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Immediate loading in partially and completely edentulous jaws: a review of the literature with clinical guidelines

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Modern oral implantology has its roots in the 1950s when the first implants for regular application were introduced. Their use was not sustained by proper scientific or clinical evidence and hence the outcomes were poor, although successful cases were occasionally reported. The achievement of osseointegration of titanium screws (22) was a giant step in the evolution of the concepts largely applied at present. Per-Ingvar Brånemark placed his first turned commercially pure titianium implant in 1965 during a fixed full jaw anchored rehabilitation of the mandible in a totally edentulous patient. This patient died in 2009 with the original implants still in function. By and large, the 1970s was the era of developments, and research was performed in an empirical way by changing implant designs and surgical and prosthetic treatment protocols (24). Slowly, the initially disappointing clinical results improved and led to the first scientific reports verified in multicenter trials (183–185). With these, the worldwide acceptance of osseointegration became a fact. This acceptance was quickly followed by modifications to the original treatment protocol and of the original implant design.

The original Brånemark protocol advocated the use of a two-stage surgical approach in which the turned implants were buried for several months under the mucosa. This stress-free prolonged submerged healing period was considered a prerequisite to achieve osseointegration (3). It was believed that otherwise, soft-tissue interposition would occur and jeopardize the outcome. After 3–6 months a second surgery was required. At this stage the abutments were connected and the prosthetic procedure was initiated. Hence, this procedure is often called a two-stage approach. In Switzerland, on the other hand, the ITI group, under the supervision of Professor Dr André Schroeder, started with the development of titanium plasma-sprayed implants and showed that a one-stage approach, in which the coronal part of the one-piece solid implant was placed slightly supramucosally, led to predictable clinical results (28). Ericsson et al. (76) were among the first to show that turned implants could osseointegrate equally well with a one-stage approach in the interforaminal area of the mandible without jeopardizing bone remodelling. Even after 5 years in function, implant survival and bone remodelling were comparable in the anterior mandible (78). Later, Collaert & De Bruyn confirmed this surgical protocol in the posterior mandible (36), leading to the conclusion that the one-stage approach is a valid treatment option.

Linkow et al. (114) were among the first to attempt to load dental implants immediately; however, success was rather limited as a result of fibrous encapsulation (113). This made the dental community adopt the delayed protocol, with a period of unloaded healing, of 3–6 months, as the standard. Nevertheless, some researchers continued their quest to decrease the treatment time. Babbush et al. (13) reported 96.1% survival of implants after 5 years with immediately loaded overdentures. This led to the assumption that micro-movements up to 100 μm, previously thought to be harmful, did not hamper the osseointegration process (27). As an intermediate change to the original Brånemark protocol, early loading in the mandible was scrutinized. The initial evolution, from the delayed, predominantly two-stage, approach, to early and immediate loading, was summarized and reviewed up to 1998 by Szmukler-Moncler et al. (164). Several studies showed a similar clinical outcome, in terms of implant survival and bone loss, when the different surgical methods and loading protocols in the totally edentulous mandible were compared (37, 49, 74, 77).

On the other hand, De Bruyn et al. (48) inserted 184 turned Brånemark implants in 36 edentulous mandibles and loaded them with a 10–12-unit bridge after, on average, 18 (range, 0–52) days. In total, 13 of the implants failed within 3 months after surgery but up to 3 years no further losses occurred. The disappointingly high failure rate of 7.1% was caused by the failure of 12 implants installed in fresh extraction sockets. This value contrasted with the 0.7% failure rate of implants installed in healed bone. The surviving implants showed total crestal bone remodelling of 0.6 mm from implant placement to 3 years, which was indicative of a steady state. Although there was, at that time, limited evidence that tooth extraction and simultaneous implant placement with a delayed loading approach did not affect implant success (16), it was deleterious in the immediate loading protocol using turned implants in the completely edentulous mandible (48). The same conclusion was drawn from partial- or single-implant studies, which showed implant loss of more than 20% for single teeth or partial bridges in fresh extraction sites when using smooth surface implants (31, 118). On the other hand, immediate implant placement and loading of moderately rough surface implants did not lead to an increased number of failures (40). Hence, it was concluded that turned surface implants could be early loaded in healed bone but that the risk for failure was too high in extraction sockets. There are indications that the latest generations of implants do not yield tremendously higher failure rates when implants are placed into extraction sockets, even with immediate loading, when certain inclusion criteria are considered. However, evidence to determine the possible advantages or disadvantages of immediate, immediate-delayed or delayed implants is insufficient and is based on a few underpowered trials often judged to be at high risk of bias (80).

Definition of immediate loading

During the transitional stage from delayed loading to immediate loading in the late 1990s, several papers indicated the positive outcome of early loading, especially in the edentulous mandible. Furthermore, this outcome occurred irrespective of the implant system or surface topography (37, 48, 144, 166). Previous reviews have described the literature from this transitional period in detail, whereby immediate loading was not yet strictly confined to those studies respecting the 72-h timeslot between surgery and prosthetic functional loading (88, 133). The time span of 3 days is practically feasible only when either prefabricated prostheses or converted existing complete dentures are used as provisional fixed prostheses. In the current paper, ‘immediate loading’ is considered as the treatment protocol in which a prosthetic reconstruction is attached to the implant(s) within 3 days after implant surgery. Although ‘immediate’ normally implies ‘directly after’, this 3-day time frame coincides with the time necessary for the dental technician to process the provisional or definitive restoration and is currently generally accepted in implant dentistry.

Immediate loading in conjunction with tooth extraction, and immediate loading using computer assisted/guided surgery, with or without open flap surgery (44, 46), are not further explored.

By and large, the references summarized in the tables present the outcome of immediately loaded implants in healed bone and can be considered as straightforward cases, as treated under daily clinical conditions. The evidence is based on research papers available before April 2012.

Advantage of immediate loading

Reduction of treatment time may explain the popularity of immediate loading. From a patient’s point of view, there is growing interest in shortening the time frame between implant placement and installation of a functional prosthesis, providing faster comfort as well as esthetics. Besides less discomfort for the patient, gain of time implies an economical benefit especially for the patient when being professionally and/or socially active. It can be speculated that from the dentist’s point of view, gain of time also saves chair time and is beneficial from a financial viewpoint. One could argue that the aspect of time management should not be decisive in choosing the treatment protocol. On the other hand, the dogmatic belief that ‘the patient has no choice’ no longer holds true. Now, expectations of chewing comfort and prosthetic outcome have increased compared with the early era of implant dentistry (130) and the patient’s attitude and satisfaction with prosthetic restorations are influenced by the current trends in adult dental health. Furthermore, the ability to adjust to removable dentures decreases with age and, with the growing number of complaints from elderly patients relating to removable dentures, an increase in the number of requests for fixed rehabilitation is expected (7).

Immediate loading of overdentures

Clinical outcome in the mandible

Immediate loading of implants supporting an overdenture in the mandible is widely used. In a systematic review (8) early or immediate loading of mandibular overdentures was compared with conventional delayed loading. The meta-analysis revealed no significant difference between conventional and either immediate or early loading with a loading period of up to 2 years. Another systematic review (115), based on 25 studies, reported bone loss of 0–0.2 mm in early loading studies and of 0.7 mm in immediate loading studies. The increased bone loss in the immediate loading condition can be explained by the fact that bone remodelling is captured completely in immediate loading studies because the baseline is taken at the time of surgery and not after several months of healing (50).

There is a large variation in the number of implants (ranging from 1 to 4) supporting a denture (Table 1). In the case of four implants, those are placed in the interforaminal area and are rigidly splinted with bars. Chiapasco et al. (35) evaluated, in a retrospective multicenter study, a total of 226 patients treated with four different implant systems and receiving an implant-supported overdenture on four implants, each connected rigidly with a U-shaped gold bar. One-hundred and ninety-four patients were followed for between 2 and 13 years (mean 6.4 years) and an implant-failure rate of 3.1% was reported. The same authors (33) compared immediate loading with delayed loading using turned implants in groups containing 10 patients. Each patient received four implants, each connected with a dolder bar. After 24 months', peri-implant bone remodelling, plaque, bleeding on probing and probing depth, as well as Periotest (Periotest, Siemens AG, Bensheim, Germany) stability values, were statistically comparable between the two groups. The good clinical outcome when four implants were rigidly connected was later confirmed in prospective studies reporting implant survival rates of 94.4–100% during a follow-up time of 12–62 months (35, 89, 121, 124, 180). The above-mentioned studies required laboratory intervention, which may imply greater expense and an additional waiting time. Eccellente and collaborators (72) evaluated 39 patients with 156 implants receiving a prefabricated conical crown that was inserted and polymerized into the existing denture. Hence, the implants were not rigidly connected and, yet, after a 1–5-year function time, the cumulative survival rate was 98.7% and the prosthesis survival rate was 100%. Similarly, Romanos et al. (149) demonstrated that four implants with a prefabricated telescopic abutment functioned very well, even when the implants were placed in extraction sockets. Their study comprised 122 patients with 499 implants in which the existing dentures were relined chair side with methacrylate resin. After 79 (range, 17–129) months, the total implant failure rate was 1.6% and only 4.3% of the implants had crestal bone loss >2 mm relative to the time of implant placement. In a comparative study on three connected implants (160), immediate loading yielded the same outcome as delayed loading after 2 years, with no failures and no difference in peri-implant bleeding on probing, plaque, probing depth or bone resorption. A further reduction, from two implants to one for supporting a mandibular overdenture, was recently suggested in two papers. Liddelow & Henry (112) evaluated the retention of an overdenture on one implant placed in the mandibular midline and reported 100% survival after 1 year and high patient satisfaction with improvement of comfort and function. Another randomized controlled trial compared the outcome of mandibular overdentures supported by one or two single standing implants with ball abutments (109). The failure rates were 17.6% and 7.9%, respectively, which is not in line with the clinical outcome normally presented with similar implants. However, this high failure rate was attributed to the fact that only 16% of the implants had a torque insertion of 40 Ncm and hence initial stability may be questionable.

One can conclude that the delayed loading protocol is not the only acceptable protocol for the mandibular overdenture (104). As summarized in Table 1, the clinical outcome of immediate loading is comparable with delayed loading in terms of implant-survival rates above 95% and bone loss below 1 mm when initial implant stability is provided. There seems to be no difference in survival of implants in connected (6, 11, 30, 161) or nonconnected (109, 111, 122, 132, 172) prostheses, and the number of implants used for the connection depends on patient selection as well as the preference of clinicians or patients.

Clinical outcome in the maxilla

Very few reports have analyzed the outcome of immediate-loading procedures in the edentulous

Table 1. Literature overview of prospective studies evaluating implant survival and bone loss in mandibular overdentures with immediate loading

	Prosthetic devices	Implant system	No. of patients	No. of implants	Implant loss (%)	Mean follow-up time (months)	Mean bone loss (mm)
Gatti et al. (89)	Four-splinted bar	Straumann TPS	21	84	4.0	37	Not reported
Chiapasco et al. (33)	Four-splinted bar	Nobel Biocare Turned	10	40	2.5	24	1.5
Romeo et al. (153)	Four-splinted bar	Straumann TPS	10	40	0.0	24	0.4
Chiapasco & Gatti (34)	Four-splinted bar	Four systems	82	328	3.9	62	Not reported
Weischer et al. (180)	Four-splinted bar	Dentsply Frialoc	18	72	5.6	Not reported	Not reported
Martinez-Gonzalez et al. (121)	Four-splinted bar	Not reported	20	80	0.0	24	Not reported
Wittwer et al. (181)	Four-splinted bar	Dentsply Ankylos	25	100	2.3	24	Not reported
Melo et al. (124)	Four-splinted bar	Neodent	11	44	0	12	Not reported
Eccelente et al. (72)	Four nonsplinted conical crowns	Dentsply Ankylos	39	156	1.3	12–60	Not reported
Stephan et al. (160)	Three-splinted bar	Nobel BiocareTiUnite	17	51	0.0	24	0
Stricker et al. (161)	Two-splinted bar	Straumann SLA	10	20	0.0	30	0.8
Attard et al. (11)	Two-splinted bar	Nobel Biocare TiUnite	35	70	1.4	12	0.4
Cannizzaro et al. (30)	Two-splinted bar	Zimmer SwissPlus	30	60	0.0	12	Not reported
Alfada et al. (6)	Two-splinted bar	Nobel Biocare TiUnite	35	70	2.0	60	Not reported
Ormianer et al. (132)	Two nonsplinted ball abutments	Zimmer Advent	14	28	3.6	18–30	Not reported
Turkyilmaz et al. (173)	Two nonsplinted ball abutments	Nobel Biocare TiUnite	10	20	0.0	12	0.3
Marzola et al. (122)	Two nonsplinted ball abutments	Nobel Biocare TiUnite	17	34	0.0	12	0.7
Kronstrom et al. (109)	Two nonsplinted ball abutments	Nobel Biocare TiUnite	19	36	18.2	12	Not reported
Liao et al. (111)	Two nonsplinted ball abutments	Nobel Biocare TiUnite	10	20	6.0	12	0.7
Liddelow et al. (112)	One implant ball abutment	Nobel Biocare TiUnite	22	22	0.0	24	0.66
Kronstrom et al. (109)	One implant ball abutment	Nobel Biocare TiUnite	17	17	18.2	12	Not reported

