A LONGITUDINAL, MULTI-CENTRE STUDY ON THE RELATIONSHIP BETWEEN INSERTION TORQUE AND PERI-IMPLANT BONE RESORPTION

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ABSTRACT

The aim of this study was to evaluate radiographically whether a high implant insertion torque results in increased bone peri-implant resorption. Two splinted and early loaded implants were placed in 32 patients recruited from five dental clinics in Italy. Insertion torque was recorded and radiographic assessment of the marginal bone level was performed after two, six and 12 months using software (ImageJ 1.42). The values of insertion torque ranged between 30Ncm to 100Ncm (mean=65Ncm). Mean peri-implant bone resorption was 0.9mm at 12 months. There were no radiographic signs of necrosis, and statistical analysis of the data showed no correlation between torque and peri-implant bone resorption (Pearson's correlation coefficient = 0.6481). The values of insertion torque between 30Ncm to 100Ncm did not result in a difference in peri-implant bone resorption after 12 months.

INTRODUCTION

Evolutions in implant techniques have brought about a reduction in the required healing time preceding the loading of implants. However, immediate or early loading of implants represents a challenge for dentists, which simultaneously involves both biological and biomechanical aspects.

In protocols of early and immediate loading, the forces due to mastication and other oral functions (i.e., phonation, deglutition) are transmitted through the implant to the surrounding healing tissue. They are then transmitted to bone tissue, depending on the geometry of the implant thread (especially important is the inclination between the upper surface of the thread and the bone tissue), implant geometry and the morphology of the implant neck.[1]

Certain amounts of stresses in early and immediate loading on the healing bone tissue can promote fibroblastic differentiation of mesenchymal cells, which can lead to fibrointegration during the healing stage, rather then osseointegration. Such healing would be considered an implant failure. To safely apply early and immediate loading protocols in dental implantology it is necessary to ensure accurate protection for the healing bone tissue from heavy occlusal forces. The only useful protection is a reduction of micro-movements that occur at the bone-implant interface. It has been demonstrated that micro-movements are not dangerous and do not interfere with healing if they are within a range of 50µm to 150µm.[2] To keep micro-movements within this range, splinting implants and/or ensuring good primary stability for the implant fixture are recommended.[3–5] Splinting more than one implant fixture increases the number of implants on which to load a specific force. In this way, stress is distributed across the various implant fixtures, increasing the odds to keep the micro-movement ranges below the cut-off value.

Mechanical factors related to fixtures (geometrical features), bone (density, quality and quantity) and surgical procedures (drills diameter, deepness of the preparation and tapping of the implant site) contribute to the primary stability of the implant. A simple and immediate way to evaluate primary stability of an implant is through the recording of final insertion torque. Insertion torque is expressed in Newton centimeters (Ncm), a measurement of the strength needed to insert the implant during an osteotomy. It depends on the local bone quality (a dense and compact bone will offer an increased resistance to cutting forces), on the size of the osteotomy preparation and on the macroscopic geometry of the implant. It is a measure that can be evaluated both with dynamometric wrenches, as well as implant surgery motor systems. The higher the measurement of insertion torque, the higher the primary stability of the implant.

It is generally accepted that implants with a torque of at least 20Ncm display a survival rate higher than ones with a lower insertion torque.[6,7] The available data do not definitively indicate the optimal value of torque required to obtain good primary stability. However, it is clear that torque value has a direct relationship with the initial bone-implant contact (BIC) value.[8,9] Some authors believe that insertion of implants with a high torque might cause excessive compression on the surrounding bone. If compression exceeds capillary pressure, temporary osteonecrosis will occur. Thus, excessive insertion torque could be responsible of a phenomenon known as "bone necrosis by pressure,"[10] which is usually limited to bone cortical, while in spongiose bone the compressive effect is absorbed by the fracture of bone trabeculae.

This study aims to evaluate radiographically whether a relationship exists between insertion torque and peri-implant bone resorption, and especially whether a high insertion torque causes increased bone resorption due to pressure necrosis.

