Early and Immediately Restored and Loaded Dental Implants for Single-Tooth and Partial-Arch Applications

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Purpose: *The objective of this consensus committee report was to review the available literature published predominantly in refereed journals to summarize findings, data, and conclusions as they related to reduced healing times and protocols for single-tooth and partial-arch clinical situations. Early loading of dental implants has been defined as restoration of implants in or out of occlusion at least 48 hours after implant placement, but at a shorter time interval than conventional healing. Immediate loading or restoration has been defined as attachment of a restoration in or out of direct occlusal function within 48 hours of surgical placement,* **Materials and Methods:** *Six articles addressing early loading, with a mixture of single-tooth and partial-arch clinical conditions and including some controlled cohort studies, were reviewed. Immediate loading or restoration of dental implants in single-tooth and partial-arch applications, was extensively reviewed. An attempt was made to isolate and categorize similar case types to discern trends and relevant factors. Variables that were considered included single- or multiple-tooth conditions, immediate or delayed placement in extraction sockets, effect of implant surface and geometry, bone quality, implant stability, surgical technique, occlusal design, effect of cigarette smoking, and stability of results.* ***Results:*** *Combined data from 6 early loading studies on single-tooth and partial-arch applications revealed 1,046 implants with a survival rate of 98.2%. Long-term data for most of the early loading studies were not yet available. Most of the publications on immediate loading or restoration of dental implants were written as case series rather than scientific studies.* ***Discussion and Conclusions:*** *In general, most publications indicated that with attention to appropriate factors, implant survival with immediate restoration was comparable to the results with conventional and early loading protocols. It should be recognized that, with few exceptions, these conclusions may be misleading statistical phenomena of the authors, as most publications were written by exceptionally experienced, highly skilled practitioners working under tightly controlled clinical conditions on a relatively small, statistically inconclusive number of implants and patients.* INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):92–102

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A far greater number of patients are edentulous in a single-tooth gap or partial-arch space than are completely edentulous. The opportunity to provide implant-supported tooth replacement for these patients significantly exceeds the opportunity for those who are completely edentulous.[1] The biomechanics of implants in these situations are significantly different than in completely edentulous conditions, particularly in the context of immediate restoration of these implants. Abundant evidence clearly exists to support immediate loading of implants under full-arch clinical conditions. Limiting implant micromotion below the threshold that could interfere with osseointegration, despite occlusal function, has been well documented and elucidated in the previous section and by many authors.[2–4] Methods to achieve this objective include placing an adequate number of (usually) threaded implants into sufficiently dense bone. Stiff restorative materials are

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used to splint implants together using the principles of cross-arch stabilization to distribute occlusal forces between the implants and immobilize them during patient function.

This article will attempt to summarize and organize the relevant literature and factors that pertain to immediate and early restoration and loading of implants in single-tooth and partial-arch applications.

METHODS

A review of the available literature from a MEDLINE search and manual journal searches revealed numerous strategies for achieving osseointegration in single-tooth and partial-arch clinical conditions. It should be noted that there is comparatively less information available on these conditions than for full-arch rehabilitation. The published information shows a tendency toward case series and case studies rather than controlled studies in this area. Further, because many publications report on case series, different clinical factors occur simultaneously. For example, authors such as Degidi and Piattelli[5] and Glauser and coworkers[6] report on series of patients with single and multiple implants in healed alveolar ridges and extraction sockets, who may or may not smoke, using different implant types or surfaces.

Drawing solid conclusions from data like these is hindered by the introduction of confounding or conflicting variables. Yet it is possible to recognize clinical principles, relevant trends, strategies, and insights from examining these publications.

EARLY RESTORATION AND LOADING

This ITI Consensus Conference Introductory Section has previously defined loading protocols and definitions. Prosthetic connection in occlusion to an implant within 48 hours of surgical implant placement is considered *immediate loading*. *Conventional loading* has been defined as restoration and loading of an implant after a healing period of 3 to 6 months. *Early loading* has been defined as prosthetic loading or utilization of an implant at any time period between immediate and conventional loading.

Cochran and associates[7] reported on a longitudinal, prospective, multicenter study of early loading of 383 ITI SLA implants (Institut Straumann, Waldenburg, Switzerland) placed in the posterior jaws of 307 patients. The implants were allowed to heal for 42 to 63 days in classes 1 to 3 bone and for 84 to 105 days in class 4 bone prior to restoration.[8] Patients who were heavy smokers or who had inadequate bone volume, bruxism, or immediate placement indications were excluded. At abutment placement and torque application, 3 implants were mobile and removed, while 3 rotated and 6 were associated with pain. All implants associated with either pain or rotation were allowed additional healing time and eventually became clinically integrated and were restored, resulting in a survival rate of 99.1%. Three hundred twenty-six implants had passed the 1-year evaluation period and 138 had passed the 2-year period without additional changes in clinical parameters.