Nobel Biocare, Zurich, Switzerland; Straumann, Basel, Switzerland; GT Neodent, Curitiba, Parana, Brazil; Zimmer Dental, Carlsbad, CA, USA; Dentsply Friadent, Mannheim, Germany.

maxilla with an overdenture (Table 2). This is not surprising, given that immediate loading of the edentulous maxilla has only recently been accepted as a viable treatment option. Two reports indicate that this treatment option is feasible, with a clinical implant survival of above 97%. Eccellente et al. (71) used the Ankylos Syncone system (Dentsply Friadent, Mannheim, Germany) in 45 subjects with four nonsplinted implants. A prefabricated conical crown was adapted to the relined existing denture. The conical crown concept resulted in stable complete-denture retention, a reduced denture base and facilitated oral hygiene. The overall implant-survival rate was 97.8% during an observation period of 12–54 months (mean = 26 months). Pieri et al. (139) attached maxillary overdentures in 22 consecutive patients. Four to five implants were connected to a bar. Three out of 103 implants failed within 1 year (97.1% survival). The most common prosthetic complication was frequent relining of the denture in the initial weeks in 27% of the patients. The patients' subjective appreciation of function and satisfaction increased significantly in comfort, functional and esthetic parameters, but not in the cleaning feasibility category. The latter indicates that patients found it difficult to maintain the high level of oral hygiene required. Although it is suggested that treatment outcome may be good, one should realize that current evidence to recommend this treatment on a routine basis is insufficient and comparative studies to provide surgical or prosthetic guidelines related to patient selection are unavailable.

Complications

One of the few papers reporting on technical complications with immediately loaded mandibular overdentures included 17 subjects in whom the existing denture was adapted to fit over the nonsplinted implants with ball abutments (106). Despite a cumulative survival of the implants of 100%, and a minimal 0.7 mm average crestal bone loss after 1 year, seven of the 17 patients endured unforeseen additional prosthetic complications that required technical repair. In two patients the denture fractured twice and an extra relining with addition of a metal reinforcement framework was necessary. In three patients early wear of the gold-cap attachment matrices were reported and the attachments were replaced. Another patient needed repositioning of the attachment, and two others needed a relining of the prosthesis. This study clearly shows that early maintenance is to be foreseen when immediate loading of the overdenture is advocated. A more pragmatic approach is to advocate provisional immediate loading using a denture base relining material on top of the healing abutments (47). To reduce detrimental forces on the implants captured in the denture base, the denture should be equilibrated properly before surgery. A stable and good-fitting denture can reduce the number of relinings needed afterwards. The concept of immediate loading with a mucosally supported overdenture has several clinical drawbacks. Postoperative swelling necessitates regular relining of the provisional denture and it is important that the patient is compliant with maintenance also regarding occlusal check-ups. Regardless of the approach taken, regular maintenance, at least every second week after surgery, is recommended to be able to reline, reinforce the oral-hygiene measures and adjust the occlusion/articulation, whenever necessary. The danger of overloading as a result of bad occlusion has also been suggested previously in early loading studies as an explanation for more failures compared with immediate loading.

Patient-centered outcomes

Few papers have evaluated patients' satisfaction with implant treatment, let alone under immediate loading conditions. Attard et al. (11, 12) studied the patient-based outcomes and associated clinical costs

Table 2. Literature overview of prospective studies evaluating implant survival and bone loss in maxillary overdentures with immediate loading

	Implant not reported/ reconstruction	Implant system	No. of patients	No. of implants	Implant loss %	Mean follow-up time (months)	Mean bone loss (mm)
Excellente et al. (71)	Four nonsplinted conical crowns	Dentsply Ankylos	45	180	2.2	26.7	Not reported
Pieri et al. (139)	Four-splinted bar	Not reported	22	103	2.9	12	0.8

Dentsply, Friadent, Mannheim, Germany.

of an immediate-loading protocol for mandibular overdentures in two groups of edentulous patients. Thirty-five patients were treated with an immediate protocol and 42 were treated with a conventional protocol (and served as a historical control). Significant improvements in perceived oral health status after treatment were observed with both the Denture Satisfaction Scale and the Oral Health Impact Profile. No difference was observed in the patient's time investment for both protocols. From an economic perspective, the immediate protocol was not less expensive than the conventional protocol because it required higher maintenance costs. Maintenance was defined as additional prosthodontic costs after the actual initial work was finished plus the recall costs. On the other hand the immediate loading protocol was more cost-effective. The latter was based on a calculation of the total cost of the procedure in relation to the extend of improvement in quality of life. Seventy-four per cent of those patients needed a reline to improve the denture seal around the bar housing.

Erkapers et al. (79) evaluated satisfaction with immediately loaded cross-arch bridges in the maxilla in 51 patients. They presented a significant improvement in satisfaction related to functional limitation, physical pain, psychological discomfort, physical disability and psychological disability using the Oral Health Impact Profile-49 questionnaire. Dierens and collaborators (66) assessed the subjective opinion of patients treated with immediate loading in total edentulous maxillae and mandibles from baseline up to 1 year. Overall comfort, eating comfort, speaking comfort and perceived esthetics improved significantly within 1 week after surgery and immediate provisionalization. This did not change significantly until the final bridge was installed after 3 (mandible) or 6 (maxilla) months, when a further significant improvement was demonstrated. The importance of one-stage surgery and immediate loading was rated as very high by patients before treatment, especially in the mandible. The general satisfaction score increased from 40 (on a scale of 100) at baseline to 98 during the first year. The above-mentioned studies are not randomized controlled trials but merely case–control studies highlighting the appreciation of patients for a faster treatment approach. Patient satisfaction with early loading compared with delayed loading in the maxilla has been investigated in a randomized controlled trial involving fully edentulous patients. All patients received five or six solid screw-type titanium implants with sandblasted, large-grit, acid-etched surfaces and loaded with full-arch prostheses (81). Patients in the immediate-loading group were significantly more satisfied compared with those in the delayed-loading group, although this may be affected by the fact that sometimes patients did not get their preferred choice of treatment because of randomization. The idea of patient satisfaction should probably not be overestimated because other studies have revealed that delayed-loaded patients regain the same level of satisfaction once their prosthesis is in place (175).

For financial purposes the overdenture on two implants is probably the first choice providing improvement in quality of life. De Kok et al. (51) compared an overdenture on two implants with a fixed screw retained prosthesis on three implants in a prospective study. In both situations the implant survival was 100% after 1 year, and patients' satisfaction and oral health-related quality of life improved similarly. Despite this outcome, other patient-related or technical aspects should be taken into consideration when immediately loaded mandibular overdentures are recommended. Converting a complete removable denture to a mandibular implant-retained overdenture, using immediate loading, yields an immediate improvement in satisfaction regarding stability and retention (21). A clinical aspect of attention is the postsurgical tissue swelling that frequently occurs and may cause patient discomfort when the predominantly mucosally supported denture is in full contact with the operated site. This swelling is already present during impression taking and hence there is a need to reline the denture within a few weeks after treatment. One should question whether clinically the delivery of the final prosthesis, immediately or within a few days after implant placement, is a requirement for the patient or the dentist. Pragmatically speaking, one could even question the necessity to incur laboratory costs before and after surgery when a delayed loading approach has more technical advantages. Three months after healing, the bone and soft tissue have adapted and the correct abutment height can be chosen, taking soft-tissue healing into consideration. With this approach the technical procedure is controlled at the dental laboratory. It can be concluded that the biological success of immediate loading of implant-retained overdentures in the mandible is evident, with an additional substantial improvement in perceived oral health status. However, prostheses often need modifications afterwards and hence immediate loading is not less expensive than conventional loading.

Immediate loading of complete fixed prostheses

Clinical outcome in the mandible

The first attempt to overcome the time problem was the introduction of the Novum Concept (Nobel Biocare, Gothenburg, Sweden), in which three implants were inserted in a tripodal location in the interforaminal area. They were connected by a horseshoe-tapered titanium bar on top of which acrylic resin teeth were polymerized. The principle was that the jaw bone of patients was adapted in order to accommodate the implants in the position required by the ready-made prefabricated metal framework. The first report by the inventor scrutinized 50 patients with 150 implants and indicated 98% survival and a total bone loss of 1.25 mm (23). However, the follow up was 6–36 months and therefore not all implants were in function for a full year. Using the Novum Concept, cumulative implant failure rates of 7.3–9.0% were reported after 1 year (97, 178). In a 1–5-year follow-up study (73) the Kaplan–Meier survival estimates demonstrated a probability of implant survival at 1 year of 95.0%, at 3 years of 93.3% and at 5 years of 93.3%. The bone loss of the remaining implants was only 1.3 mm from 3 months to 5 years. Although the outcome was called 'promising', it was actually rather disappointing compared with the 96–100% survival when implants were early/immediately loaded on four to six implants (88). De Bruyn et al. (49) performed immediate loading with an acrylic screw-retained provisional fixed prosthesis on three turned implants placed in a tripodal configuration. They had also included two extra fixtures as safety implants. After 3 years, ongoing bone loss was described and the implant loss was 9%. This, however, had caused 15% of the prostheses to be lost. It was decided to stop the experiment for ethical reasons and to include the safety implants in the construction.

Several papers have addressed immediate loading with at least five implants. De Bruyn et al. (50) treated 25 patients with five moderately rough implants in the mandible to support a 10-unit provisional fixed prosthesis for 3–4 months. Later, the provisional fixed prosthesis was replaced with a 12-unit final screw-retained fixed prosthesis with acrylic teeth mounted on a metal-casted framework. All implants survived and the accumulated radiographic bone loss was, on average, 1.2 mm after 3 years. With an arbitrarily chosen 1.5-mm bone loss as a threshold, 73% of the individual fixtures were successful after 3 years. This outcome was better than that reported by the same group using machined surface implants (174). In the latter, 18 patients were treated with predominantly turned surface implants and loaded the day of surgery. After 3 years, 96.5% of the implants survived; however, a high-risk patient with Down syndrome was included and was responsible for the loss of two implants. Excluding this patient reduced the failure rate to 1.2%. The other failure was seen in a patient in whom the metal framework broke and caused overloading of a cantilever part. Bone loss was described during the first year of loading but was stable thereafter. Mean bone loss from the time of loading to 3 years was 1.8 mm, which is within the internationally accepted criteria for success of turned surface implants and is confirmed by other papers listed in Table 3.

An immediate-loading study in the mandible, involving 25 patients with five fluoride-modified (Osseospeed, Astra Tech, Mölndal, Sweden) implants and provisionalized on the day of surgery, yielded a total bone loss of 0.11 mm from baseline to 2 years and an implant survival of 100% (39). The crestal bone preservation was better than when using the same implant design with a TiOblast surface, suggesting that the surface plays a decisive role. Froberg et al. (83) compared 44 oxidized surface TiUnite implants with 45 turned surface implants of the same design (Nobel Biocare, Zurich, Switzerland) in 15 patients, using a split-mouth design under immediate-loading conditions. After 2 years, no difference in survival (100%) was observed and bone loss from baseline to 18 months was 0.75 mm in the turned surface implant group compared with 0.8 mm in the TiUnite group. It was concluded that the healing capacity of bone in the anterior mandible was more important than was the surface condition of the implants. The difference in crestal bone remodelling can be attributed to the implant topography (turned surface), the implant design (smooth collar) or the surgical technique (countersinking). Whether this is important in the mandible is controversial. One drawback in the literature is that very often comparison of implant systems is difficult when it comes to bone loss because the baseline measurement is not always made at the time of provisional loading. Hence, when the baseline radiograph is taken at loading with the final prosthesis, the accumulated bone loss is underscored (50).

