Correlation Between Placement Torque and Survival of Single-Tooth Implants

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Purpose: *This study evaluated the survival parameters of single-tooth implants through clinical and radiographic analysis.* ***Materials and Methods:*** *Implants were restored within a 24-hour period with a provisional crown designed to receive an occlusal masticatory load. This approach was compared to implants restored after a healing period (the control group). Forty-six implants were placed in 23 patients who were each treated with 2 Frialit-2 implants placed in sites between the second premolar in the maxilla or mandible. The manufacturer's recommended formal surgical procedure was followed, and primary stability was standardized with a minimum insertion torque of 20 Ncm. The sites were randomly selected, and the clinical and radiographic parameters were standardized with individual templates.* ***Results:*** *Data were collected at 24 h, and at 1, 3, 6, 12, 18, and 24 months. The experimental group included 10 failed implants; 9 of the failed implants had been placed with an insertion torque of 20 Ncm. One implant from the control group failed during the 24-month follow-up period. The survival rate was independent of implant length, site position, and bone quality and quantity. Relative risk for implant failure was associated with insertion torque (relative risk 0.79 [CI: 0.66–0.930]; Cox regression) (*$P \leq .007$*), in the experimental group but was not significant for those in the control group (ie, implants placed after a healing period; relative risk 0.78 [CI: 0.34–1.78]; Cox regression) (*$P \leq .057$*). To achieve osseointegration, it was found that an insertion torque above 32 Ncm was necessary (*$\chi^2 = 15.68$*; *$P \leq .004$*).* ***Discussion:*** *A careful evaluation is necessary for a better understanding of the survival rates of immediately loaded implants. In this study, insertion torque was associated with the potential for risk, which can be decreased by 20% per 9.8 Ncm added.* ***Conclusion:*** *Given these results, and considering the number of patients treated, immediate provisional crowns should only be proposed with early loading if an appropriate initial insertion torque has been applied.* Int J Oral Maxillofac Implants 2005;20:769–776

Key words: *immediate provisional crowns, insertion torque, masticatory loading, single-tooth implants*

Improvement in the Brånemark[1] technique stems from comprehensive surveys regarding alterations in the surface and design of implants, as well as alteration of the surgical techniques used to place them. Satisfying patient expectations remains a challenge for the implant surgeon. To evaluate the possibility of reducing the healing period while still achieving osseointegration, researchers have investigated 3 fundamental questions: *(a)* What is the best interface between artificial material and living tissue? *(b)* What material will provide the best tissue response? and *(c)* What is the most advantageous time for implant placement?

Because of the chemical similarity of the titanium surface composition, differences in cellular modulation will influence alterations in the implant surface topography. One study suggested that surface roughness was responsible for an increase in the level of osteoblastic activity in vivo,[2] thus supporting research findings that have suggested surface roughness enables early bone apposition.[1,3–5]

Biomechanical analysis and histomorphometric assessment of placement and removal torque have confirmed a positive correlation between implant surface roughness and bone adherence.[3–6] Several

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studies have proposed analysis of the interference of mechanical stress during the initial healing phase and its alteration of the tissue present at the bone-implant interface.[1,3,4] Corso and associates[7] evaluated whether implant surfaces played a role in achieving primary stability when single-tooth implants were immediately loaded with masticatory forces. They found that there were no alterations of crestal bone level when 4 groups of implants with different surfaces were compared. Thus, they concluded that no significant effect on treatment could be attributed to the surface type.