Roccuzzo and colleagues[9] reported on a prospective, split-mouth design study comparing early loading of 68 SLA implants (sandblasted, large-grit, acid-etched) restored at 6 weeks and 68 identically shaped titanium plasma-spray (TPS) surface implants restored at 12 weeks in 32 healthy patients (all implants ITI/Institut Straumann). Solid restorative abutments were torqued to 35 Ncm at the time of restoration. Four of 68 test SLA implants rotated and the patients experienced pain at the 6-week abutment placement procedure; the implants were allowed to heal an additional 6 weeks before retorquing. None of the control implants demonstrated complications at restoration. After a 1-year evaluation, the authors noted 100% success with no significant differences in clinical parameters between the 2 groups of implants, including radiographic evaluation.

In another prospective study on ITI implants, Roccuzzo and Wilson[10] reported on 36 maxillary posterior implants placed in 19 nonsmoking patients using an altered surgical protocol to increase initial implant stability. Minimal drilling was performed, in favor of bone condensation, to compact and compress maxillary trabecular bone during implant placement. Abutments were torqued to 15 Ncm after 43 days, and the implants were restored with provisional restorations in infraocclusion. After an additional 6 weeks, the abutments were torqued to 35 Ncm for definitive restoration fabrication. One implant rotated with pain at 42 days and was subsequently removed. The other 35 implants were restored uneventfully, leading to a 1-year survival rate of 97.2%. The authors reported implant clinical indices similar to the 6-week period, although marginal bone loss of 0.55 ± 0.49 mm versus the immediate postoperative radiographs was noted.

Testori and coworkers[11] reported on a longitudinal, prospective, multicenter early loading study of 475 Osseotite implants (3i/Implant Innovations, West Palm Beach, FL) in posterior sextants of 175 patients restored at 2 months. Patients who were bruxers or had periodontal or systemic diseases were excluded, while smokers were not. Six of 475 implants failed to integrate within the first 2 months and were considered early failures, while 3 failed after restoration and were considered late failures. The cumulative survival rate was 97.7% after 3 years.

Bogaerde and colleagues[12] reported a prospective study of 31 nonsmoking, nonbruxing patients with 36 edentulous areas treated with 124 Brånemark System machined-surface Mk IV implants (Nobel Biocare, Göteborg, Sweden) provisionally restored 7 to 20 days after surgical placement. One hundred one of the implants were placed in partial-arch applications. One of the inclusion criteria was the ability to achieve 40 Ncm of insertion torque at implant placement, which was generally achieved by underpreparation of the diameter of the osteotomies. Provisional restorations with light occlusal contact were placed at a mean of 11 days postsurgically (maximum of 20 days postsurgically). Ninety-seven of 101 (96%) implants in partial arches integrated, with 3 early failures and 1 late loss at 6 months. Clinical and radiographic evaluation appeared to indicate stable results at 18 months, although according to the authors, many of the radiographic data were not readable or usable for analysis.

Cooper and coworkers[13] reported on 47 patients with 53 early loaded 11- to 17-mm Astra Tech ST implants (Astra, Mölndal, Sweden) to replace 53 maxillary anterior single teeth. Patients were excluded from treatment if they were positive for bruxism, unstable posterior occlusion, daily cigarette smoking, uncontrolled periodontal disease, systemic disease, or mobility of the teeth adjacent to the planned implant site. Acrylic resin restorations were placed into occlusal contact 3 weeks after surgery, at which time abutments were torqued with hand pressure. After 8 weeks, final abutments were torqued to 20 Ncm and definitive restorations were placed. Two implants failed following provisional restoration placement, while 51 integrated, resulting in an implant survival rate of 96.2%.

Drawing conclusions from the limited literature on early loading in partial-arch applications is difficult because of the paucity of information. Table 1 summarizes the information available from the 6 studies that were reviewed, although it should be recognized that all of the articles are not directly comparable. These reports indicate that early loading of 1,046 implants in 611 patients resulted in survival or success of 1,027 implants, for a mean survival rate of 98.2%. All authors indicated high success rates of implants and restorations consistent with delayed loading protocols, but few long-term data have yet been published. Common strategies used by most of the authors, with the exception of Bogaerde and associates,[12] appear to include rough-surfaced implants, infraocclusion, and enhanced surgical stability. None of the authors of the articles reviewed reported placement of implants in immediate extraction sockets with this loading protocol.

