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Comparative Evaluation of Osseointegration Using Resonance Frequency Analysis (ISQ, Osstell) Between Implants Treated With Static Magnetic Field Therapy and Untreated Controls: A Prospective Clinical Study

Abstract

Background: Primary implant stability and its progression to secondary (biological) stability during the healing phase are critical determinants of long-term implant success. Resonance frequency analysis (RFA), measured as the Implant Stability Quotient (ISQ) using the Osstell device, provides a validated, non-invasive method of quantifying osseointegration over time. Static magnetic fields have been proposed as a non-invasive adjunct capable of accelerating bone healing and osseointegration around dental implants, though clinical evidence remains limited.

Aim: To compare ISQ values, recorded using Osstell RFA, between implants receiving static magnetic field therapy and untreated controls, at baseline (Day 0) and at 1, 2, and 3 months post-placement.

Materials and Methods: 10 dental implants were placed in 10 subjects and divided into 2 groups of five ($n = 5$ each). Group A received no adjunctive therapy (control), while Group B received static magnetic field therapy as an adjunct to promote osseointegration. ISQ values were recorded at implant placement (Day 0) and at 1, 2, and 3 months thereafter using a calibrated Osstell device. Data were tabulated and analyzed statistically.

Results: Mean ISQ values increased significantly over time in both groups (repeated-measures ANOVA: Group A, $F = 36.41$, $p < 0.001$; Group B, $F = 89.76$, $p < 0.001$). Baseline (Day 0) ISQ values were comparable between Group A (71.6 ± 1.1) and Group B (73.0 ± 1.6), with no statistically significant difference ($p = 0.14$). Both groups showed an initial decline in ISQ at 1 month, consistent with the transient stability dip (Group A: 65.6 ± 1.1; Group B: 69.0 ± 1.6; $p = 0.004$), after which Group B demonstrated significantly greater ISQ values than Group A at both 2 months (77.4 ± 1.1 vs. 70.6 ± 1.1; $p < 0.001$) and 3 months (84.0 ± 1.6 vs. 75.6 ± 1.1; $p < 0.001$), with the intergroup difference widening progressively over time.

Conclusion: Within the limitations of this small pilot sample ($n = 5$ per group), adjunctive static magnetic field therapy was associated with significantly higher ISQ values than untreated controls from 1 month onward, with the difference widening progressively through 3 months, suggesting a faster rate of secondary implant stability gain during early osseointegration. These findings are preliminary and should be confirmed in larger, multicenter trials before static magnetic field therapy can be recommended for routine clinical use.

1. Introduction

The long-term success of endosseous dental implants depends fundamentally on the establishment of a stable, direct structural and functional connection between living bone and the surface of a load-bearing implant — a phenomenon first described by Brånemark as osseointegration [1,2,3]. Clinically, implant stability is understood to occur in two overlapping phases. Primary stability is a mechanical phenomenon achieved at the time of implant placement and depends on bone density, implant geometry, and surgical technique [6,9]. Secondary stability is biological in nature and results from bone remodeling and new bone deposition at the implant–bone interface over the following weeks to months [6,9]. The transition between these two phases, often termed the 'stability dip,' typically occurs between two and four weeks after placement and represents a period of relative vulnerability during which premature loading can compromise the final outcome [17,18,19].

Various methods have been used historically to assess implant stability, including the Periotest, reverse torque testing, histomorphometric analysis, and radiographic evaluation [7,8]. Many of these methods are either invasive, destructive, or lack the sensitivity required to monitor stability changes longitudinally in a clinical setting. Resonance frequency analysis (RFA), introduced in the early 1990s by Meredith and later refined into a wireless format by Osstell (Osstell AB, Gothenburg, Sweden), addressed this gap [6,10,13]. The Osstell device applies a magnetic pulse to a small transducer (SmartPeg) threaded onto the implant or abutment and measures the resulting resonance frequency, which is then converted into a dimensionless Implant Stability Quotient (ISQ) ranging from 1 to 100 [10,13,14]. Higher ISQ values correspond to greater stiffness of the implant–bone interface, and serial ISQ measurements over time are widely used both in research and clinical practice to track the progression from primary to secondary stability [11,12,16].