The all-on-four concept was introduced in 2003 and basically refers to the placement of two axially loaded anterior implants and two tilted ones in the posterior zone. The tilted implants are aimed to pass

Table 3. Literature overview of prospective studies evaluating implant survival and bone loss in fixed mandibular bridges with immediate loading

	Prosthetic device	Implant system	No. of patients	No. of implants	Implant loss (%)	Mean follow-up time (months)	Mean bone loss (mm)
Henry et al. (97)	Three implants –Novum	Nobel Biocare Turned	51	153	9.1	12	0.4
van Steenberghe et al. (178)	Three implants – Novum	Nobel Biocare Turned	50	150	7.3	12	1.1
Engstrand et al. (73)	Three implants – Novum	Nobel Biocare Turned	95	285	6.3	30	1.3
De Bruyn et al. (49)	Three implants	Nobel Biocare Turned	20	60	10.0	36	2.1
Klee de Vasconcellos et al. (107)	Four implants	Connect	15	60	0.0	19	1.1
Melo et al. (124)	Four implants	Neodent	11	44	0.0	12	Not reported
Hinze et al. (98)	Four implants	BIOMET3i Nanotite	18	72	2.8	12	0.8
Francetti et al. (82)	Four implants	Nobel Biocare TiUnite	44	172	0.0	12	0.7
Agliardie et al. (4)	Four implants	Nobel Biocare TiUnite	24	96	0.0	19–47	Not reported
Agliardi et al. (5)	Four to five implants	Nobel Biocare TiUnite	93	388	0.3	12	0.85
Ganeles et al. (86)	Five to eight implants	Straumann TPS/SLA/Frialit/Astra	27	161	0.6	25	Not reported
Nikkelis et al. (131)	Five to six implants	Southern Implants	10	51	0.0	24	Not reported
Testori et al. (169)	Five to six implants	BIOMET3i Osseotite	19	116	2.6	38	Not reported
Testori et al. (170)	Five to six implants	BIOMET3i Osseotite	62	325	0.6	29	Not reported
Fröberg et al. (83)	Five to six implants	Nobel Biocare TiUnite/Turned	15	89	0.0	18	0.8
Van de Velde et al. (174)	Five to six implants	Nobel Biocare Turned/TiUnite	18	91	3.3	45	1.8
Aalam et al. (1)	Five implants	Nobel Biocare Turned	16	90	3.3	36	1.2
De Bruyn et al. (50)	Five implants	Astra Tech TiOblast	25	125	0.0	36	1.2
Collaert et al. (39)	Five implants	Astra Tech Osseospeed	25	125	0.0	24	0.11

Connect AR, Sao Paolo, Brazil; Astra Tech, Mölndal, Sweden; Nobel Biocare, Zurich, Switzerland; Straumann, Basel, Switzerland; Southern Implants Inc., Irene, South Africa; Neodent, Curitiba, Brazil; BIOMET3i, Palm Beach, FL, USA.

the mental foramen and require an angulated abutment (120). A large cohort clinical study involving 245 patients and 980 implants installed in the mandible revealed patient- and implant-related success of, respectively, 94.8% and 98.1% at 5 years. This was further reduced to 93.8% and 94.8% after 10 years of follow up (116). This resulted in a prosthesis survival rate of 99.2% with up to 10 years of follow up. Unfortunately, bone-evaluation data were not reported. Apparently, the tilted implants are not subjected to a higher failure rate in the mandible but there are indications that stress patterns around the tilted distal implants depend on the angulation and this may affect crestal bone remodelling (4). For implants placed at angles of 15 and 30°, little difference exists between the angled and axially loaded anterior implants. However, based on an *in-vitro* photoelastic stress analysis study, the peri-implant bone around the 45° angled distal abutment may be more prone to occlusal overload than bone surrounding implants with shallower tilts (17).

Summarizing the data presented in Table 3, it can be concluded that the three-implant fixed prosthesis yields an implant failure of 7.4%. It is suggested that three implants are insufficient to support an immediately loaded fixed prosthesis, especially taking into consideration the additional costs for reoperations and repairs in that scenario. When four to six implants are used, the total failure rate is calculated to be 0.75%. Hence, it can be concluded that immediate loading performs at least equally as well as the conventional loading protocols of the past in edentulous mandibles. Few studies have investigated the cost–benefit of this treatment. In a clinical study (32) comparing two-stage delayed loading with immediate loading, the patients treated with the delayed protocol required significantly more postoperative control visits with denture relinings.

Clinical outcome in the maxilla

There are relatively few research papers available on immediate-loading protocols and treatment outcome for maxillary full-jaw reconstructions. It is obvious that the number of implants installed per jaw was high in the early days, probably because of uncertainty about the outcome and the wish to have a safety margin in the event of failures. This, of course, had a negative cost–benefit effect. One problem with the available literature is that several alterations in treatment protocols were combined. Some reports often show a mix of mandibular and maxillary cases, combine immediate placement and healed sites and have large dropouts during follow-up. Some cross-sectional studies indicated that immediate loading could be a feasible option in selected patients (99, 166). Ibanez and collaborators (100) treated 26 maxillary edentulous patients with a total of 216 dual acid-etched implants (Osseotite; BIOMET 3i, Palm Beach, FL, USA) and none failed in the 12–74 months of follow up. The average crestal bone loss was 0.56 mm after 12 months and 0.94 mm after 74 months. The patients included bruxers and smokers and those with short implants, and none of these was identified as being a risk factor. On the other hand, large implant numbers were used in each patient, and thus success was attributed to a more evenly distributed occlusal load. One retrospective study (58) involved 42 subjects with a total of 399 implants. The average number of implants per jaw was nine, and 37 subjects even had eight to 12 implants per jaw. The estimated implant survival was 98% after 5 years.

Strietzel et al. (162) reported an implant survival of 99.6%, but a significant association between implant success and implant length emerged from their data. This finding was confirmed by Kinsel & Liss (106) in a retrospective evaluation of 344 Straumann implants (Straumann, Basel, Switzerland) immediately loaded in the mandible, maxilla or both jaws for complete fixed prosthesis. The total survival was 95.3% with a loading time between 2 and 10 years, but again, reduced implant length emerged as a significant predictor of implant failure. Additionally, in a retrospective study (59) including 780 implants, implants more than 13 mm long showed a significantly better outcome compared with shorter implants, with better crestal bone preservation.

Later prospective studies focused on more realistic and affordable protocols involving fewer implants per jaw and using the all-on-four concept with two axial and two tilted implants (in order to avoid the sinus area) or using four implants placed axially. Hinze et al. (98) showed, in a prospective study on 37 patients with four implants, an implant-survival rate in the maxilla of 96.6% and no statistically significant difference in either 1 year survival or bone loss between axial (0.82 mm) or tilted (0.76 mm) implants. Babbush et al. (14) showed 99.3% survival after 29 months. On the other hand, a retrospective follow-up study (117) evaluated 221 patients with a total number of 995 implants and reported that 13% of the implants had biological complications and 17% had technical complications after 5 years. The failures clustered in 30% and 38% of the patients, respectively.

Table 4 gives an overview of prospective clinical studies with at least 1 year of follow up. It can be concluded that immediate loading in the maxilla is a viable treatment option providing that sufficient numbers of implants are used. When six to eight implants are placed, the failure rate ranges between 0 and 3.3%. However, there seems to be a tendency for a higher implant-failure rate when the number of implants is reduced from six to four, with the failure rate, in this instance, ranging from 1.6 to 7.2%. Also, longer implants, better initial implant stability and cross-arch splinting are considered important to ensure a predictable outcome. Despite good clinical survival, the technical complications should not be neglected or underestimated.

Clinical outcome using provisional implants

Provisional or transitional implants were initially developed to retain a provisional bridge, probably because osseointegration was thought to be unlikely for immediately loaded implants. All possible indications and contraindications are listed in a review (45) based on 11 clinical and three histologic studies. The advantages of transitional implants include complete denture retention, stability and support, maintenance and chewing, phonetics, esthetics, patient comfort and protection of bone grafts. This treatment option can be helpful in cases of lower bone quality, less initial implant stability or whenever bone-regenerative procedures are performed. Provisional implants were used in the 1990s when it was believed that immediate loading hampered osseointegration. As such, their use in straightforward cases is currently no longer popular or required. Some of the studies related to these provisional implants have provided valuable histological information on immediate loading and are worth quoting.

Balkin et al. (15) retrieved mini-implants for light microscopy evaluation after 4–5 months of immediate function and they described osseointegration with mature and healthy bone. Iezzi et al. (101) retrieved three provisional implants that had functioned for a 4-month period and showed bone trabeculae around the implants, as well as bone remodelling and Haversian systems close to the surface, indicative of proper osseointegration. In another trial, 254 transitional/provisional implants were placed in 64 patients and remained functional for 2–462 days. The total survival was 82% but primary stability appeared to be a significant factor in implant survival. However, gender, type of suprastructure, tooth status of the antagonistic jaw and implant location did not affect their survival (96). The importance of primary stability was also obvious from the results of a study, based on removal torque tests, that used four provisional implants in 31 patients (159). They suggested that transitional implants may be safely removed from the maxilla after 7–15 months but the risk for fracture increases in the mandible after 10 months of loading. These aforementioned studies point to the importance of initial stability, bone quality and function time when immediately loaded implants are used. Histological studies have demonstrated that osseointegration may hamper removal of the provisional implants, especially in the mandible and after a longer functioning time. This must be taken into consideration in the event that provisional implants need to be removed.

Human histologic findings related to immediate loading

The longest time of histologic evaluation of an immediately loaded implant pertains to a blade implant that was functional for 20 years and removed because of abutment fracture. Histological sections prepared for light microscopy showed average bone–implant contact of 51% and well-maintained mineralized tissues (65). Romanos et al. (152) evaluated 29 immediately loaded implants of different brands and designs with a function of 2–10 months. By and large, the bone–implant interface showed bone contact of 67% on average, which is perfectly indicative of a high level of osseointegration. Two immediately loaded and bilaterally splinted dual acid-etched (Osseotite; BIOMET 3i, Palm Peach, FL) implants were retrieved after 4 months of function in the mandible (171). Histomorphometric evaluation showed osteogenesis and bone remodelling and high bone-to-implant contact ranging from 78 to 85%. Piattelli et al. (138) retrieved a fractured titanium plasma-sprayed implant 8 and 9 months after loading. Sixty to seventy per cent bone–implant contact and a few osteoblasts positive for alkaline phosphatase were indicative of bone formation. Degidi et al. published several papers reporting on different implants located in both jaws, anteriorly as well as posteriorly (61–63). Overall, the formation of mineralized tissue was not impeded by immediate loading, epithelial down-growth was absent and the bone–implant contact ranged from 60 to 81%. The mineralized tissue neighboring the implant surface showed little fibrous tissue or inflammatory infiltrate, and large quantities of newly formed bone were present at the interface. Degidi

Table 4. Literature overview of prospective studies evaluating implant survival and bone loss in fixed maxillary bridges with immediate loading

	No, of implants	Implant system	No. of patients	No. of implants	Implant loss (%)	Mean follow-up time (months)	Mean bone loss (mm)
Ibanez et al. (100)	Eight to 10implants	BIOMET3i Osseotite	26	217	0.0	12–74	0.94
Collaert & De Bruyn (38)	Six to eight implants	Astra Tech TiOblast	25	195	0.0	36	0.7
Kinsel & Lamb (105)	Six to eight implants	Straumann SLA	14	104	1.9	60	Not reported
Degidi et al. (55)	Six to eight implants	Dentsply XivePlus	20	153	0.0	12	0.6
Degidi et al. (54)	Seven implants	Dentsply XivePlus	30	210	2.2	36	0.98
van Steenberghe et al. (177)	Six to seven implants	Nobel Biocare TiUnite	24	164	0.0	12	1.2
Ostman et al. (134)	Six to seven implants	Nobel Biocare TiUnite	20	123	0.8	12	0.8
Romanos and Nentwig (150)	Six implants	Dentsply Ankylos	15	90	3.3	42	Not reported
Bergkvist et al. (19)	Six implants	Straumann SLA	28	168	1.2	32	Not reported
Nikkelis et al. (131)	Six implants	Southern Implants	14	85	0.0	24	Not reported
Hinze et al. (98)	Five implants	BIOMET3i Nanotite	19	95	5.3	12	0.8
Tealdo et al. (167)	Four to six implants	BIOMET3i Osseotite	21	111	7.2	20	0.8
Testori et al. (168)	Four implants	BIOMET3i Osseotite	41	164	2.1	12	0.9
Malo et al. (117)	Four implants	Nobel Biocare TiUnite	221	995	4.2	Up to 10 years	Not reported
Agliardi et al. (5)	Four implants	Nobel Biocare TiUnite	61	224	1.6	12	0.9

Astra Tech, Mölndal, Sweden; Southern Implants, Irene, South Africa; Nobel Biocare, Zurich, Switzerland; Straumann, Basel, Switzerland; Dentsply Friadent, Mannheim, Germany; BIOMET3i, Palm Beach, FL, USA.

et al. (60) compared the bone–implant interface of immediately loaded and submerged implants with a sandblasted or acid-etched surface after 4 and 8 weeks of healing. The bone–implant contact of the immediately loaded implant was 66% and 76% after 4 and 8 weeks, respectively, compared with 66% and 62% in the delayed loaded implants. It is clear that both groups revealed high bone–implant contact. Once integrated, these implants also show a soft-tissue reaction with regard to both periodontal and morphologic aspects, comparable with those of conventionally loaded implants. It is evident from the available human histology that the dogmatic view of epithelial down-growth that would lead to exfoliation of the implants is no longer sustainable (92).