IMMEDIATE RESTORATION AND LOADING

Early publications on immediate restoration of single, unsplinted implants in the esthetic zone were presented as case reports and series. Kupeyan and May[14] and Wöhrle[15] reported on series of 10 and 14 immediately restored implants, respectively, in the maxillary anterior region. Kupeyan and Kay performed their study in healed ridges with machined titanium Brånemark System implants (Nobel Biocare), while Wöhrle reported on roughened-surface Steri-Oss Replace implants (Nobel Biocare) in immediate extraction sites. Both groups indicated that all implants clinically integrated and remained stable for the observation periods of 6 months to 3 years.

Additional case reports of small series of patients by Andersen and coworkers,[16] Aires and Berger,[17] Touati and Guez,[18] Lorenzoni and coworkers,[19] Kan and associates,[20] and Cannizzaro and Leone[21] confirmed the observations of 100% survival of single-tooth replacement in the maxillary anterior region. All authors advocated maximization of implant stability by using long implants and eliminating occlusal contact in centric and excursive movements. Lorenzoni and coworkers[19] advocated the use of an occlusal splint for 8 weeks to prevent loading of the restoration by nonocclusal forces such as the tongue or food bolus. Kan and associates[20] placed patients on a liquid diet for 2 weeks postoperatively, followed by a soft diet for 5 months. With the exception of Andersen and colleagues,[16] who indicated that 2 of their 8 patients were cigarette smokers, it appears that patients who smoked more than 10 cigarettes per day or had parafunctional occlusal habits such as bruxism or clenching were excluded from treatment by most authors.

Ericsson and associates[22] reported on 14 consecutive patients treated with Brånemark System MKII implants (Nobel Biocare) in the maxillary anterior area. Nonsmoking patients with negative histories for parafunctional habits had implants placed in healed ridges and immediately restored out of occlusion. Two (14%) implants failed to integrate within the first 5 months. All others were clinically integrated and maintained stable radiographic bone levels throughout the observation period of 18 months.

Table 1 Publications on Early Loading

Authors	Type of study	Implant system	No. of patients	Groups	No. of implants	No. of early loaded implants	Time before loading	Survival/ success	Other
Roccuzzo et al 2001[9]	Pros sm	Straumann SLA versus TPS	32	68 pairs of implants	68 SLA versus 68 TPS; 136 total	68	Provisional restoration: 6 weeks SLA, 12 weeks TPS	68 (100%)	4 SLA implants rotated at 6 weeks, but subsequently healed
Testori et al 2002[11]	Pros	Osseotite (3i)	175	99 single-tooth, 119 short-span prostheses, 11 full-arch	405	405	Provisional restoration: 2 months	396 (97.8%)	97.8% success
Cooper et al 2001[13]	Pros	Astra	47	53 single-tooth implants	53	53	Provisional restoration after 3 weeks, definitive 8 to 12 weeks	51 (96.2%)	2 implants lost
Cochran et al 2002[7]	Pros	Straumann SLA	307	Various	383	383	Provisional restoration: 6 weeks in type 1 to 3 bone, 12 to 15 weeks in type 4 bone	380 (99.1%)	3 rotated and were removed, 6 others painful at evaluation subsequently healed; 3 failed of 383
Roccuzzo/Wilson 2002[10]	Pros	Straumann SLA	19	Various in type 4 maxillary bone using bone condensation	36	36	6 weeks for provisional with 15 Ncm torque, 12 weeks final torque	35 (97.1%)	97.1% survival
Bogaerde et al 2003[12]	Pros	Brånemark System machined	31	56 implants in mandible, 45 implants in maxilla	101	101	Provisional restoration: 7 to 20 days	97 (96.0%)	96% success
Totals			611			1,046 early loaded implants			1,027 (98.2%) surviving/ successful implants

Pros = prospective; sm = split-mouth.

Table 2 Publications on Single-Tooth Immediate Restorations

Authors	Type of study	Implant system/ surface	No. of patients	No. of implants	Successful implants	Success rate (%)
Wöhrle 1998[15]	Pros	Steri-Oss TPS and HA	Single tooth, 14	14	14	100.0
Kupeyan/May 1998[14]	Pros	Brånemark machined	Single tooth, 10	10	10	100.0
Ericsson et al 2000[22]	Pros	Brånemark machined	14	14	12	85.7
Hui et al 2001[23]	Pros	Brånemark machined	13	13	13	100.0
Andersen et al 2002[16]	Pros	ITI TPS	Single tooth, 8	8	8	100.0
Rocci et al 2003[26]	Pros	Brånemark machined	Not specified	27	22	81.5
Calandriello et al 2003[24]	Pros	Nobel Biocare TiUnite 5.0 mm	Mandibular molars, 44	50	50	100.0
Lorenzoni et al 2003[19]	Pros	Frialit-2	Single tooth, immediate provisional, 9	12 maxillary	12	100.0
Kan et al 2003[20]	Pros	Steri-Oss Replace	Single tooth, immediate provisonal, 35	35 maxillary	35	100.0
Cannizzaro/Leone 2003[21]	Rand	Centerpulse Spline twist	Single tooth (immediate loading vs conventional), 28 (2 × 14)	46	46	100.0
Degidi/Piattelli 2003[5]	Retro	Multiple	Not specified	58	56	96.6
Totals				287	278	96.7

Pros = prospective; Rand = randomized; Retro = retrospective.