Immediate implant placement at the time of tooth extraction was the concept of Tübingen ceramic implants in the mid-1970s.[8] Stable soft- and hard-tissue levels could be obtained by placing root-shape implants, especially for single-tooth replacement.[9] A period of 3 to 6 months' healing with no loading was developed using what could be considered an empirical approach. The existing dispute in the understanding of this matter is complex because experiments and protocols have used different implant designs, prostheses, and timetables for the initiation of implant function. Studies developed to assess immediately loaded implants in the mandible with restorations having cross-arch stabilization have shown good treatment results, since micromovement is inhibited.[10–19]

Wohrle[20] obtained 100% clinical and radiographic success in 14 patients treated with single implants placed immediately following tooth extraction. All implants were placed with a minimum torque of 45 Ncm and subsequently restored with a provisional crown placed immediately after surgery. In a prospective multicenter study that included 10 private clinics and 155 patients, 429 Osseotite implants were placed (3i Implants Innovations, Palm Beach Gardens, FL) in a single-staged surgical approach and loaded after 2 months.[21] Single-tooth provisional restorations, fixed prostheses, and overdentures were among the immediate implant restorations investigated and followed for 10 to 13 months. Of the 429 implants, 83 were single-tooth implants. The cumulative survival rate was 99.5% at 10.5 months and 98.5% at 12.6 months. Such preliminary results have led the present authors to believe that such a protocol can be successful.[21]

Another study involved 22 patients, 14 of whom received single-tooth implants restored within 24 hours, with provisional crowns relieved in centric and lateral occlusal contacts. Eight patients treated with the conventional protocol served as a control group.[22] The survival rate was 85% in the experimental group. Average marginal bone loss around the implants was similar for the 2 groups, around 0.1 mm at an 18-month follow-up.[22] In a prospective multicenter study assessment, Cooper and colleagues[23] evaluated premature placement in function of single free-standing implants in the maxilla and assessed changes in hard and soft peri-implant tissues. The cumulative survival rate was 96.2%, independent of implant length, position in the arch, or the quality and quantity of bone. They reported that of the 100 involved papillae analyzed, 74 demonstrated positive measures, 8 showed no alteration, and 18 demonstrated negative measures.

The clinical survival of immediately loaded single-tooth implants placed in fresh extraction sites was compared to that of immediately loaded single-tooth implants placed in healed sites in 26 patients in whom 28 implants were placed and immediately restored with provisional crowns.[24] Nineteen implants were placed in fresh extraction sites and 9 implants (the control group) were placed in healed sites. The cumulative survival rates were 82.4% and 100% for the fresh extraction and healed sites, respectively. The follow-up period ranged from 6 to 24 months, with an average of 13 months for the fresh extraction sites and 16.4 months for the healed group.

Based on findings in the related literature, the purpose of this investigation was to evaluate the survival parameters of single restored implants with immediate provisional crown placement and masticatory loading compared to those of implants placed according to a protocol that included an initial 3- to 6-month healing phase before prosthesis fabrication and loading. Assessment included the analysis of accumulated survival, peri-implant health, clinical, and radiographic parameters.

MATERIALS AND METHODS

In 1999, 1,500 patients with missing teeth were examined. Only 23 patients fulfilled inclusion and exclusion criteria. To be included, patients had to report a condition of good health and had to be missing 2 teeth from the anterior maxilla or mandible, between the left and right second premolars. The implant sites were analyzed by panoramic radiographs and tomograms and subsequently classified with regard to bone quantity and quality following Lekholm and Zarb[25] criteria. To be included in the study, the sites had to be able to support implants 3.8 to 4.5 mm in diameter and 10 to 15 mm in length. Smokers, diabetics, patients with degenerative diseases, those who presented with oral pathology or had missing molars, those who were not properly orally rehabilitated, psychologically unsta-

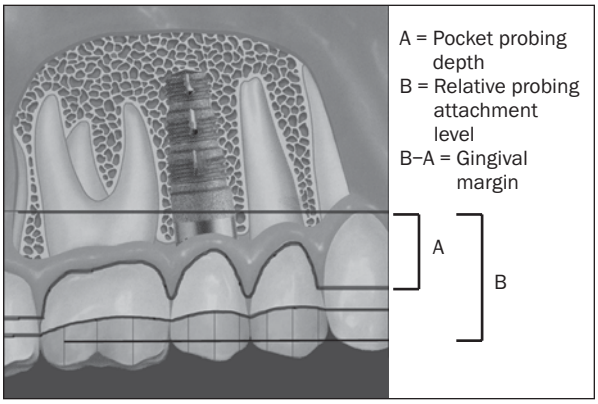

Fig 1 Individual guide used to register pocket probing depth, relative probing attachment level, and gingival margin. Illustration adapted with permission from Friadent, Mannheim, Germany.