Complications with provisional reconstructions

It is essential that the temporary prosthesis does not hamper soft-tissue healing, that the implants are rigidly splinted during the whole period of provisionalization and that the prosthesis is in balance with the antagonistic teeth to enhance equilibrated loading on all the implants. Suarez Feito et al. (163) evaluated the incidence of technical complications in 242 consecutively treated patients with 1011 implants supporting a provisional bridge during a 2–3-month period after surgery. In total, 8.3% of the patients had at least one fracture and 7.4% of the restorations fractured, of which more than half occurred during the first 4 weeks. Bridges in the mandible, bridges without cantilevers and those opposing natural teeth had a better chance to be free of technical failures. With an opposing implant-supported prosthesis the fracture risk was 4.7-times higher. Reduced proprioception from the periodontal ligament around natural teeth may be responsible for application of greater masticatory forces in those specific cases. Cantilevers and the location in the maxilla increased the risk by factors of 3.4 and 3.5, respectively. The aforementioned study confirmed the findings of Nikellis et al. (131), reporting implant and prosthesis survival rates of 100% but a fracture rate of 16.6% in the provisional restorations when the opposing dentition was an implant-borne restoration. Their provisional restoration had an orthodontic wire embedded for reinforcement of the acrylic resin. The principle of rigid fixation or splinting of the implants by the provisional appliance is based on the rationale to avoid excessive micromotion of the implants. However, one should realize that an orthodontic wire is not able to prevent this motion and that the embedding of a wire cannot prevent fractures of the resin. Furthermore, there is literature suggesting that a controlled micromotion of 50–150 μm is not necessarily detrimental to osseointegration. However, above this threshold, fibrous encapsulation prevails over osseointegration (165). On the other hand, fractures of the provisional reconstruction may lead to implant failure (174). Collaert & De Bruyn (38) suggested a metal framework to reinforce the provisional reconstruction in the maxilla because they found a jaw-dependent difference in the incidence of technical fractures. In the mandible, they used a 10-unit provisional bridge manufactured in the laboratory. It contained maximally one tooth as a cantilever and was basically a screw-retained provisional reconstruction on temporary titanium cylinders. An example of a provisional reconstruction is given in Fig. 1.

The described method of provisionalization has been proven to be unreliable in the maxilla, as seven out of nine provisional reconstructions encountered early fractures. The protocol was changed and the other provisional reconstructions received a cast metal bar that embedded the resin. Those were functional for a 6-month period without further complications. A possible reason for fracture in the maxilla could also be related to the higher number of implants. When six to eight implants are installed, the interimplant distance is smaller and the bulk volume for the resin is reduced, which may jeopardize the strength of the construction. The standard procedure in the maxilla, in use since 2004 at the Department for Periodontology and Oral Implantology of Ghent University, is summarized in Fig. 2.

The general finding that especially the maxilla is prone to fracture of the provisional reconstructions may be related not only to the interimplant distance but also to the buccopalatal width. Often, the provisional construction is more bulky because of the reinforcement. As shown in Fig. 3E, the palatal thickness of the reconstruction is caused by the glass-fiber reinforcement and bulk material surrounding the titanium cylinders. This may have an impact on phonetic problems. In a clinical study involving immediately loaded maxillary rehabilitations (127), 10% of the patients reported nonadaptable speech deterioration. Similar findings were observed in immediately loaded all-on-four reconstructions (176), whereby 53% of the subjects mentioned problems with speech after treatment. According to these subjects, their speech problems were related to the implant treatment. It was suggested that the palatal position of the angulated abutment on the most posterior implants created a space problem for the tongue. Often in totally eden-

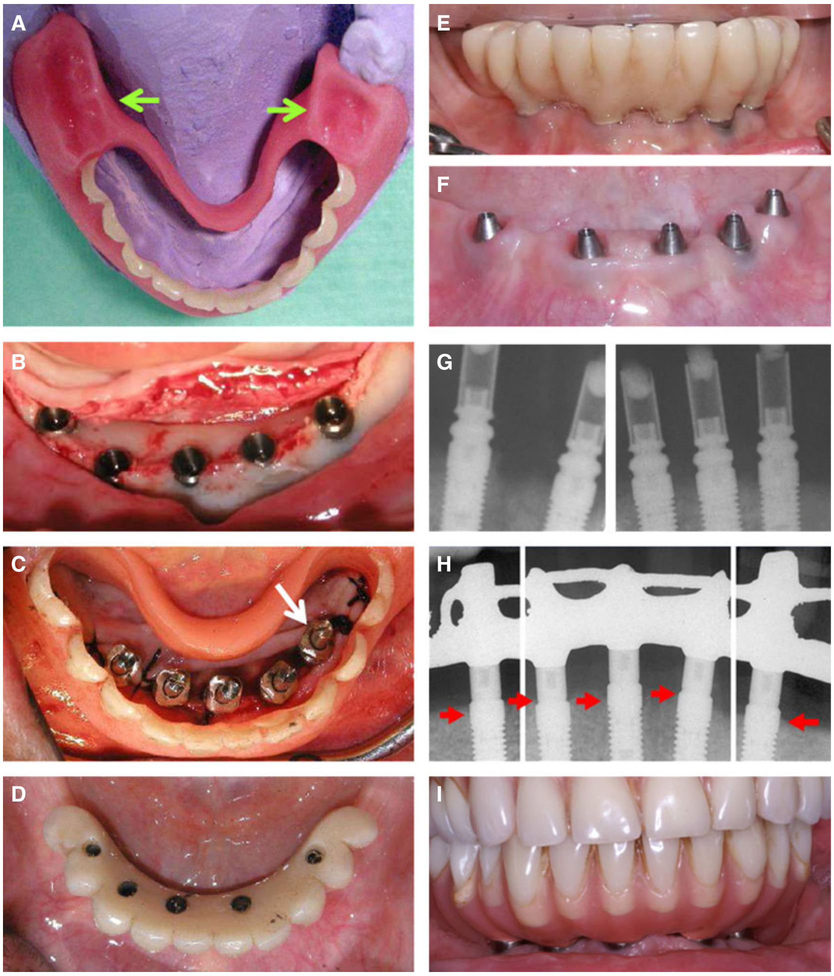

Fig. 1. Case report of a male patient, edentulous in both jaws, provided with an immediately loaded restoration in the mandible. The lower denture was modified into a surgical guide (A), adjusted with occlusal supports in the posterior zone for easy retrievability of the correct bite during surgery (A, arrows). Five implants were placed in the interforaminal area (B) and the impression copings were inserted on abutment level (C). The impression and the bite were taken simultaneously. The autopolymerizing resin was poured between the acrylic teeth and the lingual flange of the guiding denture was used during surgery and for impression taking. The full acrylic provisional restoration (D) was screw retained with provisional titanium cylinders and the fit was checked on periapical radiographs (G). After 3 months, soft-tissue recession was visible (E) and the implants were checked with the prosthesis removed (F). The final reconstruction is a metal framework (H) with denture teeth chemically bonded with acrylic and a distal cantilever of 1.5–2 cm (I). After 3 years further soft-tissue recession was visible (I) but the bone level was stable (H, red arrows).

tulous patients the surgery is guided by an existing removable denture on which the teeth are axially placed on the heavily resorbed crest that may be located more inwards. This can, in most cases, only be solved by recontouring and thinning out the provisional reconstruction. This may, however, weaken the construction and hence should be avoided in the provisional loading stage. On the other hand, phonetic problems should be solved using the provisional reconstruction before finalizing the prosthetic work. In the esthetic zone a 3–6-month provisionalization period is recommended to obtain fully healed and stabilized soft tissues. After placement of the provisional reconstruction the swollen soft tissues are under slight compression (Fig. 3F–H) but during the initial healing soft-tissue recession occurs (Fig. 3I). This can be corrected in the final reconstruction.

Whereas more than 93% of provisional restorations can be free of complications in short time spans of 0–6 months (38, 50, 163, 174), this is not the case for longer functioning times. In a case–control study of computer-aided design/computer-aided machining-guided surgical implant placement using Nobel Guide in 13 patients', the implant failure rate was 9% but fracture of the provisional restoration was common in one of every third framework with the highest

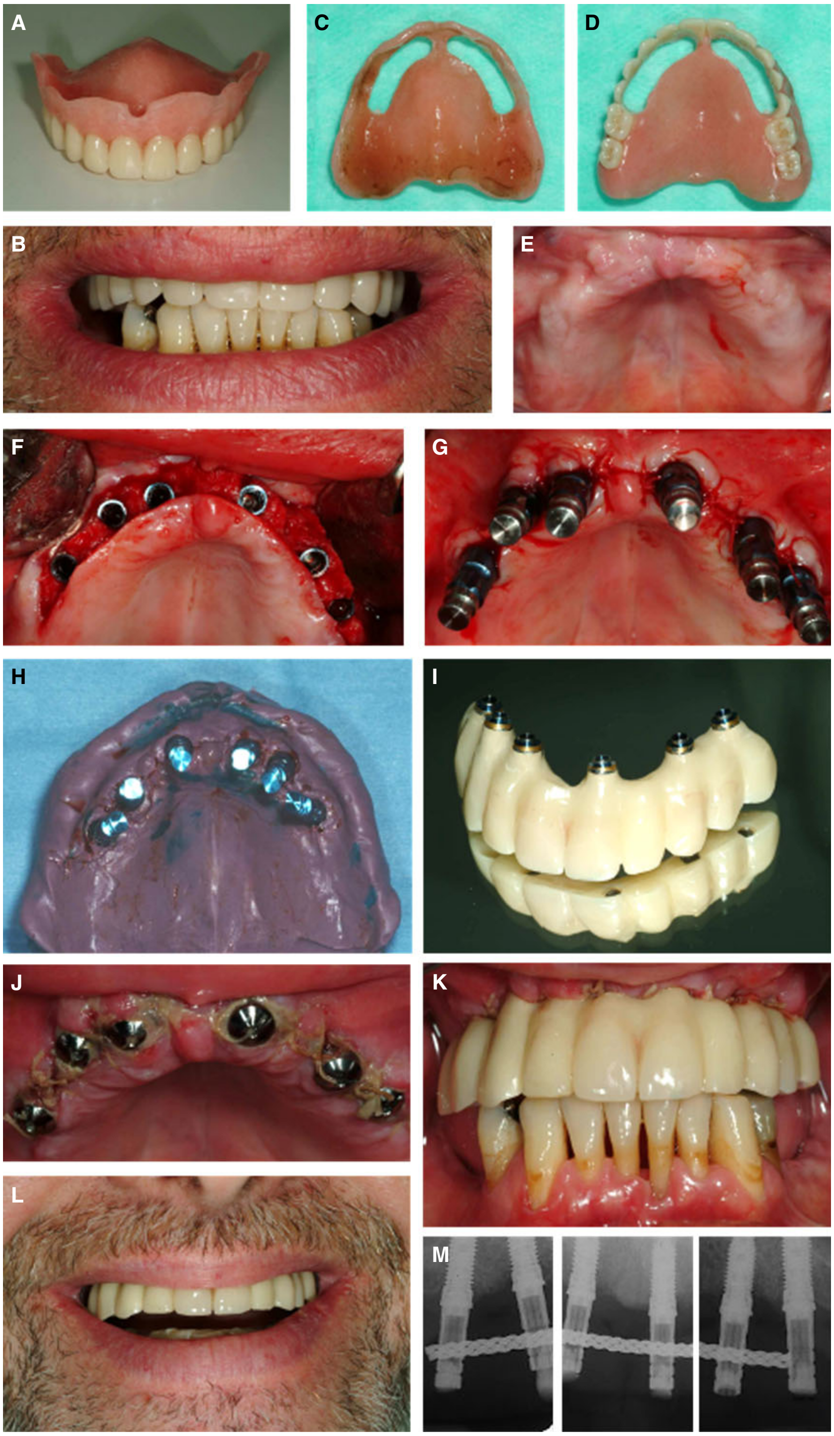

Fig. 2. Case report of a male patient edentulous in the maxilla (A,B). The denture was modified to be used as surgical drill guide (C,D) and for impression taking on implant (F–H) or abutment level in correct occlusion. Healing abutments were placed (J) and the provisional restoration (I) was screw-retained, metal-thread reinforced and in full acrylic (K–M). The denture teeth were used whenever possible. The provisional prosthesis was installed within 48 h. Care was taken to avoid overcompression of the soft tissues. This provisional restoration stays in function for 4–6 months, although in some cases it remains in place for a longer period of time. It is recommended to have a regular check-up because the risk for fractures increases with longer function time.