Hui and coworkers[23] studied 2 groups of patients with 24 implants to compare results between immediate placement of implants in 11 extraction sites and immediate placement and restoration in 13 extraction sites in the maxillary anterior region. Heavy smokers and patients with bruxism were excluded. Machined-surface Brånemark System implants 13 to 18 mm long were placed with torque values of 40 to 50 Ncm, with the authors attempting to achieve bicortical anchorage. Provisional restorations were placed the day of surgery with a design of "protected occlusion," where implants were placed out of contact in all excursive movements. No implants were lost and no complications were encountered. The authors noted that the esthetic outcome of the immediate provisionalization group was better because the provisional restorations preserved the gingival contours.

In an article focusing exclusively on mandibular molars, Calandriello and colleagues[24] reported on 44 patients, including 7 smokers, who received fifty 5-mm-wide Nobel Biocare TiUnite implants at least 10 mm in length. All implants were placed in alveolar ridges that had healed for at least 4 months following tooth extraction. They found 100% implant survival at 1 year in bone quality of types 2 and 3.[8] Despite their restorative protocol of keeping provisional restorations out of occlusion, they noted that several provisional restorations fractured, indicating that some occlusal function occurred.

Cannizzaro and Leone[21] reported on a prospective study of 28 patients that compared immediate loading of 46 single implants and 46 matched conventionally loaded implants. All implants were microtextured, self-tapping Centerpulse Spline Twist MTX implants (Centerpulse Dental, Carlsbad, CA) with at least 3.75-mm diameter and 13-mm length. The authors reported a 100% success rate (46 of 46) with the immediately loaded implants and a 97.8% success rate (45 of 46) in the conventionally loaded group. This study is noteworthy for the randomization of other variables, including medical compromise, cigarette smoking, and implant location in patients. Each of the groups of 14 patients included 3 moderate smokers, 1 patient with cardiac disease, 1 patient with controlled hypertension, 1 patient with controlled type 2 diabetes, and 1 patient with asymptomatic HIV infection.

Additional reports of single immediately restored implants are contained within the data from other publications of immediately restored or loaded implants. Table 2 presents the results from 11 publications that include data on single-tooth immediate restoration cases. The listed studies, though not directly comparable, include the observation that 278 of 287 implants achieved clinical osseointegration, for a survival or success rate of 96.7% by various criteria, under immediate restoration conditions. Common themes of the authors include maximization of implant stability and elimination of direct occlusal contact.

Glauser and associates[6] sought to test the limits of immediate loading, placing 127 consecutive implants (76 maxillary and 51 mandibular) in 41 patients, including smokers. The clinical conditions included single-tooth, partial-arch, and full-arch situations in healed ridges and extraction sockets. Patients with bruxism and imperfect alveolar ridges were not excluded. Brånemark System machined Mk IV implants (Nobel Biocare), with a modest taper, were used to increase stability at the time of surgical placement. Restorations were usually placed the day of surgery and were fabricated in centric occlusal contact without excursive contact. After 1 year, results indicated that 22 implants were lost in 13 patients, including 7 maxillary implants in 1 patient, for a survival rate of 82.7%. Thirty-four percent of 41 implants in the maxillary posterior area failed, while only 9% of the other 86 implants in all other areas failed. Patients with parafunctional habits (22 implants) had failure more often (41%) than nonbruxers (105 implants, or 12%). The authors observed that implants placed in conjunction with guided bone regeneration procedures to cover exposed threads had a better survival rate (90% of 84 implants) than implants placed into adequate ridges (67% of 43 implants). Further, they noted that implants placed into immediate extraction sockets were more successful (44 of 49; 90%) than those placed into healed sites (61 of 78; 78%).

VARIABLES

Extraction Sockets

Malo and coworkers[25] placed 94 consecutive machined-surface Brånemark System Mk II implants (Nobel Biocare) in maxillary anterior areas of 49 nonsmoking, nonbruxing patients, with 23 areas restored with fixed partial dentures and 31 single-tooth restorations. Fourteen of 57 maxillary and 13 of 37 mandibular implants were placed in fresh extraction sockets. Stability of the implants was enhanced by underdrilling the apical extent of the osteotomies to increase compression of apical bone during implant placement. Four implants placed into immediate extraction sockets failed to integrate, resulting in a success rate of 85.2% in immediate extraction sockets. All other implants achieved clinical integration. Although the protocol called for fabrication of provisional restorations out of occlusion, 12 provisional crowns loosened and three fractured, indicating that occlusal loading occurred during function.