MATERIALS AND METHODS

Patient Selection

Five Northern Italian Centres have participated in this study. Each patient was informed about the study's aims and gave informed consent. Thirty-two patients were enrolled according within the following criteria:

Inclusion Criteria

- Age between 30 and 65 years;
- Good oral hygiene;
- Need to rehabilitate a partial edentulism of mandible/maxilla with at least two splinted implants and
- Acceptance of treatment plan and signature of informed consent.

Exclusion Criteria

- Radiotherapy at the head/neck region within the last 12 months;
- Uncontrolled diabetes;
- Pregnancy;
- Poor oral hygiene and/or motivation;
- Drug or alcohol abuse;
- Therapy with bisphosphonates;
- Active inflammation/infection in the sites of implant insertion;
- Smoking >10 cigarettes/day;
- Psychiatric disease;
- Need for bone-augmentation procedures including sinus augmentation;
- Severe bruxism or clenching; or
- Lack of opposing occluding dentition in the area intended for implant placement.

Surgical and Prosthesis Procedure

Two splinted implants (JDEvolution, JDentalCare, Modena, Italy) were placed in each patient in order to rehabilitate a partially edentulous mandible/maxilla. Full-thickness crestal flaps were elevated with minimal extension to minimize patient discomfort. Implant sites were prepared according to the manufacturer's instructions. The implants were placed using an implant surgery motor system.

If necessary, the insertion of the implant was been completed using a dynanometric wrench (JDTorque, JDentalCare, Modena, Italy), which allows the registration of the final insertion torque value. If insertion torque of at least 20Ncm was not reached, patients were excluded from the study.

All patients received post-surgical instructions:

- Apply ice on the region for four to six hours;
- Consume soft food for the first 48 hours and avoid chewing hard food in the rehabilitated sites for six weeks;
- Avoid smoking for 48 hours after surgery;
- Brush involved regions with a soft toothbrush;
- Rinse their mouths with 0.2% chlorhexidine mouth rinse twice a day until the removal of sutures.

Antibiotic and anti-inflammatory therapy was prescribed to all patients, in accordance with established guidelines. Amoxicillin (1 gram) was administered one hour before surgery and every 12 hours thereafter for five to six days. In case of allergy to penicillin, clarithromycin was used (500mg one hour before surgery followed by 250mg every 12 hours thereafter for six days).

To reduce post-surgery pain, Ibuprofen (400mg) was administered every 12 hours for three days. All patients included in the study underwent an oral hygiene treatment regimen the day before surgery in order to reduce variability from an oral environment colonized by bacterial plaque at the time of surgery. The level of oral hygiene of each patient was evaluated at each follow-up visit and, if necessary, patients were invited to undergo a session of oral hygiene and motivation (every three to six months depending on their level of hygiene).

Patients were treated following an early loading protocol, so that the definitive prosthesis was delivered after a healing time of two months. A representative clinical case is shown in Figs. 1 to 7.

Fig. 1: Intraoral pre-operative view.

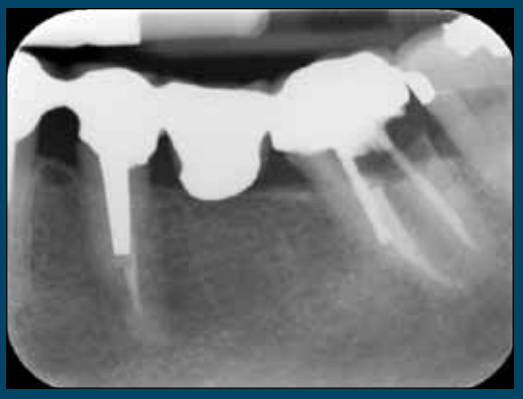

Fig. 2: Pre-operative radiography.