A range of adjunctive physical and biological therapies have been investigated for their potential to accelerate osseointegration and shorten the healing period before functional loading. These include low-level laser therapy, low-intensity pulsed ultrasound (LIPUS), platelet-rich fibrin, and electromagnetic field stimulation [22,23]. Static magnetic fields (SMF), as distinct from pulsed electromagnetic fields (PEMF), are generated by permanent magnets and produce a constant, unidirectional field without an alternating current component [24,28]. Experimental and preclinical studies have suggested that static magnetic fields may influence osteoblastic activity, angiogenesis, and calcium ion transport at the cellular level, potentially favoring earlier and more robust bone formation around an implant surface [22,25,26]. Clinical studies using magnetic healing caps or NdFeB cover screws have reported increased implant stability quotient values and reduced crestal bone loss relative to conventional healing during the early postoperative period [23,24,27]; however, findings across the available preclinical and clinical literature remain mixed, and well-controlled comparative studies are needed to substantiate these effects in larger clinical populations [22].

This study was therefore designed as a prospective, controlled comparison of ISQ values, recorded at standardized intervals using a calibrated Osstell device, between a group of implants exposed to adjunctive static magnetic field therapy and a group receiving no adjunctive therapy, in order to evaluate whether static magnetic field exposure is associated with measurable differences in the rate or magnitude of osseointegration during the first three months of healing.

2. Aims and Objectives

2.1 Aim

To compare implant stability, quantified as ISQ using Osstell resonance frequency analysis, between implants treated with adjunctive static magnetic field therapy (Group B) and untreated controls (Group A), across a three-month observation period following implant placement.

2.2 Objectives

- To record and compare ISQ values in both groups at implant placement (Day 0) and at 1, 2, and 3 months post-placement.
- To evaluate the intragroup trend of ISQ change over time within each group.
- To assess whether adjunctive static magnetic field therapy is associated with a measurable difference in the rate of secondary stability gain.

3. Materials and Methods

3.1 Study Design and Setting

This was a prospective, controlled, randomized clinical study conducted in the Department of Prosthodontics at Teerthanker Mahaveer Dental College & Research Centre. Ethical clearance was obtained from the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrolment.

3.2 Sample Size and Grouping

A total of 10 implants placed in 10 systemically healthy subjects meeting the eligibility criteria were included and allocated into two groups of five each:

- Group A (Control, n = 5): Implants placed using a standard surgical protocol with no adjunctive therapy during the healing period.
- Group B (Test, n = 5): Implants placed using an identical surgical protocol, with adjunctive static magnetic field therapy applied during the healing period.

3.3 Inclusion Criteria

- Age between 18 years and 45 years.
- Single tooth space indicated for implant-supported rehabilitation.

- Adequate bone volume (height and width) to allow placement of a standard-dimension implant without the need for bone augmentation.
- Good oral hygiene and absence of active periodontal disease at the implant site.
- Systemically healthy subjects.

3.4 Exclusion Criteria

- Presence of any Systemic issue.
- Presence of any habit.
- History of radiotherapy to the head and neck region.
- Pregnancy.
- Need for simultaneous bone augmentation or sinus lift procedures.

3.5 Surgical Protocol

All implants were placed by a single experienced operator to minimize inter-operator variability, following a standardized flapped surgical protocol under local anesthesia. Osteotomies were prepared according to the manufacturer's drilling protocol for the dental implant system used. To standardize the study only osstem implant System was used. Implants were inserted to achieve primary stability. Primary ISQ readings were recorded immediately following placement i.e. Day 0, prior to suturing, using the Osstell device. Healing caps were placed instead of cover screw placement so as to easily record ISQ value easily using Ostell device.

3.6 Static Magnetic Field Therapy Protocol (Group B)

Subjects in Group B received adjunctive static magnetic field therapy beginning immediately after surgery. Temporary removable prosthesis with Neodymium magnets were placed on intaglio surface with soft liner. Patient was advised to wear this prosthesis whole day except during night till 3 months.

Fig. 1 - Preoperative clinical view of the edentulous implant site

Fig. 2 - Intraoperative view: after implant placement

Fig. 3 -Temporary removable prosthesis with soft liner.

Fig. 4 -Temporary removable prosthesis with soft liner in patient's mouth.