incidence in the carbon-fiber frameworks (182). Browaeys et al. (26) showed a large number of cases with fractures of resin-based provisional restorations reinforced with metal cast, metal thread or glass fiber. They evaluated 749 dual acid-etched implants (Osseotite®; BIOMET 3i) supporting immediately loaded, complete cross-arch, fixed bridgework on four to nine implants. The cumulative survival of the implants after 7 years was 91% with an accumulated crestal bone loss of 1.38 mm. This outcome suggests a highly successful procedure, certainly because a substantial number of implants in their study had been inserted in compromised bone normally not considered for immediate-loading procedures, such as grafted bone (24%) or posterior bone (14%), or in smokers (24%) with hampered bone quality. For financial reasons, the provisional restorations actually used were semi-permanent and were not replaced

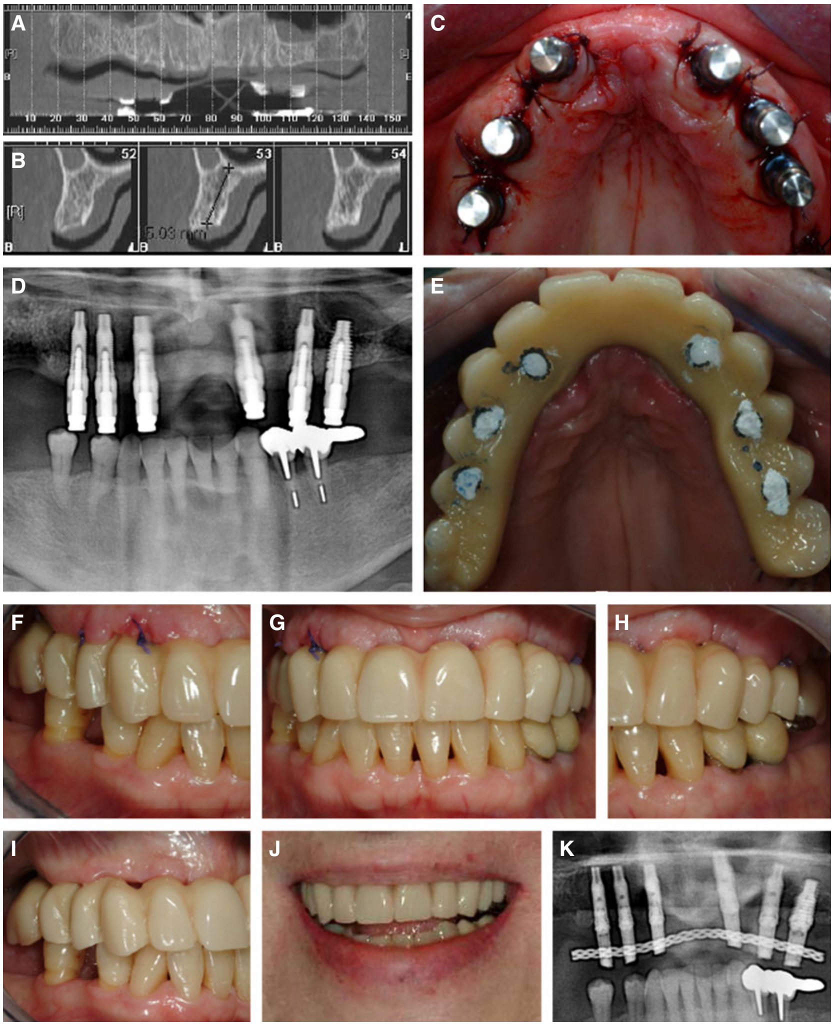

Fig. 3. **Case report of a female patient, 65 years of age, edentulous in the maxilla. A CatScan analysis revealed enough bone height and volume (A,B) for placement of six Nanotite Certain® implants (BIOMET3i) nicely distributed over the arch. Impression was taken on fixture level (C,D). The provisional restoration was full acrylic and screw retained (E). After placement of the provisional restoration the swollen soft tissues were under slight compression (F–H) but during the following 3 months soft-tissue recession occurred (I). The provisional restoration remained functional for 6 months to allow patient adaptation (J) and uneventful healing of bone (K).**

with final bridges. However, 25% of the restorations experienced fractures and, in some patients, this occurred frequently.

Implant-supported temporary solutions can be manufactured in the dental laboratory based on an implant impression or may be produced immediately after surgery with a chair-side approach in the dental office. The laboratory procedure is well controlled and has several advantages over chair-side manufacturing of temporary constructions, such as better finishing of the fit and inclusion of a metal or glass-fiber reinforcement, and may have better esthetics. On the other hand, extended logistics and planning are required and these provisional restorations tend to be more expensive and to take a longer time to produce. Examples of laboratory-produced provisional restorations are given in Figs 1–3. By and large, in the mandible these provisional restorations can be delivered 6–8 h after surgery, but in the maxilla, when reinforcements are required, often an extra technical working day is required. It is the experience of the present authors that many patients refuse the possibility of immediate loading with a laboratory-made temporary bridge because of cost and in those patients a chair-side made temporary construction can be a good alternative. Details of the chair-side procedure are shown in Fig. 4. This procedure has the advantage of an immediate reduction of impairment, immediate splinting and cost-effectiveness. The sometimes lower esthetic outcome and the possible risk of contamination of the surgical site with temporary prosthetic materials are drawbacks of the procedure. Obviously, these factors need to be balanced against the simplicity of the procedure, the cost-effectiveness and the gain of time. A variety of different temporary components is currently available to simplify chair-side procedures. Depending on the planned final reconstruction, different components can be used in order to make the restorative phase less complicated. This also depends on treatment choices, such as: (i) implant-supported or abutment-supported final restoration; (ii) screw retained or cement retained; (iii) the necessity to sculpt soft-tissue volume during the healing phase; or (iv)

Fig. 4. Case report showing the immediate-loading protocol from planning to final prosthetic restoration using the QuickBridge® concept (BIOMET3i). A fully edentulous patient with an old denture (A) received a new tooth set-up (b) for prosthetically driven surgery (C). Screw-retained low profile abutments were placed and tightened to 20 Ncm (D). QuickBridge® Titanium Cylinders were mounted onto the abutments and hand tightened (E). QuickBridge Caps were snapped onto the Titanium Cylinders (F) and the mucoperiostal flap was closed with intermittent sutures (G). From the maxillary tooth set-up, a vacuum-formed template was made (H). The template was filled with composite resin and seated onto the QuickBridge® Caps (I). After setting of the composite the caps are attached into the restoration, and can be snapped off, trimmed, polished and replaced on top of the metal cylinders with chlorhexidine gel without cement (J). Three months following soft-tissue maturation, the patient was seen for fabrication of the definitive restoration (K). The provisional restoration was snapped off from the Titanium Cylinders (L). The vacuum-formed template used for fabrication of the provisional restoration was reused to make an occlusal registration. With this technique, information about the interocclusal height, midline and shape of the teeth is provided to the dental technician for fabrication of the framework master (M–O). QuickBridge® Titanium Cylinders were removed (P). Pick-up impression copings were placed onto the abutments and hand tightened (Q). An open-tray impression was made with polyvinylsiloxane impression material (R). In the laboratory, a tooth set-up was fabricated onto the master cast. From the tooth set-up, the framework master was fabricated using a cut-back technique (S–X). The Copy Milled Framework was returned to the dental laboratory (Y). The Copy Milled Framework was finalized with porcelain (Z, AA). The patient returned to the dental clinic. The BellaTek Copy Milled prosthesis was placed. The implant-supported, screw-retained prosthesis was tightened to 20 Ncm and the screw-access openings were restored with composite resin (BB, CC).

prefabricated or individualized abutments for the final restoration.

Östman et al. (136) evaluated the clinical outcome of the cost-effective temporary prosthesis. The prostheses extended from two-unit bridges supported by two implants, to full-arch constructions supported by six implants. The temporary prostheses were monitored from the day of surgery and delivery to the time of replacement with a permanent prosthetic construction 3–6 months later. No implants were lost during the observation time, but 3% of the temporary prostheses fractured and 6% loosened during the follow up. The study indicated that the chair-side concept tested for manufacturing the temporary prosthesis for immediate loading of dental implants is a viable approach. In Fig. 4, a typical example of a full-arch maxillary restoration using the QuickBridge concept is presented.

With immediately loaded full-arch implant restorations a fully balanced occlusal scheme is recommended. It is suggested that the cusps are flattened and the articulation is balanced. This spreads the load on all implants and reduces risks of technical fractures. This should be easily achievable when the restoration opposes a complete removable denture. Balanced occlusion implies bilateral simultaneous anterior and posterior contact in centric and eccentric positions, in which the loading forces are distributed over a large area. If the full arch opposes natural teeth, it is recommended that the natural teeth are adjusted to obtain group function and not canine guidance. This avoids lateral forces, which are sometimes detrimental for osseointegration. Additionally, narrowing the orobuccal width of the occlusal surface reduces the bending moments and the lateral force components (128). The provisional restoration will, after a few months of oral function, be adapted to the articulation pattern. Additionally, it allows an adaptation process for the patient, especially in terms of phonetics. Care should be taken to copy and paste the information from the provisional restoration into the final prosthesis. The dental technician should be warned that this is essential, although it may not always correspond to the ideal morphology of a natural dentition.

It seems realistic to conclude that the provisional restoration should be considered as a temporary solution subjected to certain mechanical risks. In particular, fracture of the framework may lead to implant failure. Also, occlusal wear is frequently reported and this may hamper balanced occlusion and articulation. This points to the importance of regular check-ups during the period of temporization. Patients should be asked to report immediately in the event of a technical complication. From a liability point of view they should be informed properly about those risks.

Clinical guidelines for the totally edentulous patient

As in conventional implant procedures, the treatment outcome largely depends on patient selection, presurgical planning, surgical skills and prosthetic quality. The surgical procedure is comparable with the conventional procedure but fixation of the provisional restoration may, for some restorative dentists, become a problem. As seen in Fig. 4, the wound is still bleeding a few hours after surgery and tissues may be swollen. It is recommended to insert the provisional restoration as soon as possible after surgery because the tissues should not be completely adapted around the healing abutment. It may be difficult to place the provisional restoration around fully adapted soft tissues when the prosthetic border is located deep submucosally. The placement of the provisional restoration may require some surgical skills in order to be fast and comfortable for the patient, and is most commonly performed with bleeding tissues. A screw-retained solution is certainly preferable over a cemented one as it is more tissue friendly. Sometimes, additional suturing or flap adaptation may be required at this stage. Also, the provisional restoration requires evaluation and often adaptation of occlusion and articulation. Finally, postoperative control sessions for suture removal, plaque-control measures and prosthetic follow-up and modifications are necessary. Hence, a clear division of the tasks within the team is recommended if one wants to reduce the number of complications. Although it has been suggested that early manipulation of the restoration may hamper osseointegration, removal of the provisional prosthesis for suture removal on the day 10 after surgery did not jeopardize survival of the restoration, as shown in a cohort study involving 71 patients (20). On the other hand, manipulation of the provisional restoration may be uncomfortable for the patient and this can be avoided by using resorbable suture materials.

Much has been speculated on the critical importance of the implant surface as a decisive factor for immediate loading. Several clinical papers (33, 83, 99, 129, 174) have pointed out that the first-generation turned implants had a good outcome under immediate loading in the mandible. In this respect, only one single-blind, randomized, controlled split-mouth study is available and it compares the outcome of machined implants vs. titanium oxide-anodized implants under immediate loading conditions in the posterior mandible (84). Ten patients with a bilateral posterior edentulous zone received 20 rough and 22 smooth implants. After 3 years the cumulative survival rate was 95% for all implants and there was no difference in crestal bone loss. Although the current generation of surface-enhanced implants perform much better in a larger number of treatment indications, the surface is not the only, or the most important, factor in implant success (41). In immediately loaded full-jaw, initial implant stability, reflected by a high insertion torque value, is suggested by many researchers as being a key issue, and adaptation of the drilling protocol has been suggested to improve biomechanical interlocking of implant with bone (38, 50, 131, 174). When an implant is not stable it needs to be replaced with a wider one. Apical stability can further improve by selecting a longer implant if anatomically feasible (162). A biomechanical rationale to decrease the risk of overloading is reasonable, and enhancing the immobilization of the implant by splinting is recommended. Several other factors may affect loading, such as patient factors, implant position, cantilever forces and occlusal load force and direction (126). In this respect, some have recommended soft food during the initial healing period after immediate loading (128, 150), whereas others have not given any dietary restrictions to their patients (38, 39, 174).