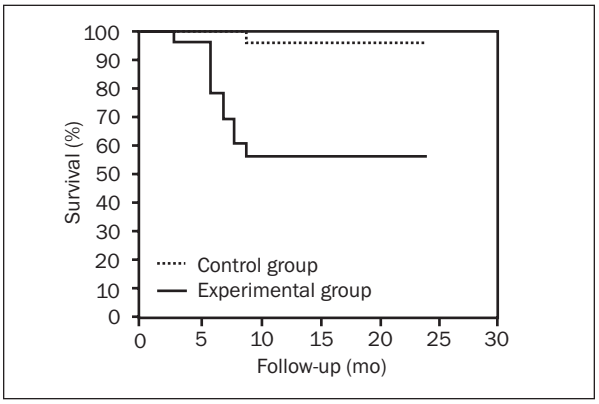

Fig 2 Comparison of survival probability (cumulative survival rates) for the experimental and control groups (Kaplan-Meier analysis). *P* = .001 (log-rank test).

ble individuals, bruxers, and patients medicated with substances that might affect surgical site healing were also excluded.

Nine male and 14 female patients with ages ranging from 18 to 60 years, median age 35.4 ± 9.1 years, were selected. Each patient received a single Frialit-2 implant (Friadent, Mannheim, Germany) with an immediate provisional crown made of Protec (Friadent) and a control implant. The control implants were restored using a delayed approach. Implant placement and primary stability were standardized as mandated by protocol and placed with a minimum placement torque of 20 Ncm. The immediate provisional crown was relieved by 1.5 mm on the occlusal and 1 mm at the incisal and was free of contact from centric occlusion and lateral movements.

Individual templates were fabricated for obtaining periapical radiographs immediately after surgery, at 24 h and 1, 3, 6, 12, 18, and 24 months postsurgery. Standardized radiographs were processed using an automatic film processor (AT-2000 Air Technes; Kodak-Ektaspeed Plus; Eastman Kodak, Rochester, NY) with an indirect digital system. Digital images were analyzed by a quantitative method obtained from INC Software (Schick Technologies, Long Island, NY). Radiographic analyses evaluating bone loss were obtained using a reference point at the top of the mesial and distal aspects of the implant at the cortical bone level. For analysis of the clinical parameters, the Gingival Index, Plaque Index, and Papilla Index[26] were used with individual guides to register probing depth and relative attachment level (Fig 1). The changes in pocket probing depth (PPD) and relative probing attachment level (RPAL) in the experimental and control groups were obtained by subtracting the measurements made at the sixth month and the first month postoperatively. Negative PPD values were used to indicate a decrease in depth, while the positive values indicate an increase in depth. Negative RPAL values reflect a gain of attachment level, whereas the positive values reflect a loss of attachment level. These parameters were calculated for the experimental and control groups. The gingival margin position was defined in this study as being the difference between the RPAL and PPD measurements for the control and experimental groups (ie, the differences between the sixth month and the first month measurements). Negative values indicated a gain in tissue volume while the positive values indicated recession. All patients consented in writing to participate in this investigation.

Statistical Methods

The survival time of implants was estimated for both groups using the Kaplan-Meier curve. The McNemar test was applied for paired groups to identify similarities among them. Chi-square tests were used to measure the significant statistical correlation with the survival or failure in the experimental group, and Cox regression coefficients were used to determine the relative risk between study variables such as implant diameter, implant length, site, insertion torque, and bone quality and quantity for the control and experimental groups.