Rocci and associates[26] placed 97 machined-surface Brånemark System Mk IV implants (Nobel Biocare) in the partially edentulous maxillary arches of 46 patients, 8 of whom were smokers. Bruxers were excluded. The authors used an elaborate surgical guide and flapless surgery and placed prefabricated provisional restorations. There was no discussion of occlusal design. Eight of 97 (8%) implants were mobile within 8 weeks. Five of the lost implants were single-tooth replacements, of which 2 were immediate placements into extraction sockets.

Chaushu and colleagues[27] studied a group of 26 immediately restored cylindric, press-fit hydroxyapatite-coated implants. Seventeen implants were placed in immediate extraction sockets and 9 were placed in healed alveolar ridges. Occlusal contact in centric occlusion was described as “minimized.” Three of 17 implants placed in extraction sockets failed within the first month, for a survival rate of 82.4%, while all of the implants placed in healed ridges survived. All of the failed implants were placed in the maxilla using a combination of conventional drilling and osteotome bone compression for site preparation. It is important to note that this is the only publication reviewed in this section where press-fit, cylindric implants were evaluated for immediate restoration.

Following up on their earlier work, Malo and associates[28] coordinated a multicenter study with 116 machined Brånemark System implants (Nobel Biocare) with various diameters and configurations placed in 76 patients. These implants were placed in the esthetic zone using surgical techniques of underpreparation of the apical osteotomies to increase initial stability such that insertion torque was greater than 30 Ncm for all implants. Twenty-four patients in this group smoked more than 10 cigarettes per day. The authors reported a 96.5% (112 of 116) success rate for integration and 100% (22 of 22) integration in fresh extraction sockets. None of the smokers lost implants, leading the authors to conclude that initial implant stability was more important than smoking in influencing implant survival and normal healing with this group. A higher failure rate was noted with 3.3-mm-diameter implants, although this was not statistically significant because of the small sample size.

Glauser and coworkers[29] reported on a 38-patient series in which 102 Brånemark System Mk IV TiUnite implants were placed (Nobel Biocare); 23 were placed in immediate extraction sites and immediately loaded, 8 were placed in incompletely healed extraction sites, and 71 were placed in healed sites. Twelve smokers were included. Ninety-seven percent (99 of 102) of the implants were clinically successful at 12 months. The authors concluded that neither smoking nor immediate or recent extraction sites had an effect on survival outcome. One patient, who accounted for all of the failed implants, developed an early postoperative infection from a simultaneous guided bone regeneration procedure.

Table 3 Publications on Immediate Restorations in Extraction Sockets

Authors	Implant system	No. of implants integrated/ placed	Success rate (%)	No. of integrated/placed control implants
Wöhrle 1998[15]	Steri-Oss TPS and HA	14/14	100.0	
Malo et al 2000[25]	Brånemark MKII machined	23/27	85.2	
Hui et al 2001[23]	Brånemark machined	13/13	100.0	11/11 unloaded in sockets
Chaushu et al 2001[27]	Various HA cylindric	14/17	82.4	9/9 in healed ridges
Malo et al 2003[28]	Brånemark machined	22/22	100.0	
Glauser et al 2003[29]	Brånemark TiUnite	23/23	100.0	
Cannizzaro/Leone 2003[21]	Centerpulse Spline Twist	46/46	100.0	45/46 unloaded in sockets
Kan et al 2003[20]	Steri-Oss HA	35/35	100.0	
Overall		190/197	96.4	

Degidi and Piattelli[5] followed 646 implants under various clinical conditions. While they did not specifically report statistics of extraction sockets versus healed ridges, they indicated that they only had 2 failures with 58 single-tooth implants. Both of these failures occurred in immediate extraction cases where bone condensation was performed for site preparation. The Frialit-2 implants (Friadent, Mannheim, Germany) used in these cases had few macro-geometric features to enhance primary stability. In addition, the authors noted that in both cases the patients exhibited parafunctional habits that applied excessive forces to the implants early in the healing process.