Schnitman & Hwang (157) evaluated a number of implant patients for whom the decision to load immediately or to perform one-stage or two-stage surgery based on initial per-operative implant stability coincided well with the implant survival rate. In other words, implants that had a high insertion torque and were immediately loaded had significantly better survival than those that had a low insertion torque and were delayed loaded. Bone density measured on computed tomography images, and insertion torque or resonance frequence analysis, reflecting implant stability, correlated well and can be considered as useful for making implant-loading decisions. Also, Li et al. (110) found the maximal insertion torque value to be a prognostic factor in success. Ding et al. (67, 68) performed finite element analysis to evaluate the effect of diameter and length on stress and strain distribution in the crestal surrounding cortical bone around implants under immediate loading. Increasing implant diameter and length decreased the stress and strain on the alveolar crest. Buccolingual loading notably increased both stress and strains compared with axial loading. The diameter was more important than the length. A similar conclusion was drawn independently in another finite element study in which the length was more important for axial loading and the diameter played a more important role in the stability during buccolingual loading. It was concluded that an implant exceeding 4 mm in width and 11 mm in length was the most optimal for immediate loading in type B/2 bone (108). It is also suggested that prostheses loaded on more implants reduce the strain in the bone adjacent to the implant and reduce the risk for early overloading (125).

Immediate loading of single implants

Clinical outcome

With respect to immediate loading of single implants, a distinction needs to be made between immediate loading with or without occlusal contact of the restoration with the opposing dentition. Terminology such as functional and nonfunctional loading has also been used in the context of immediate restoration, respectively corresponding to occlusal and nonocclusal loading. Clearly, these terms may be confusing because the lack of occlusion does not preclude a restoration to be functional.

Table 5 gives an overview of clinical prospective studies pertaining to immediate loading of at least 10 patients with single implants installed in healed, native bone. Although immediate restoration may not be important from an esthetic point of view in the load-carrying part of the dentition, some investigators specifically studied the clinical outcome of the procedure in the posterior maxilla or mandible (2, 43, 94, 155). In the vast majority of the studies, conventional flap surgery was used because bone regeneration usually precludes the possibility for immediate loading as primary wound closure is required in order to stabilize the blood coagulum and the biomaterials used. On the other hand, limited reconstruction was combined with immediate loading by Hall et al. (95). However, given the paucity of studies, the combination of single implant placement, bone regeneration and immediate loading may not be considered as standard procedure.

A number of studies used a nonocclusal loading protocol (42, 57, 75, 95, 140, 141, 143, 154). In other studies, occlusal contact was allowed between the restoration and the opposing dentition (2, 43, 69, 94, 147, 155, 179). On the basis of the included studies a

Table 5. Literature overview of prospective studies on immediate loading of single implants

Authors	Study design	Groups	Implant system	Follow up (months)	No. of implants/ no. of patients	Region	Flap/ flapless	Bone regen eration	Occlusal contact	Implant survival (%)	Bone loss (mm) mean (SD)	Screw-retained/ cemented provisional crown	Early complication	Midfacial soft-tissue changes	Papilla changes	Pink & White Esthetic Score	Patient-centered outcomes
Ericsson et al. (75)	Case series	Immediate loading	Nobel Biocare Turned	18	14/14	Anterior maxilla, Anterior mandible	Flap	No	No	85.7	Not reported	Cemented	One crown loosening	Not reported	Not reported	Not reported	Not reported
		Delayed loading	Nobel Biocare Turned	18	8/8	Anterior maxilla, Anterior mandible	Flap	No	No	100	Not reported	Cemented	None	Not reported	Not reported	Not reported	Not reported
Proussaefs et al. (140)	Case series	Immediate loading	Nobel Biocare Hydroxyapatite Coated	12	10/10	Anterior maxilla	Flap	Not reported	No	100	0.90 (0.32)	Screw-retained	None	Not reported	Not reported	Not reported	Not reported
Proussaefs et al. (141)	Case series	Immediate loading	Nobel Bioacare Hydroxyapatite Coated	36	10/10	Anterior maxilla	Flap	Not reported	No	100	1.00 (0.26)	Screw-retained	None	Not reported	Not reported	Not reported	Not reported
Cornelini et al. (43)	Case series	Immediate loading	Straumann SLA	12	30/30	Posterior mandible	Not reported	No	Yes	96.7	6 mo: 2.30 (0.40)	Screw- retained	None	Not reported	Not reported	Not reported	Not reported
Ottoni et al. (137)	Case series (split mouth)	Immediate loading	Dentsply Frialit	24	23/23	Anterior maxilla, Anterior mandible	Not reported	Not reported	No	56.5	12 mo M: 1.36 D: 2.44	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
		Delayed loading	Dentsply Frialit	24	23/23	Anterior maxilla, Anterior mandible	Not reported	Not reported	N/A	95.7	12 mo, M: 1.57 D: 1.92	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
Abboud et al. (2)	Case series	Immediate loading	Dentsply Ankylos	12	20/20	Posterior maxilla, Posterior mandible	Flap	No	Yes	95	Maxilla: 0.00 (0.59); Mandible: 0.03 (0.36)	13 screw-retained /seven cemented	Two crown loosening and fracture, one infectious complication caused by cement remnants	Not reported	Not reported	Not reported	Not reported

Table 5. (*Continued*)

Authors	Study design	Groups	Implant system	Follow up (months)	No. of implants/ no. of patients	Region	Flap/ flapless	Bone regen eration	Occlusal contact	Implant survival (%)	Bone loss (mm) mean (SD)	Screw-retained/ cemented provisional crown	Early complication	Midfacial soft-tissue changes	Papilla changes	Pink & White Esthetic Score	Patient-centered outcomes
Ryser et al. (154)	Randomized controlled trial	Immediate loading	Zimmer Splines Hydroxyapatite Coated	24	16/16	Maxilla, mandible	Flap	Not reported	No	Not reported	Not reported	Not reported	Not reported	Not reported	Mean Papilla index 3.6 for both groups	Not reported	Not reported
		Delayed loading	Nobel Biocare Hydroxyapatite Coated	24	25/25	Maxilla, mandible	Flap	Not reported	N/A	Not reported	Not reported	Not reported	Not reported	Not reported	Mean Papilla Index = 3.6 for both groups	Not reported	Not reported
Donati et al. (69)	Randomized controlled trial	Immediate loading/ osteotome	Astra Tech Osseospeed	12	50/149 (overall)	Anterior maxilla, Anterior mandible	Flap	No	Yes	94	0.31	Cemented	Not reported	Not reported	0.2 – 0.3 mm mean papilla reduction	Not reported	Not reported
		Immediate loading	Astra Tech Osseospeed	12	54/149 (Overall)	Anterior maxilla, Anterior mandible	Flap	No	Yes	98.1	0.25	Cemented	Not reported	Not reported	0.2 – 0.4 mm mean papilla reduction	Not reported	Not reported
		Delayed loading	Astra Tech Osseospeed	12	57/149 (overall)	Anterior maxilla, Anterior mandible	Flap	No	N/A	96.5	0.38	Cemented	Not reported	Not reported	0.5 – 0.6 mm mean papilla reduction	Not reported	Not reported
Hall et al. (95)	Randomized controlled trial	Immediate loading	Southern Implants	12	14/14	Anterior maxilla	Flap	Yes	No	92.9	0.63 (1.00)*	Screw-retained	None	0.7 mm mean recession*	No change or gain	Not reported	Not reported
		Delayed loading	Southern Implants	12	14/14	Anterior maxilla	Flap	Yes	N/A	100	0.78 (1.01)*	Screw-retained	One crown fracture	0.3 mm mean recession*	No change or gain	Not reported	Not reported
Guncu et al. (94)	Case series	Immediate loading	Nobel Biocare TiUnite	12	12/12	Posterior mandible	Flap	No	Yes	91.7	0.45 (0.39)	Cemented	Not reported	Not reported	Not reported	Not reported	Not reported
		Delayed loading	Nobel Biocare TiUnite	12	12/12 (overall)	Posterior mandible	Flap	No	N/A	100	0.68 (0.3)	Cemented	Not reported	Not reported	Not reported	Not reported	Not reported
Roa & Benzi (147)	Case series	Immediate loading	Nobel Biocare TiUnite	12	51/46	Posterior mandible	Flapless	?	Yes	100	1.12 (1.06)	Cemented	Five abutment screw loosening	Not reported	Not reported	Not reported	Not reported
Siddiqui et al. (158)	Case series	Immediate loading	Zimer Screw Vent	12	51/44	Maxilla, mandible	Flap	No	No	98	0.98 (0.67)	Not reported	Not reported	Not reported	Not reported	Not reported	Survey
Schincaglia et al. (155)	Randomized controlled trial	Immediate loading	Nobel Biocare TiUnite	12	15/15	Posterior mandible	Flap	No	Yes	93.3	0.77 (0.38)	Screw-retained	None	Not reported	Not reported	Not reported	Not reported
	Randomized controlled trial	Delayed loading	Nobel Biocare TiUnite	12	15/15	Posterior mandible	Flap	No	Yes	100	1.20 (0.55)	Screw-retained	None	Not reported	Not reported	Not reported	Not reported

Table 5. (*Continued*)

Authors	Study design	Groups	Implant system	Follow up (months)	No. of implants/ no. of patients	Region	Flap/ flapless	Bone regen eration	Occlusal contact	Implant survival (%)	Bone loss (mm) mean (SD)	Screw-retained/ cemented provisional crown	Early complication	Midfacial soft-tissue changes	Papilla changes	Pink & White Esthetic Score	Patient-centered outcomes
Degidi et al. (57)	Randomized controlled trial	Immediate loading	Dentsply XiVE Plus	36	30/30	Anterior maxilla	Flap	No	No	100	0.85 (0.71)	Screw-retained	1 crown fracture	Not reported	53% complete papillae	Not reported	Not reported
	Randomized controlled trial	Delayed loading	Dentsply XiVE Plus	36	30/30	Anterior maxilla	Flap	No	N/A	100	0.75 (0.63)	Screw-retained	None	Not reported	45% complete papilla	Not reported	Not reported
Cooper et al. (42)	Case series	Immediate loading	Astra Tech Osseospeed	12	58/58	Anterior maxilla	Flap/ Flapless	/	No	98.3	0.81 (0.86)	Cemented	Not reported	0.3 mm mean soft-tissue gain	0.2 mm median papilla gain	Not reported	Not reported
Raes et al. (143)	Case series	Immediate loading	Astra Tech Osseospeed	12	23/23	Anterior maxilla	Flap	No	No	100	0.20 – 0.30	Cemented	None	1.0 mm mean recession	0.3 – 0.6 mm mean papilla gain	10.4 mean PES; 7.0 mean WES	Oral Health Impact Profile-14 survey
Vandeweghe et al. (179)	Case series	Immediate loading	Southern Implants	12	15/14	Anterior maxilla	Flap	No	Yes	100	1.20 (0.22)	Cemented	Four abutment screw loosening	0.4 mm mean recession	0.1 mm mean M papilla gain; 0.4 mm m ean D papilla loss	8.5 mean PES; 6.5 mean WES	Oral Health Impact Profile-14 survey

Astra Tech, Mölndal, Sweden; Southern Implants, Irene, South Africa; Nobel Biocare, Zurich, Switzerland; Zimmer Dental, Carlsbad, CA, USA; Straumann, Basel, Switzerland; Dentsply Friadent, Mannheim, Germany.
*Baseline: permanent crown placement.
D, Distal; M, Mesial; N/A, Not Applicable; PES, Pink Esthetic Score; WES, White Esthetic Score.

clear impact of the presence or absence of occlusal contact on implant survival – generally ranging from 85.7 to 100% – could not be demonstrated.

As the variation in implant survival was clearly smaller for delayed loading (95.7–100%) than for immediate loading (85.7–100%), the latter could possibly be more prone to failure. On the other hand, the available randomized controlled trials did not show a consistent impact of the loading protocol on implant survival (57, 69, 95, 155). However, clinicians should interpret these findings with caution because of the following. First, one should realize that patients are usually strictly selected, treated and followed when participating in a clinical study, and these conditions may not necessarily correspond to daily practice (87). Second, most studies may have been underpowered given the limited number of implants installed, especially in papers reporting on single-implant treatment. In this respect, the outcome of meta-analyses pooling data from different clinical studies becomes particularly interesting. Atieh et al. (9) published a systematic review with meta-analysis on this topic and concluded that more failures are to be expected following immediate loading of single implants when compared with delayed loading. In fact, compared with delayed loading, both occlusal and nonocclusal loading demonstrated a five-times higher risk for implant failure. Interestingly, these findings may predominantly apply to the anterior part of the dentition because, on the basis of another systematic review by the same group, a significant impact of the loading protocol on implant survival could not be demonstrated in the molar area (10). Nevertheless, the aforementioned observations may support the view that immediate loading of single implants is not to be considered as the standard of care. An important parameter to take into account in the decision-making process could be the implant insertion torque, which was shown by Ottoni et al. (137). In this comparative study, 23 patients received two single implants. One implant was immediately loaded with a provisional crown, whereas the other was loaded after a healing period. In both treatment groups 10 out of 23 implants were installed with poor primary stability (20 Ncm, as described in the study). Immediately loaded implants failed in 10/23 patients and, of these, nine had been placed with poor insertion torque. In contrast, only one conventionally loaded implant failed.