RESULTS

Nine male patients and 14 female patients (39.1% and 60.9%, respectively) were included in this research, with a mean patient age of 35.4 ± 9.1 years. Two experimental sites that initially failed were retreated with the same surgical procedure after 1 year of healing but were not included in the analysis. The follow-up took between 6 and 24 months. Figure 2 shows the life table analysis of survival and failure

Table 1 Absolute (n) and Relative (%) Frequencies of Parameters Related to Survival and Failure in the Experimental Group

	Survival		Failure			
Variable	**n**	**%**	**n**	**%**	χ^2	***P***
Age (y)						
10–20	—	—	1	10.0	6.0	.1988
20–30	5	38.5	1	10.0		
30–40	2	15.4	7	70.0		
40–50	4	30.7	1	10.0		
50–60	2	15.4	—	—		
Total	13	100.0	10	100.0		
Diameter (mm)						
3.8	12	92.3	9	90.0	—	> .99
4.5	1	7.7	1	10.0		
Total	13	100.0	10	100.0		
Length (mm)						
10	—	—	1	10.0	2.17	.5369
11	3	23.0	1	10.0		
13	5	38.5	2	20.0		
15	5	38.5	6	60.00		
Total	13	100.0	10	100.0		
Site						
8	2	15.4	—	—	10.48	.2331
7	—	—	1	10.0		
5	4	30.8	—	—		
4	2	15.4	1	10.0		
9	—	—	1	10.0		
11	—	—	1	10.0		
12	3	23.0	5	50.0		
13	—	—	1	10.0		
24	1	7.7	—	—		
20	1	7.7	—	—		
Total	13	100.0	10	100.0		
Insertion torque (Ncm)						
20	1	7.7	9	90.0	15.68	.0004
32	9	69.2	1	10.0		
45	3	23.1	—	—		
Total	13	100.0	10	100.0		
Bone quantity						
A	5	38.5	2	20.0	—	.3452
B	8	61.5	8	80.0		
Total	13	100.0	10	100.0		
Bone quality						
1	3	23.1	—	—	4.54	.1033
2	9	69.2	7	70.0		
3	1	7.7	3	30.0		
Total	13	100.0	10	100.0		

for the control and experimental groups. One implant restored according to the delayed placement protocol failed after 9.0 months.

With regard to potential risk factors such as implant diameter ($P > .99$), length ($P = 0.774$), site ($P > .99$), insertion torque ($P = 0.388$), bone quantity ($P > .99$), and bone quality ($P > .99$), the treatment and control groups were compared using the McNemar test. No statistically significant differences were revealed; the results were similar for the 2 groups.

Statistical analysis was performed to determine possible associations between implant failure and parameters related to the sites and implants. The chi square test measured signficant differences in the survival and failure rates for various factors in the experimental group (Table 1). A significant correlation was found in regard to insertion torque ($\chi^2 = 15.68$; $P = .004$). There were 10 failures in the experimental group; 9 of the failed implants had been placed with an insertion torque of 20 Ncm. Only 1 experimental group implant placed with an insertion torque of 20 Ncm survived. In the control group, 10 implants were placed with an insertion torque of 20 Ncm; just 1 failed 9 months after restoration. Table 2 shows an association

Table 2 Cox Regression Coefficients to Determine Risk Factor

	Experimental			Control		
Risk factor	Risk	95% CI	*P*	Risk	95% CI	*P*
Diameter (per 0.22 mm)	1.54	0.08–22.07	NS	0.01	−0.01–5.7	NS
Length (per 0.7 mm)	1.10	0.76–1.66	NS	0.44	0.08–2.33	NS
Insertion torque (per 9.8 Ncm)	0.79	0.66–0.93	≤ 0.007	0.78	0.34–1.79	≤ 0.57
Bone quantity						
A	0.63	0.23–1.36	NS	0.98	0.26–2.17	NS
B	0.98	0.55–1.82	NS	1.03	0.57–2.05	NS
Bone quality						
1	0.63	0.23–1.36	NS	0.98	0.36–2.17	NS
2	0.97	0.55–1.86	NS	1.03	0.58–2.18	NS
3	—	—	—	—	—	—
Site						
Canine	—	—	—	—	—	—
Incisor	3.02	0.41–11.06	NS	0.98	0.26–3.27	NS
Premolar	0.56	0.26–1.63	NS	1.03	0.49–3.03	NS

CI = confidence interval; NS = not significant.

