night or whenever necessary and could be regarded as immediate underloading. Therefore, it cannot be compared with cases of a provisional fixed prosthesis used in partial or total edentulism inserted the same day. These are the only cases that could be designated under the term of "immediately loaded" implants. A review of the literature shows that the same term "immediate loading" is used to define a variety of clinical situations. In order to compare data in a meaningful way, terminology should only refer to specific procedural situations. The authors suggest the following terminology: IFL = same day teeth plus occlusal contact and INFL = same day teeth without occlusal contact. Figures 28 and 29 show implant lengths used in this study.

In conclusion, the evaluation of loading times in this study considered the following factors: the conditions under which Brånemark placed implants particularly demanding; loading, in itself, does not prevent healing; early and immediately loaded implants osseointegrate, as has been shown in several experimental studies;[5-11] early and immediately loaded implants have been clinically demonstrated.[3]

In the authors' opinion, whenever esthetic, psychological, or functional conditions allow it, second stage surgery is no longer necessary. In totally edentulous patients IFL may be used in a reliable way, whether with

bar-retained overdenture or fixed provisional prosthesis. In the partially edentulous patient, where adequate bone quality and quantity are available, the INFL method brings together the advantages of IFL while reducing the biomechanical risks to a minimum. Careful patient selection remains, in any case, a matter of fundamental importance.

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