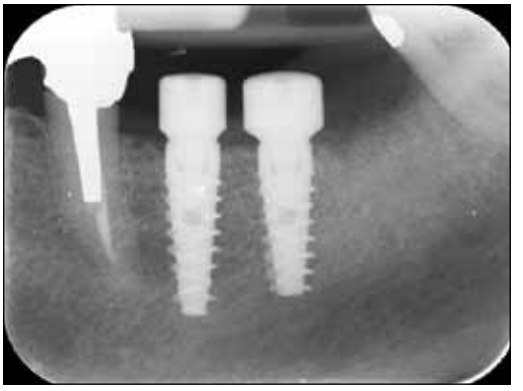

Fig. 3: Intraoral radiography immediately after implant placement. The two implants in site 3.6 and 3.7 were inserted with a torque of 65Ncm and 85Ncm, respectively.

Fig. 4: The final titanium abutments were placed 2 months after implantation.

Fig. 5: Occlusal view at placement of the definitive prosthesis.

Fig. 6: Buccal view of the definitive prosthesis.

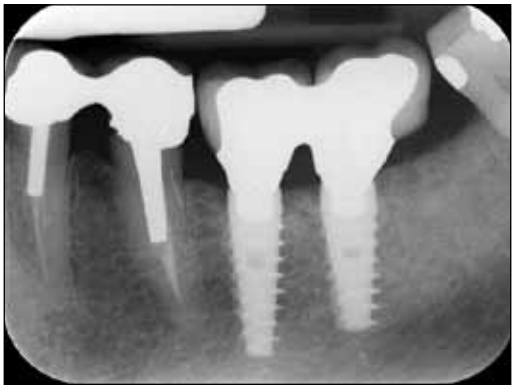

Fig. 7: Intraoral radiography after 12 months loaded.

Clinical and Radiographic Follow-up

Patient follow-up occurred at regular intervals and involved clinical and radiographic evaluation as well as recording of signs and symptoms. The following controls were planned:

- T1: a check-up two months after implants placement (with delivery of the definitive prosthesis);
- T2: a check-up after six months and
- T3: a check-up after 12 months.

At each check-up the following success criteria were applied to evaluate each implant:

1) No clinically detectable mobility;
2) No evidence of peri-implant radiolucency;
3) No recurrent or persistent peri-implant infection;
4) No complaint of pain at the site of treatment;
5) No complaint of neuropathies or paraesthesia; and
6) Crestal bone loss not exceeding 1.5mm by the end of the first year of functional loading.[11]

For the radiographic evaluation, intraoral radiographs were taken using the paralleling technique. Each intraoral radiograph was evaluated using the software ImageJ 1.42. (Fig. 8). Radiographic images were calibrated based on the length of the implant fixture inserted. The distance between the head of the fixture (indicated as 0) and the site where the crestal bone meets the collar of the implant was measured (Fig. 9).

RESULTS

All 32 patients were treated according to the study protocol, and all implants reached the minimal torque value needed to be included in the study (20Ncm). There were no drop-outs, and all patients regularly attended the check-ups and maintained a good level of oral hygiene. None of the implants have failed after 12 months, and no patient reported pain from palpation, percussion or function. All implants were clinically stable and meet the success criteria. Survival and success rates after 12 months were 100%.

Overall, 64 implants were placed. Length and diameters of the implants are reported in Table 1. The values of the insertion torque for each implant are reported in Table 2. The median value of the insertion torque was 65Ncm (SD = 18.04). The values of mean peri-implant bone resorption at T1, T2 and T3 are reported in Table 3.

"None of the implants have failed after 12 months, and no patient reported pain from palpation, percussion or function."