Table 3 Gain or Loss of RPAL at All Analyzed Sites

		Gain		No gain/loss		Loss	
RPAL	Total	n	%	n	%	n	%
Control	84	27	32.14	48	57.14	9	10.72
Experimental							
Total	120	11	9.17	54	45.00	55	45.83
Surviving implants	66	11	16.67	38	57.58	17	25.75
Failures	54	0	0.00	17	31.48	37	68.52

Table 4 Decrease or Increase in PPD at All Analyzed Sites

		Decrease		No decrease/increase		Increase	
PPD	Total	n	%	n	%	n	%
Control	84	22	26.19	57	68.17	5	5.64
Experimental							
Total	120	19	15.83	56	46.67	45	37.50
Surviving implants	66	9	13.64	35	53.03	22	33.33
Failures	54	10	18.52	21	38.89	23	42.59

was found between insertion torque and potential risk of implant failure. The risk decreased by 20% per 9.8 Ncm added (ie, the standard deviation) (relative risk 0.79 [CI: 0.66–0.93]) ($P \leqslant .007$), but no statistically significant differences were found for other variables.

Clinical Parameters

Both the Plaque and Gingival Indices revealed acceptable oral hygiene in these patients. No signs of plaque retention or inflammation were seen in the majority of implants for either group.

The means and standard deviations for PPD and RPAL, determined using the method described, showed gain in RPAL and decrease in PPD for both groups. When survival and failure were compared, the failed implants showed lost RPAL and increased PPD, but no clinical signs of inflammation (such as redness, edema, or suppuration) were observed. The summarized results are shown in Tables 3 and 4.

Recession was demonstrated in both groups, but it was higher for the experimental group. The percentage of sites at which there was no alteration in the position of the gingival margin was 59.52% for the control group and 48.17% for the experimental group (Table 5). After 6 months, increases in scores in the papilla index introduced by Jemt[26] were seen for both groups. Increases of 88.2% mesially and 65.7% distally were seen for the experimental group; increases of 83.3% mesially and 50% distally were seen for the control group.

Table 5 Rates of Gingival Margin Gain or Loss Obtained from All Analyzed Sites

		Gain		No gain/loss		Loss	
PPD	Total	n	%	n	%	n	%
Control	84	16	19.05	50	59.52	18	21.43
Experimental	120	23	19.17	59	49.17	38	31.66

The average bone loss observed in the first year of this study was 1.57 (± 0.97) mm mesially and 1.92 (± 0.85) mm distally for the control group and 1.36 (± 0.59) mm mesially and 2.44 (± 1.29) mm distally for the experimental group. Although these values were higher than those reported in similar studies, no significant differences were observed between the 2 groups in regard to bone loss ($P > .05$).

DISCUSSION

Several quantitative and qualitative scientific parameters have been identified for determining implant survival. Changes in the papilla index, a measure of peri-implant tissue, were positive in both the experimental and control groups after 6 months. These data confirmed the findings of other studies[20,23] that revealed gains in papilla length.

Recession of the gingival margin was observed in both groups; however, it was greater for the experimental group. In the control group, no alteration in gingival margin was observed for 59.52% of sites; in the experimental group, no alteration was observed for 49.17% of sites. These results contrast with those of Small and Tarnow,[27] who reported on 63 implants placed following 1- and 2-stage surgical protocols. They found that 80% of sites had buccal recession, with the majority of sites showing recession after a postsurgical period of 3 months.[27] Therefore, it is suggested that in such cases, definitive prostheses should be placed 3 months after implant placement. The differences in outcome may be attributed to the fact that in the present study, a healing abutment was not placed in cases of delayed loading. The replacement of healing abutments with anatomically prepared crowns, whether acrylic or porcelain, better maintained gingival margins and papillae.