Eight publications that lent themselves to summation and comparison are shown in Table 3. The data pooled from subsets of patients indicate that 197 implants were placed into extraction sockets, resulting in clinical integration of 190, for a clinical success rate of 96.4%. Comparison of the results and conclusions of some articles indicate that a few authors documented poorer integration rates in immediate placement situations. Those authors who achieved high success rates in either condition include Wöhrle,[15] Hui and coworkers,[23] Glauser and associates,[29] and Malo and colleagues,[28] who reported common strategies to optimize results. They favored implants with macro-geometric features such as threads to increase immediate bone-to-implant stability and contact. Surgical procedures were modified to increase apical bone density, including underdrilling and self-tapping. Occlusal loads were reduced, with provisional restorations left out of occlusion. Cigarette smoking did not appear to be a factor in achieving integration. Circumstantial reports suggest that implant site preparation through bone condensation may not be optimal for immediate restoration in extraction sockets, in comparison to early loading applications where this type of bone preparation did not appear to affect outcomes.

Single Teeth Versus Multiple Splinted Teeth

Many authors have demonstrated high success rates with immediately restored implants in partial-arch configurations. Case reports and case-control series demonstrating nearly 100% success rates have been reported by Malo and coworkers,[25,28] Jaffin and associates,[30] Chatzistavrou and coworkers,[31] Degidi and Piattelli,[5] Calandriello and associates,[32] and others. Degidi and Piattelli[5] reported 100% success of implants (166 of 166) supporting fixed partial dentures in their nonloaded groups. Rocci and colleagues[26] reported significantly higher integration rates with multiple-tooth conditions (94%) than with single teeth (81%) using machined-surface implants.

Implant Surface

In a different patient series comparing the influence of implant surface on clinical results, Rocci and coworkers[33] reported a 95.5% success rate with Nobel Biocare TiUnite (roughened-surface) implants in 2- to 4-unit splints but an 85.5% success rate with machined-surface Nobel Biocare implants. This difference in success rate was more pronounced when evaluating implants placed into type 4 bone, where 45% (5 of 11) of machined-surface implants failed and only 8% (1 of 12) of roughened-surface implants failed. These findings are similar to those of Glauser and associates,[6,29] who demonstrated poor success with machined-surface implants in poor bone quality but good success when roughened surfaces were used in these areas.

Number of Implants, Occlusion, and Placement Technique

One strategy used to enhance success rates has been to increase the number of implants. Calandriello and colleagues[32] used 1 implant per tooth and obtained 98% survival. Degidi and Piattelli[5] recommended a prosthetic unit-to-implant ratio of at least 1.4 in the maxilla and 1.5 in the mandible. They further recommended that restorations be fabricated out of occlusion, in agreement with Malo and coworkers,[28] while Calandriello and colleagues[32] recommended light occlusal contact in centric occlusion. In an early loading study, where most restorations were placed within 1.5 weeks of implant surgery, Bogaerde and associates[12] similarly reported high success with light occlusal contact. Most authors recommend altering implant surgical procedures to increase initial stabilization by avoiding tapping the osteotomy sites and by underdrilling the apical width of the osteotomies to increase apical compression. This was specifically mentioned by Malo and coworkers,[25] Calandriello and colleagues,[32] and Bogaerde and associates.[12]

Bone Density and Quality

Numerous references have been made in the preceding sections regarding the impact of, or association between, bone density or quality and implant success with immediately restored or loaded implants. This implicit relationship between bone density, initial implant stability, and successful osseointegration has been generally accepted by clinicians and confirmed in the literature in relation to conventional loading protocols as described by Jaffin and Berman.[34] Mirroring these findings in immediate restoration and loading conditions, Rocci and coworkers[26] noted survival of 22 of 27 (81%) machined titanium implants placed in "soft bone" but 66 of 70 (94%) in dense bone, which was statistically significant at $P >$ .02. Similarly, Glauser and associates[6] noted the survival of 66% of implants placed in type 4 bone, but 91% in all other types of bone. In reporting 100% success for integration, Cannizzaro and Leone[21] noted that 38 of 48 of their immediately loaded implants were placed in bone density type 2[8] or denser. None of the implants in their study were placed in bone density of less than type 3.

Several authors refer to their stability criteria for immediately loading or restoring dental implants, regardless of bone quality. Wöhrle[15] sought insertion torque of 45 Ncm for single restorations and Hui and associates[23] indicated the need for 40 to 50 Ncm. Horiuchi and coworkers[35] observed a mean insertion torque of 42 Ncm for implants used in mandibular full-arch immediate loading cases. Bogaerde and associates[12] recommended a minimum insertion torque of 40 Ncm. Calandriello and coworkers[32] indicated that their requirements for immediate loading were a minimum insertion torque of 60 Ncm for single teeth, 45 Ncm for implants supporting partial-arch restorations, and 32 Ncm for implants supporting full-arch restorations. Andersen and coworkers,[16] Malo and associates,[25,28] Degidi and Piattelli,[5] and Lorenzoni and colleagues[19] all indicated that their minimum insertion torque values were 30 to 35 Ncm. Glauser and coworkers[29] reported a mean insertion torque of 27 Ncm in their later study. Although Cannizzaro and Leone[21] did not report insertion torque value, they reported that abutments were torqued to 30 Ncm, indicating that the implants achieved at least this degree of stability.