Fig. 8: This image processing was done with the software ImageJ 1.42

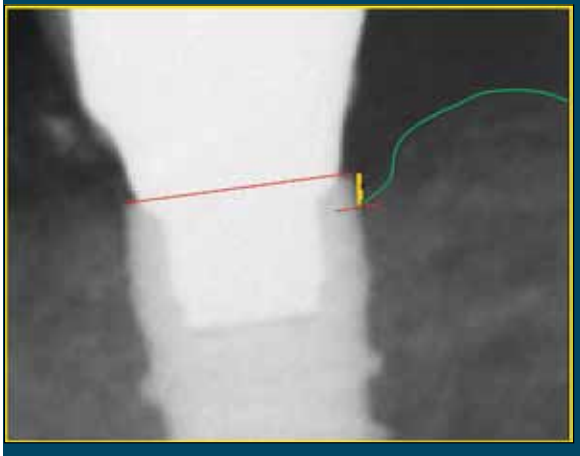

Fig. 9: Digital measurement of the peri-implant bone resorption.

Table I: Lengths and diameters of inserted implants.

LENGTH	IMPLANTS
8	0
10	8
11.5	23
13	33
15	0
DIAMETER	**IMPLANTS**
3.7	0
4.3	41
5	23

Table 2: Insertion torque of the implants placed.

PATIENT'S ID	IMPLANT 1	IMPLANT 2
1	85	80
2	85	65
3	60	60
4	75	85
5	65	90
6	70	75
7	80	65
8	65	85
9	95	70
10	60	60
11	75	80
12	55	60
13	80	65
14	85	60
15	60	75
16	85	90
17	45	70
18	75	40
19	35	70
20	50	60
21	40	50
22	100	100
23	80	65
24	100	55
25	45	50
26	50	35
27	55	75
28	30	50
29	40	35
30	35	40
31	45	65
32	75	50

Table 3: Peri-implant bone resorption at two, six and 12 months. Mean and standard deviation (DS).

MEAN (mm)	STANDARD DEVIATION	
2 months	0,4594	0,213
6 months	0,6987	0,314
12 months	0,9466	0,316

Fig. 10: Relationship between implant's insertion torque and peri-implant bone resorption.

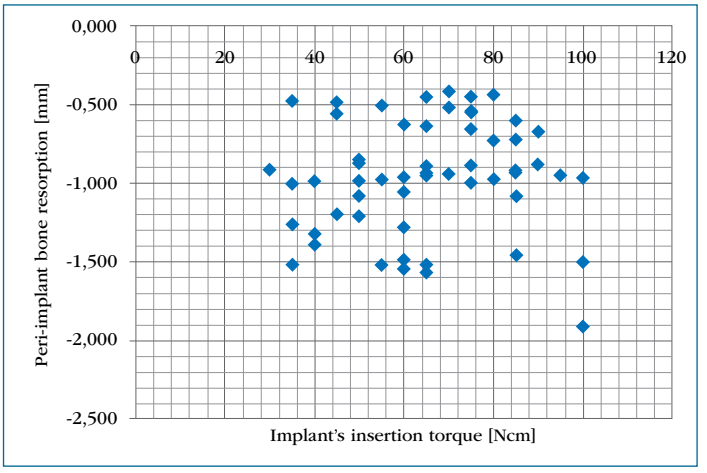

Fig. 10 reports on the x-axis the values of bone resorption at 12 months, and on the y-axis the values of insertion torque for each implant. As evident from this graph, no direct or inverse relationship was observed between the insertion torque values and peri-implant bone resorption (Pearson's correlation coefficient = 0.6481). No relationship was observed when the same analysis was performed using the values of peri-implant bone resorption observed at T1 (two months), in case the necrosis due to a high torque value occurred at earlier time points after surgery (Pearson's correlation coefficient = 0. 4705).

DISCUSSION

Osseointegration is a complex biological phenomenon guided by a series of biochemical events that stimulate angiogenesis, osteoblastic differentiation of mesenchymal cells, extracellular matrix deposition and, in the end, mineralization.

The early and immediate loading of implants causes an increase of the stresses acting on the healing tissues.[12] If loading is high enough to induce excessive micromovements, the fibrocellular blastema developed in the immediate healing phase undergoes a fibrous differentiation.[2] If loading does not induce excessive micromovements, the newly developed bone tissue is stimulated to acquire a microstructure adequate to the intensity and direction of the forces acting on it through the implant.