Table 5 shows mean bone loss at study termination in reference to the moment of implant installation. Within the limits of comparing different implant systems, these data demonstrate limited peri-implant bone resorption following immediate loading of single implants. In fact, the vast majority of papers described mean bone loss below 1 mm (2, 42, 57, 69, 94, 95, 140, 155, 158), which is remarkably low taking into account that these figures include the amount of remodelling that takes place as a result of biologic width development. The latter may be considered as the main cause of hard-tissue adaptation in the early healing phase and is basically initiated by the establishment of a transmucosal connection (25). This remodelling is an inevitable phenomenon and may not be affected by the timing of restoration. Therefore, there may be no biologic basis to presume a relevant impact of the loading protocol on bone remodelling.

Complications

As seen in Table 5, provisional crowns were either screw-retained (43, 57, 95, 140, 141, 155) or cemented (42, 69, 75, 94, 143, 147, 179). Abboud et al. (2) used both retention methods, whereas Ottoni et al. (137), Ryser et al. (154) and Siddiqui et al. (158) did not provide details.

Apart from one biologic impediment in the study by Abboud et al. (2), all complications were of a technical nature. These included abutment screw loosening, crown loosening and crown fracture. In all but one study (179), complications occurred in <10% of cases. Four out of 14 abutment screws loosened in the study by Vandeweghe et al. (179), which was attributed to the fact that no torque wrench had been used at the time of installation. Given this information, clinicians should torque abutment screws up to 15–20 Ncm to limit abutment screw loosening.

Single-unit restorations are recommended to be completely out of occlusion and articulation, whereas short-span bridges can be placed in light centric occlusion. One should avoid lateral forces.

Soft tissue and esthetics

Although a number of studies have been published on immediate loading of single implants, most provided data on traditional outcome variables (e.g. implant survival and bone remodelling). Only seven of the selected papers in Table 5 clearly described the soft-tissue aspects of treatment outcome (42, 57, 69, 95, 143, 154, 179). This is somehow surprising given the fact that esthetics could be considered as a potentially important rationale for immediate loading of single implants.

With respect to midfacial soft-tissue changes, all but one paper (42) described recession ranging from a mean of 0.3 to 1.0 mm (95, 143, 179). Papilla changes over time seemed less conclusive. Some described some papilla reduction (69, 179), whereas others demonstrated limited papilla gain (42, 95, 143).

Only two studies reported on the esthetic outcome of immediately loaded single implants (143, 179) using the Pink Esthetic Score and the White Esthetic Score. These indices, based on objective criteria, were introduced by Fürhauser et al. (85) and Belser et al. (18), respectively. An interesting finding was that the mean Pink Esthetic Score differed substantially between the study of Raes et al. (143) and that of Vandeweghe et al. (179) (10.4 vs. 8.5 on a scale of 14), which could be attributed to the inclusion of predominantly periodontitis patients by Vandeweghe et al. (179). In this respect, it is well known that periodontal disease may cause papilla reduction and papillae have a key impact on the total Pink Esthetic Score score. On the other hand, Vandeweghe et al. (179) used a permanent zirconia abutment on the day of surgery and cemented a provisional resin crown onto it. The rationale for this technique relates to the biocompatibility of zirconia (93) and the fact that the soft-tissue seal will never be disrupted when the zirconia abutment is left in place. However, one should realize that there are no clinical studies suggesting superiority of one technique over another in terms of soft-tissue preservation. Furthermore, it may be difficult to determine the ideal outline of the definitive abutment at the time of surgery, given the inevitable remodelling that will take place thereafter, which is not fully predictable in the individual patient.

Although the aforementioned observations show obvious trends in soft-tissue remodelling and esthetics following immediate loading of single implants, comparative, and preferably randomized, controlled studies need to be consulted to evaluate whether soft tissues react differently following immediate loading vs. delayed loading.

The impact of a provisional implant crown on papillae was first studied by Jemt (103). Soft tissues were allowed to heal to either provisional resin crowns that were placed at the time of second-stage surgery, or to healing abutments before final crown insertion. Even though provisional crowns allowed soft tissues to restore faster than healing abutments alone, similar papilla volume was described, as assessed by the papilla index (102).

The impact of the loading protocol for single implants on papilla fill was further evaluated in a randomized controlled trial (154). In this study, single implants were either immediately restored at the day of surgery with a provisional crown or were restored at the time of second-stage surgery. After 1 and 2 years of function, no significant difference in the papilla index (102) could be found.

In 2006, Hall et al. (95) performed a similar randomized controlled study, focusing on midfacial soft-tissue remodelling in addition to papilla alterations. All patients received a provisional crown either at second-stage surgery or at the day of implant placement. It is noteworthy that a distal releasing incision was made allowing for limited buccal bone grafting in the event of bone fenestrations and/or dehiscences. Irrespective of the group, papillae remained unchanged or demonstrated similar up-growth. With respect to the midfacial level, a significant apical displacement was found of, on average, 0.3 and 0.7 mm following conventional restoration and immediate restoration, respectively. The disparity was not statistically significant. However, in this context, one should take into account that baseline registration occurred 4 weeks after permanent crown installation and thus did not take into account possible remodelling that could have taken place before this time point.

Recently, den Hartog et al. (64) published the results of a randomized controlled study focusing on objective esthetic ratings in addition to midfacial and papilla alterations. Again, patients received a single implant, sometimes in previously augmented bone, that was either restored at the day of surgery or after 3 months of osseointegration. Irrespective of the treatment protocol, papillae demonstrated significant gain, as demonstrated by linear measurements and the papilla index (102), whereas the midfacial soft-tissue level showed a steady state. These results correspond with aforementioned studies, but again relate to a narrow time frame (6–18 months of follow up). Den Hartog et al. (64) used the Pink & White Esthetic Score of Belser et al. (18) as well as the Implant Crown Aesthetic Index of Meijer et al. (123) to assess the esthetic outcome of single implants. After 18 months the mean Pink Esthetic Score was 7.1 and 6.5 (on a scale of 10) for immediately restored implants and conventionally restored implants, respectively. On the basis of the Implant Crown Aesthetic Index, 80% of the immediately restored implants could be considered as satisfactory. The corresponding value for conventionally restored implants was 62%. The disparities between the treatment groups were never statistically significant.

The aforementioned papers demonstrate that soft-tissue remodelling and esthetics are barely affected by immediate loading of single implants installed in healed bone. However, this may not be the case for single implants installed in extraction sockets, as shown in a randomized controlled study performed by De Rouck et al. (52). In this study, immediate implants were restored with an implant crown either at the day of surgery or after 3 months of osseointegration, during which a removable partial denture was worn. After 1 year, immediate loading resulted in 0.8 mm less midfacial recession. Although immediate implant placement is not the topic of this paper, the disparity between this study and the aforementioned studies becomes intriguing and can be explained by the fact that an immediate implant crown may optimally support the ideal soft-tissue architecture that is present upon tooth extraction. Note that soft-tissue collapse becomes inevitable in all other scenarios.

The lack of a significant impact of the loading protocol on soft-tissue remodelling suggests that the timing for placing a provisional implant restoration is not that relevant. However, it does not imply that a provisional implant crown becomes redundant when it comes to soft-tissue conditioning. In this respect, a provisional resin restoration has the particular advantage of being easily adapted in any way. Tissue abundance may be eliminated by adding some flowable composite or resin, hereby increasing pressure on the tissues and resulting in recession. Alternatively, the transmucosal part of the provisional crown can be easily made concave, allowing for soft-tissue ingrowth. In Fig. 5, an immediately loaded single implant is presented.

Patient-centered outcomes

Only two studies included in Table 5 described patient-centered outcomes (158, 179). Raes et al. also provided such results in another paper (142). Siddiqui et al. (158) used a questionnaire and found that most subjects were ‘very satisfied’ with the procedure. About 50% of the patients rated their appearance and mastication to be ‘greatly improved’ after the treatment and all would recommend it to others. Vandeweghe et al. (179) and Raes et al. (142) used a validated questionnaire (Oral Health Impact Profile-14) to assess changes in oral health-related quality of life by the installation of an immediately loaded single implant. Vandeweghe et al. (179) demonstrated significant improvement between the preoperative and 6-month postoperative condition in terms of speaking, pain and eating comfort. In addition, patients felt less tense, could relax more easily and were less embarrassed after 6 months. Particularly interesting in the study by Raes et al. (142) was that a comparison was made between immediately loaded single implants installed in extraction sockets with those installed in healed bone. Even though there were no significant differences in the Oral Health Impact Profile-14 score before treatment, the healed group showed significantly higher improvement for functional limitation, physical disability, physical pain and psychological discomfort. Between the preoperative condition and 1 year in the healed bone group, all seven domains improved significantly compared with only three domains in the extraction group. However, the overall Oral Health Impact Profile-14 score between groups was not substantially different.

Immediate loading of the partially edentulous patient

Clinical outcome

Table 6 shows the clinical outcome of immediately loaded implants supporting a fixed partial denture. Two were prospective case series (56, 135), two were randomized controlled trials with an intersubject parallel design (53, 148) and three were randomized controlled trials with an intrasubject split-mouth design (29, 84, 151). The impact of the loading protocol on implant survival was investigated by Romanos et al. (151). Both immediate loading and delayed loading resulted in survival rates of 100%. Two randomized controlled trials evaluated the influence of implant surface characteristics on implant survival (84, 148). All used the Branemark System and demonstrated high survival (ranging from 95.5 to 100%) of implants with an oxidized surface. However, turned implants were clearly less successful under similar clinical conditions, with a 10% lower survival rate, which was a consistent observation. Cannizzaro et al. (29) investigated the impact of the surgical approach (flap surgery vs. flapless surgery) on clinical parameters and demonstrated comparable implant survival and bone remodelling for a flapless procedure and conventional surgery. In most studies occlusal contact was allowed during the early stages of healing (29, 84, 135, 151). These studies demonstrate high survival of surface-modified implants under immediate-loading conditions in the partially edentulous jaw (> 95%). Degidi et al. (53) evaluated the clinical impact of this parameter in a randomized controlled trial and confirmed no significant influence of immediate occlusal loading on implant survival or on bone remodelling. As demonstrated in Table 6, bone remodelling was limited around implants supporting a fixed partial denture under immediate-loading conditions, which parallels earlier findings on immediately loaded single implants.

Fig. 5. Case report showing tooth 14 to be extracted and replaced with a NanoTite™ Tapered (BIOMET3i) Implant. A 4-mm-diameter PreFormance® Cylinder (BIOMET3i) was placed onto the implant (A) and adjusted for occlusal clearance (B–D). The screw-access opening was blocked with a light impression material. A bright color of impression material was selected for easy retrieval of the access hole after temporary crown fabrication (E–G). A prefabricated crown shell was tried-in on the prepared post (H), filled with composite resin (I) and pressed over the cylinder (J). The patient was asked to bite in occlusion and the composite resin was light-cured (K,L). The screw access hole was located with a diamond drill (M,N). The impression-material plug was removed (O). The abutment screw was removed and the temporary crown was unmounted (P,Q). The temporary restoration was trimmed and polished, inserted and screw torqued up to 20 Ncm (R–T). The temporary restoration in place (U). The screw access hole was blocked with impression material and the temporary crown was trimmed out of occlusal contact (V–X). Three months postoperatively the patient returned to the dental office for final impressions (Y). A laboratory-designed abutment and a zircona crown was fabricated. The abutment was mounted and tightened by hand. After analyzing the gingival contour, and the shade and fit of the crown, the abutment was tightened to 20 Ncm. The crown was cemented with permanent cement (Z, CC).