A few authors have begun to include resonance frequency analysis data[36,37] in assessing implant stability. Calandriello and coworkers[24] reported a mean implant stability quotient (ISQ) of 76 and a minimum of 58 at implant placement for their single molar implant study using 5-mm-diameter implants. Glauser and associates[29] reported a mean ISQ at placement of 71 (SD = 8). Of particular interest in this study was the observation of a rapid decrease in mean ISQ value to 63 at 1 week, which gradually increased toward baseline during the 1-year observation period.

Implants with high initial stability appear to survive well under immediate restoration or loading protocols. It would seem that implants placed in softer bone are less stable than those placed in denser bone unless surgical strategies to increase stability are applied. Studies that use insertion torque values are in general agreement that the values should be at least 30 to 35 Ncm. Resonance frequency analysis may prove to be another useful method to aid in selection of the loading protocol.

Implant Surface/Geometry

Most of the data presented on immediately restored and loaded implants have been collected from studies with threaded implants. An exception is the report by Chaushu and associates,[27] who used press-fit cylinders and reported a relatively high failure rate (17.6%) in extraction sockets but a 100% success rate in healed ridges.

Implants with a sparse thread pattern have also been evaluated. Degidi and Piattelli[5] used 82 Frialit-2 implants with immediate loading and reported 6 failures, for a success rate of 93.7%. In immediately restored, unloaded implant sites, they reported 2 failures of 62 Frialit-2 implants (Friadent) in extraction sockets, for a success rate of 96.6%. The 2 failures in this group occurred in extraction sockets that were prepared using bone condensation procedures. Lorenzoni and coworkers[19] reported on immediate restoration of Frialit-2 implants in extraction sockets and had 100% success using occlusal splints for 2 months after placement to eliminate forces on the implants.

Few investigators have directly compared the integration rates of roughened, threaded surfaces with those of machined, threaded surfaces. Rocci and coworkers[33] noted a significant increase in success rate when comparing Nobel Biocare TiUnite surface threaded implants with machined-surface threaded implants. They found the success rate for the roughened-surface implants to be 95.5% (63 of 66) versus 85.5% (47 of 55) for the machined threaded surfaces. The difference in success rate was particularly striking when evaluating implants placed in poor quality, type 4 bone[8]: 1 of 12 rough-surfaced implants failed, compared with 5 of 11 machined-surface implants. These results are similar to those in case series reported by Glauser and associates.[6,29]

Alternatively shaped implants have been developed specifically for immediate restoration and loading applications. These include the Altiva NTR System (Altiva, Minneapolis, MN) and the Sargon system (Sargon Enterprises, Beverly Hills, CA). Buchs and coworkers[38] reported on the Altiva NTR, which is a 1-piece implant with a dual helical thread pattern designed to increase initial bone stability and eliminate prosthetic abutments and screws. The authors reported on a series of 142 implants that were used in single-tooth (51) and partial-arch (91) clinical situations. Smokers and unhealed extraction sockets were excluded from the study. Nine failures were reported, for a success rate of 93.7%. When the data were further refined, they noted success rates of 83.3% (10 of 12) in type 1 bone, 95.7% (45 of 47) in type 2 bone, 88.9% (24 of 27) in type 3 bone, and 71.4% (5 of 7) in type 4 bone.[8] One hundred twenty-six of 142 implants were followed at least 1 year, and the implant survival rate did not change after the second month. No data are available to address success criteria of bone level stability, radiographic changes, or gingival indices for this implant system.

Jo and coworkers[39] reported on 286 expandable implants manufactured by Sargon and used in 75 patients. Eighty-two of 90 implants placed in extraction sockets were immediately loaded, and 164 of 196 implants placed into healed ridges were immediately loaded. The unloaded implants, including all implants placed into type 4 bone, were deemed not sufficiently stable for immediate loading and were allowed to heal conventionally. The implants were designed to allow for expansion of the apical wings of the implant to re-establish intimate contact with the surrounding bone if implant mobility was noted in the first few weeks of healing. Two hundred eight of 286 implants required apical expansion during early healing. Results indicated that 81 of 82 (98.8%) immediately restored implants placed in extraction sockets and 156 of 164 (95.1%) immediately restored implants placed in healed ridges survived a minimum of 13 months and up to the maximum observation period of 40 months. Sixty-nine implants had 75 complications. Thirteen of these implants failed. Some of the complications appeared to be unique to the implant design. Implant fracture was not observed. As with the Altiva NTR system, long-term success criteria and data are not available for this implant system.