The primary stability of the implant at the time of placement is fundamental to obtaining immobility of the fixture with respect to bone tissue when chewing stresses are applied. It represents a key factor for high implant survival rates when applying early and immediate loading protocols.

The primary stability of the implant depends on bone density and quality, optimal implant dimensions (length and diameter), implant macro-geometry and under-preparation of the implant site. In this study, implants with standard length and diameter were used (JDEvolution, JDentalCare, Modena, Italy). They are characterized by an adequate design mainly due to the deepness and the cutting performance of the threads. The screwing of a self-tapping implant inside an osteotomy with dimensions lower than the implant diameter (underpreparation) causes the engagement of the threads in peri-implant bone and bone compaction. Therefore, for mechanical reasons, an increase of the implant(s) primary stability and of the insertion torque is observed, followed by bone compression.

Bone tissue is very sensitive to temperature and pressure, which are both able to induce necrosis. Necrotic tissue is gradually removed and substituted with vital bone tissue during the surgical wound healing. If the implant is prematurely loaded, bone must be vital to be able to react adequately, and within a short time, to mechanical stresses. Guidelines recommend the use of implant surgery motor systems adequately irrigated (to avoid overheating), which permit torque control to avoid excessive compression of the bone. It is generally accepted that implants placed with a torque higher than 20Ncm have survival percentages higher that the ones placed with a lower insertion torque,[7] which display an insufficient primary stability. The value of torque which represents the cut-off value to avoid necrosis has not yet been definitively established. However, it is suggested to not exceed a value of 80Ncm to 90Ncm.

Several reports in the literature demonstrate that a relationship exists between the insertion torque and the primary stability of the implants.[6, 13] Ottoni *et al.*[7] have demonstrated that high insertion torque can significantly improve survival rates of immediately loaded single implants. Trisi *et al.*[14] suggest that if an implant is placed with 100Ncm torque and is immediately loaded, it is unlikely to have micromovements sufficient to cause fibrointegration.

Torque is an indicator of the primary stability from a tri-dimensional point of view. The force needed to insert the fixture reflects an intimate three-dimensional contact that occurs between the osteotomy and the implant surface. With increasing insertion torque, the bone compression increases, which may cause so-called "bone necrosis by pressure."

In this study, the lowest insertion torque required for inclusion was 20Ncm. The drills were used under constant irrigation, eliminating the possibility of bone necrosis due to increased temperature. There was no above limit set for insertion torque, however one is usually required. The values of insertion torque recorded in this study ranged between 30Ncm and 100Ncm (mean=65Ncm). No differences were observed in the peri-implant resorption between implants placed with low or high insertion torque. In the implants placed with the highest value (100Ncm), no radiographic signs of necrosis were observed.

The highest value of insertion torque used in this study is lower than values that can be reached to get the most out of the compressive effect of the fixture on the bone. However, it is not easy in routine clinical practice to get values of insertion torque higher than 100Ncm. Our results are in agreement with a recent study by Meltzer *et al.*[15], who have placed implants with high values of insertion torque (mean 90Ncm–100Ncm, with values up to 120Ncm). These implants were immediately loaded and were followed for 24 months. Sixty-six

out of 67 implants had complete osseointegration. Radiographic examination did not reveal anomalous images or marked resorption of the cortical crestal bone. In another study, Trisi histologically evaluated the healing of implants with high torque values (up to 150Ncm with a mean value = 110Ncm)[1]; between the first and the 45th days after placement no signs of bone necrosis by pressure were observed.[16]

In conclusion, based on the results of this study, the values of insertion torque do not affect bone healing, and there are no radiologic signs of bone necrosis for values of insertion torque between 30Ncm and 100Ncm. Further histological studies are warranted to better evaluate the role of insertion torque in the healing processes that regulate osseointegration of dental implants.

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