Complications

With respect to early complications, most papers provided some information (53, 56, 84, 135). Besides complications of a biologic nature that related to early implant loss, mainly technical complications were reported. An interesting finding was the lack of

Table 6. Literature overview of prospective studies on immediate loading of the partially edentulous patient

Authors	Study design	Groups	Implant system	Follow up (months)	No. of implants	No. of patients	Region	Flap/ flapless	Bone regeneration	Occlusal contact	Implant survival (%)	Bone loss (mm) mean (SD)	Screw retained/ cemented provisional crown	Early complications
Rocci et al. (148)	Randomized controlled trial	Immediate loading	Nobel Biocare TiUnite	12	66	22	Posterior mandible	Flapless	Not reported	Not reported	95.5	0.9 (0.7)	Cemented	Not reported
		Immediate loading	Nobel Biocare Turned	12	55	22	Posterior mandible	Flapless	Not reported	Not reported	85.5	1.0 (0.9)	Cemented	Not reported
Romanos et al. (151)	Randomized controlled trial (split mouth)	Immediate loading	Dentsply Ankylos	18–36	36	12 (overall)	Posterior mandible	Flap	Not reported	Yes	100	Not reported	Not reported	Not reported
		Delayed loading	Dentsply Ankylols	18 –36	36	12 (overall)	Posterior mandible	Flap	Not reported	N/A	100	Not reported	Not reported	Not reported
Östman et al. (135)	Case series	Immediate loading	Nobel Biocare Turned (n=77) or TiUnite (n=180)	12	257, of which nine were connected with a tooth	77	Mandible	Flap	Not reported	Yes	98.4 (turned: 96.1; TiUnite: 99.4)	0.7 (0.8) (Turned: 0.5 (0.8); TiUnite: 0.7 (0.8))	Screw-retained	One temporary hypoesthesia, three abutment screw loosening
Degidi et al. (57)	Case series	Immediate loading	Dentpsly XiVE Plus	48	93	40	Posterior maxilla/posterior mandible	Flap	Not reported	No	100	1.16 (0.90)	Screw-retained	One fracture of provisional fixed partial denture
Degidi et al. (53)	Randomized controlled trial	Immediate loading	Dentpsly XiVE Plus	36	50	25	Posterior mandible	Flap	Not reported	Yes	98	0.95 (0.32)	Screw-retained	One swelling, discomfort and pain as a result of implant failure
		Immediate loading	Dentpsly XiVE Plus	36	50	25	Posterior mandible	Flap	Not reported	No	98	0.99 (0.38)	Screw-retained	One swelling, discomfort and pain as a result of implant failure
Fung et al. (84)	Randomized controlled trial (split mouth)	Immediate loading	Nobel Biocare TiUnite	36	20	10 (overall)	Posterior mandible	Flap	No	Yes	100	0.41 (0.77)	Screw-retained	(Overall) Three failures of provisional fixed partial denture
		Immediate loading	Nobel Biocare Turned	36	22	10 (overall)	Posterior mandible	Flap	No	Yes	90.9	0.26 (0.44)	Screw-retained	(Overall) Three failures of provisional fixed partial denture
Cannizzaro et al. (29)	Randomized controlled trial (split mouth)	Immediate loading	Zimmer Swiss Plus	12	67, of which 24 were postextraction	40	Maxilla/mandible	Flap	Not reported	Yes	97.0 (healed bone: 97.7)	0.33 (0.50)	Cemented	Not reported
		Immediate loading	Zimmer Swiss Plus	12	76, of which 25 were postextraction	40	Maxilla/mandible	Flapless	Not reported	Yes	97.4 (healed bone: 98.0)	0.24 (0.29)	Cemented	Not reported

Nobel Biocare, Zurich, Switzerland; Zimmer Dental, Carlsbad, CA, USA; Dentsply Friadent, Mannheim, Germany.

studies with data on soft-tissue parameters, esthetic aspects or patient-centered outcomes following immediate loading of multiple implants in the partially edentulous patient. Given that, it may not be surprising that the vast majority of the papers reported on immediate loading in the load-carrying part of the dentition and not in the esthetic zone (53, 56, 84, 148, 151). In this context, clinicians should realize that there is no solid scientific basis to perform an immediate loading procedure on multiple implants in the esthetic zone of the partially edentulous patient. Clinical studies are clearly needed in this field.

Guidelines in the partially edentulous patient

Taking into account earlier factors for success, immediate loading in the partially edentulous jaw by means of a fixed prosthesis seems predictable in terms of implant survival (95.5–100%). However, there are no studies with data on soft-tissue parameters, esthetic aspects or patient-centered outcomes, and the available studies mainly relate to the load-carrying part of the dentition. Hence, clinicians should be warned that the esthetic predictability of this treatment approach needs further investigation. As discussed earlier in the context of completely edentulous jaws, splinted implant-supported dental prostheses will reduce the occlusal load transfer to the implants compared with a situation with free-standing implant units (90, 91). Splinting may reduce lateral forces onto implants, if at least three are placed in a tripod or a cross-arch manner (145, 146). In such situations, lateral forces are partly compensated by more favorable axial implant forces. When two implants are splinted, this no longer applies as two implants are placed ‘in-line’. The principle of cross-arch stabilization and load reduction has been well documented (70, 119, 120). With respect to occlusion, very light centric occlusal contacts are recommended, with no lateral excursive contacts for posterior restorations. In the canine area, group function should be aimed for. In the anterior region, light or no occlusal contacts are recommended, with distribute protrusive contacts as much as possible to the natural neighboring teeth (50, 156). Regular prosthetic check-ups are required to check for excess wear and to adjust the occlusal pattern whenever required. These visits could be used to modify the emergence profile whenever this is deemed necessary in the interest of optimal esthetics. Additionally, oral-hygiene measures are evaluated and reinforced. In Fig. 6 an immediately loaded partial case is shown.

Final conclusions and summary

The introduction of immediate loading was a paradigm shift in implant dentistry because it was believed that an unloaded period was essential for bone healing in order to promote osseointegration. This belief could not be confirmed by clinical studies or by human histology. An important factor for success is primary implant stability. The latter can be improved by adapting drilling protocols to enhance lateral compression of the bone and by using tapered implant designs with apical thread fixation. To some extent, the use of implants with a microrough surface and rigid splinting may compensate for suboptimal stability. It is essential to avoid fracture of the provisional restoration at all times because this may result in local overloading and implant failure. Also, unevenly distributed occlusal contacts may contribute to failure and therefore occlusion ought to be evaluated at every occasion, especially in the early phase of healing.

Taking into account these aspects, immediate loading in the fully edentulous mandible by means of an overdenture has been shown to be predictable in terms of implant survival (94.4–100%) but may result in additional costs owing to the need for repeated relining. The scientific basis for the overdenture concept in the maxilla is limited. Immediate loading in the fully edentulous jaw by means of a fixed prosthesis is a well-documented treatment concept. When four or more implants are placed, the implant failure is 0–3.3% in the mandible. In the maxilla, four to six implants yield a failure rate of up to 7.2% but this is reduced to 3.3% when the number of implants is increased. Care should be taken to avoid complications during the initial healing stage, and careful maintenance and follow up are required. Provisional fixed prostheses are particularly prone to fracture in the maxilla and hence require reinforcement.

Immediately loaded single implants have demonstrated lower survival rates, of 85.7–100%, and no clear impact of occlusal contact. In fact, a meta-analysis demonstrated a five-times higher risk for failure of immediate loading compared with delayed loading. No study showed superior soft-tissue preservation or esthetics following immediate loading of single implants when compared with other loading protocols. However, this finding may not imply that a

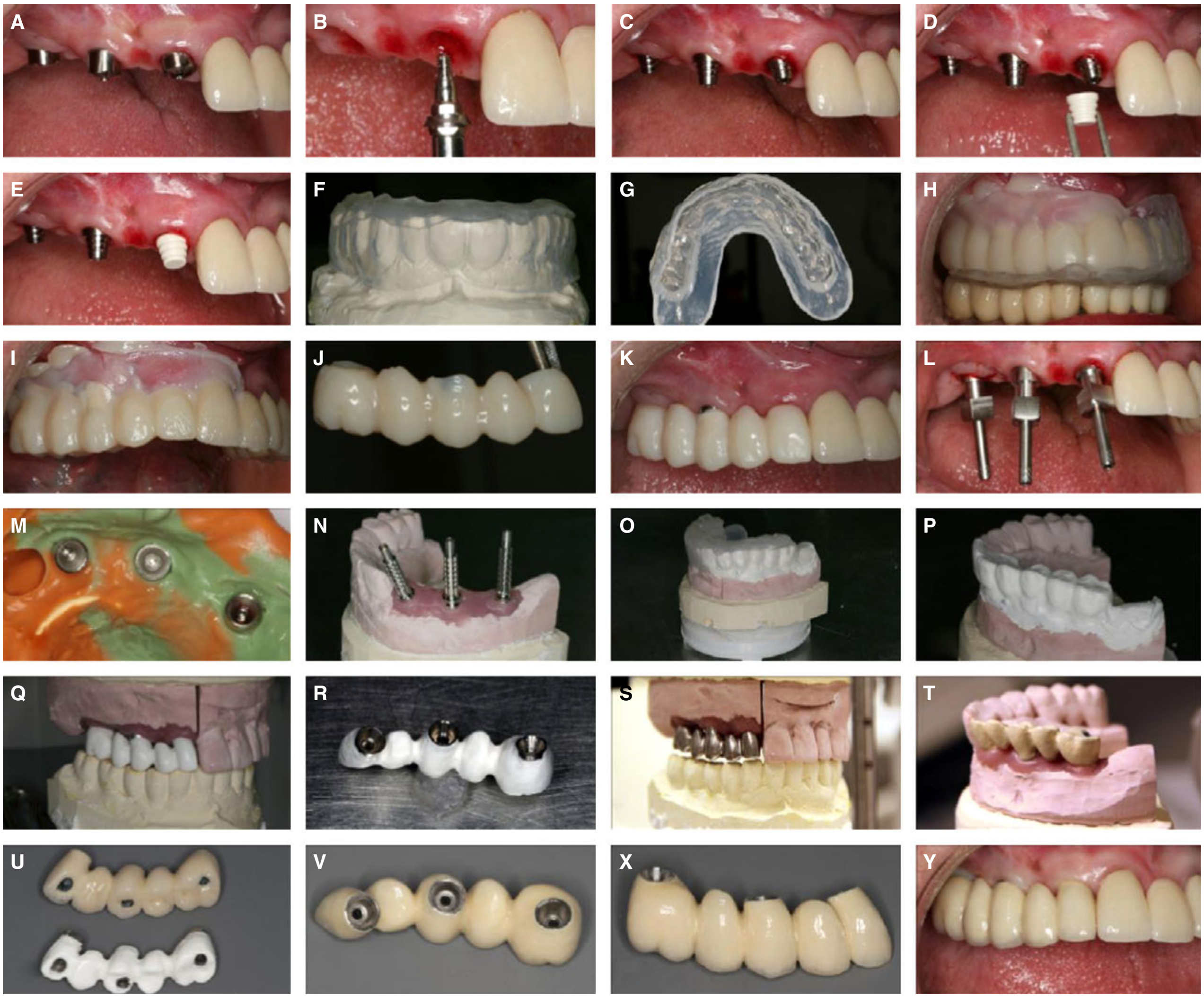

Fig. 6. Case report on immediate loading in the first quadrant on screw-retained abutments (A,B). QuickBridge® Titanium Cylinders were mounted onto the abutments and hand tightened (C). QuickBridge Caps were snapped onto the titanium cylinders (D,E). A template was made before surgery. This was performed by pressing a 2.5-mm-thick thermoformed material over the stone model (F,G). The template was filled with composite resin and seated onto the QuickBridge® Caps (H). The restoration was then snapped off, trimmed and polished, and replaced with chlorhexidine gel (I–K). Three months after soft-tissue maturation, pick-up impression copings were placed onto the abutments and hand tightened (L). An open-tray impression was made with polyvinylsiloxane impression material (M). At the dental laboratory, titanium cylinders were mounted and adjusted to the appropriate height (N). The templates used for fabrication of the temporary construction were reused at the dental laboratory and filled with self-curing acrylic mixed with barium resin in order to fabricate the framework master. From the tooth set-up, the framework master was fabricated using a cut-back technique (O–R). The master cast and the framework master were scanned and a copy-milled framework was prepared (S). This one was blasted, one layer of bonding was applied and then three layers of opaque and porcelain were applied. View of the prosthesis following glazing, which was performed as the last step (T–X), is given. Definitive bar side-by-side with the framework master (U). Screw access holes were covered with composite (Y).

provisional implant crown becomes redundant when soft-tissue conditioning is deemed necessary.

High patient satisfaction is the most important advantage of immediate loading, especially during the early healing phase. In this context, one should also realize that studies have revealed comparable patient satisfaction in patients following delayed loading once their prosthesis is in place. In the decision-making process, this aspect should be properly discussed with the patient along with other advantages and disadvantages of immediate loading.

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