In summary, the available literature, which is available mostly in a case-series format, is limited and inconclusive with regard to surface and shape characteristics for implants used for immediate restoration and loading. A strong inference can be drawn that implants with increased macroscopic stabilization features such as threads and microscopic enhancements such as surface treatments appear to have improved integration rates compared with smoother designs. TPS and hydroxyapatite coatings, SLA, and increased oxidation appear to improve integration success over machined surfaces, particularly in areas of challenging bone quality. Newer designs like mechanical expansion and large helical threads may offer alternative methods of initial stabilization, but it has not yet been shown that implants with these alternative geometries can achieve long-term success as currently defined.

Stability of Results

It is clear that immediately restored and loaded implants in partial- and single-tooth applications can achieve integration using many implant systems and protocols. Other clinical outcomes that have been evaluated include hard and soft tissue changes. Ericsson and coworkers[22] noted that once implants were restored, they lost a mean of 0.1 mm of bone over the 1-year evaluation period, which was similar to data obtained from their control group of delayed loaded implants. Lorenzoni and associates[19] noted that implants placed with an immediate restoration demonstrated 0.45 mm mesial resorption and 0.75 mm distal crestal resorption at 6 and 12 months, which was less than that observed for a standard 2-stage approach. Hui and coworkers[23] reported crestal bone loss of no more than 0.6 mm during their 16-month observation period. Andersen and associates[16] noted a mean gain of radiographic crestal bone level of 0.53 mm during their 5-year observation period. This gain was explained as closure of the vertical defects of the extraction socket walls toward the implant surface. Cannizzaro and Leone[21] noted radiographic bone loss of 0 to 1 mm on 95.7% (44 of 46) of their immediately loaded implants and 93.3% (43 of 44) of their control group at 24 months, indicating no statistical difference between the immediately loaded and conventional treatment modalities.

Degidi and Piattelli[5] reported mean bone loss of 1.1 mm after 5 years on 87 immediately restored or loaded implants. Rocci and associates[26] noted mean bone loss of 1.0 mm after 1 year, 0.4 mm during the second year, and 0.1 mm in the third year of their study. In their single-tooth, mandibular molar study, Rocci and colleagues[33] similarly measured a mean of 0.9 mm crestal bone loss with TiUnite (ie, rough-surfaced) implants and 1.0 mm with machined-surface implants. Malo and coworkers[28] found mean bone loss of 1.1 mm, Calandriello and associates[32] measured mean bone loss of 1.2 mm, and Glauser and colleagues[29] measured mean bone loss of 1.2 mm in their studies after 1 year. These bone loss measurement data are similar to those reported for conventional loading protocols.[40,41] Crestal bone resorption data were not reported for the less traditional implant designs of Sargon and Altiva NTR.

Of particular interest to clinicians when placing implants in the esthetic zone are the stability and behavior of soft tissue contours. Achieving stable osseointegration is an important element of predictable implant dentistry, but preserving or creating stable, harmonious soft tissue contours is also of paramount importance. Wöhrle,[15] Hui and coworkers,[23] and Kan and associates[20] reported gingival marginal changes of immediately restored implants. Wöhrle[15] noted minimal marginal tissue changes in 12 of 14 patients and recession of 1 to 1.5 mm in the remaining 2 implants. Hui and coworkers[23] did not report data on soft tissue stability, but noted that the esthetic results in their immediately restored sites were superior to those achieved with a staged approach because of gingival architecture preservation.

In a carefully documented study, Kan and associates[20] followed 35 maxillary anterior immediately restored implants placed into extraction sockets. After 1 year, they noted radiographic crestal bone loss of 0.26 mm mesially and 0.22 mm distally. Gingival marginal recession was 0.55 mm midfacially, 0.53 mm at the mesial papilla, and 0.39 mm at the distal papilla. These changes are similar to those reported for conventional loading protocols by Bengazi and coworkers[42] and are slightly less than those reported by Small and Tarnow.[43] Additionally, a histomorphometric study in macaque monkeys by Siar and coworkers[44] supports the observation that no significant differences in crestal bone level or gingival margin location were seen between immediately loaded and conventionally loaded implants.

In general, the case reports and studies indicate that once immediately loaded implants integrate, they appear to have longitudinal bone loss and soft tissue stability comparable to those of conventionally loaded implants. Limited data suggest that immediate restoration of implants in the esthetic zone might facilitate and stabilize gingival architecture more than a staged approach. No evidence suggests that deleterious gingival complications can be directly attributed to immediate restoration or loading protocols.

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