It is not completely understood why bone loss occurs in the first year. Such loss may be attributed to the healing and remodeling process, surgical trauma, implant design, technical characteristics, or a second surgical step for the placement of an abutment and the subsequent establishment of biologic width. Bone loss may also be directly related to functional load. Gomez-Roman and colleagues[28] stated that the machined collar is part of the subcrestal implant design and should not be calculated with bone remodeling.

In the present study, bone loss in the first year averaged 1.57 mm and 1.36 mm mesially for the control and experimental groups, respectively, and 1.92 mm and 2.44 mm distally, respectively. According to the method of Gomez-Roman and colleagues,[28] the values should be reduced by 0.4 mm to account for the height of the machined collar. Despite the fact that these data are higher than those found in the related literature,[7,16,21,22,29,30] no statistically significant differences were noted between the 2 groups.

The control group had a cumulative survival rate of 95.7%. The experimental group had a survival rate of only 56.5%. Cumulative survival rate was not directly related to the length or diameter of the implants, quantity or quality of bone, position in the arch, or implant placement surgical techniques. However, statistical significance was found for the torque insertion variable ($\chi^2 = 15.68$; $P = .004$). The potential for risk (Cox) was 0.79 (0.66–0.93) ($P \leq .007$). Nine of the 10 failed implants in the experimental group were placed with an insertion torque of 20 Ncm; only 1 implant placed with the same torque survived. The failure rate in the control group did not correlate with the insertion torque values, since 9 (90%) of the 10 implants placed using 20 Ncm insertion torque were successful. The achievement of high insertion torque is likely related to the achievement of higher primary fixation. The existence of micro- and macromovements that affect primary stabilization and can induce the presence of fibrous tissue seems to be established. However, the magnitude of the range of movement that may result in failure is not yet clear. It has been reported that micromovements of 150 to 500 µm are considered excessive and unhealthy.[31] Brunski[32] reported that the critical threshold ranges from 50 to 150 µm. Micromovements of 100 µm for implants with bioinert surfaces may be acceptable. Nonetheless, such thresholds need to be correlated to surface and design.[32]

Skalak and Zhao[33] have suggested that substantial forcefitting stresses on the order of several tens of mega pascals can be generated when a titanium cylinder is placed into a hole in bone with a diameter only 100 microns smaller than the cylinder. Horiuchi and coworkers[34] credited their good results to the

use of a drill with small diameter, 2.85 mm, for the placement of a 4-mm-diameter implant to increase mechanical engagement and add additional stability. Wohrle[20] obtained 100% success in 14 patients with primarily fixed implants placed with a minimum torque of 45 Ncm. However, no mention was made of how many patients were treated to establish this experimental group.

A careful evaluation is necessary for a better understanding of 3 questions: Should osteotomy diameter be reduced for the purpose of increasing initial stability, thus providing a desirable level of initial fixation sufficient to improve the implant success rate when implants are placed in function early? What should the bone cell deformity pattern and response be when implants are subjected to increased mechanical stress and heat arising from their placement in narrower bone sites? With regard to implants that have surfaces treated with a particulate for increased roughness and/or biologic characteristics that favor bone adherence, would it be possible to maintain the integrity of such surfaces during placement in sites with smaller diameters? Additional research is needed on alterations of the protocol technique when the early loading of single implants is attempted.

CONCLUSION

Within the limits of the present study, it has been concluded that the routine immediate loading of single implants should not be proposed, since the data presented herein demonstrated unacceptable survival rates of implants using this treatment approach. Immediate loading in single-tooth indications should only be considered if the implant can be placed with an insertion torque greater than 32 Ncm.

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