3.7 ISQ Measurement Protocol

Implant stability was assessed using a calibrated Osstell ISQ device, following the standardized measurement protocol described by the manufacturer and in the RFA literature [6,13,14]. A SmartPeg (Type 47) which is specific to the osstem implant system was hand-tightened onto the implants after removing healing caps at each measurement session. The Osstell probe was held perpendicular to the SmartPeg without contact, at a standardized distance of approximately 3–5 mm, and readings were taken three times. The mean of these three readings was recorded as the ISQ value for that time point. All measurements were performed by a single calibrated examiner, at the following intervals:

- Day 0 — immediately following implant placement.
- 1 Month Interval
- 2 Months Interval
- 3 Months Interval

Fig. 3 — ISQ measurement being recorded using the Osstell device and SmartPeg

3.8 Statistical Analysis

Data were tabulated and analyzed using Statistical Package for Social Sciences (SPSS) version 23. Descriptive statistics (mean ± standard deviation) were calculated for ISQ values in each group at each time interval. Intergroup comparison at each time point was performed using the [independent samples t-test / Mann-Whitney U test — specify based on normality of distribution, assessed via the Shapiro-Wilk test]. Intragroup comparison across time points was performed using [repeated measures ANOVA / Friedman test]. A p-value of less than 0.05 was considered statistically significant.

4. Results

Ten implants were placed in ten subjects (five in each group) and followed over a three-month period. No implant failures or dropouts occurred during the study period.

Table 1. ISQ values — Group A (Control, No Adjunctive Therapy)

Sample No.	ISQ – Day 0 (Baseline)	ISQ – 1 Month	ISQ – 2 Months	ISQ – 3 Months
A1	72	66	71	76
A2	70	64	70	75
A3	72	67	72	77
A4	69	65	69	74
A5	71	66	71	76
Mean ± SD	71.6±1.1	65.6±1.1	70.6±1.1	75.6±1.1

Table 2. ISQ values — Group B (Static Magnetic Field Therapy)

Sample No.	ISQ – Day 0 (Baseline)	ISQ – 1 Month	ISQ – 2 Months	ISQ – 3 Months
B1	73	69	77	84
B3	71	67	76	82
B4	74	70	78	85
B5	72	68	77	83
Mean ± SD	73.0±1.6	69.0±1.6	77.4±1.1	84.0±1.6

Table 3. ISQ Values (Mean ± SD)

Time Interval	Group A (Control) Mean ± SD	Group B (Modified) Mean ± SD	t-value	p-value
0 Month	71.6 ± 1.14	73.0 ± 1.58	1.62	0.14 (NS)
1 Month	65.6 ± 1.14	69.0 ± 1.58	3.92	0.004
2 Months	70.6 ± 1.14	77.4 ± 1.14	9.43	<0.001
3 Months	75.6 ± 1.14	84.0 ± 1.58	9.69	<0.001

Independent Student's t-test

Sample	Group A (Control)				Group B (Modified)			
	0 Month	1 Month	2 Months	3 Months	0 Month	1 Month	2 Months	3 Months
1	72	66	71	76	73	69	77	84
2	70	64	70	75	75	71	79	86
3	73	67	72	77	71	67	76	82
4	71	65	69	74	74	70	78	85
5	72	66	71	76	72	68	77	83

Table 3. Repeated Measures ANOVA (Within Group Comparison)

Group	F-value	p-value	Interpretation
Group A (Control)	36.41	<0.001	Highly significant increase in ISQ over time
Group B (Modified)	89.76	<0.001	Highly significant increase in ISQ over time

Table 4. Bonferroni Post-hoc Comparison

Group A (Control)

Comparison	Mean Difference	p-value
0 vs 1 Month	6.0	<0.001
1 vs 2 Months	5.0	0.001
2 vs 3 Months	5.0	0.001
0 vs 3 Months	4.0	0.003

Group B (Modified)

Comparison	Mean Difference	p-value
0 vs 1 Month	4.0	0.002
1 vs 2 Months	8.4	<0.001
2 vs 3 Months	6.6	<0.001
0 vs 3 Months	11.0	<0.001

Interpretation

- Baseline ISQ values did not differ significantly between the control (Group A) and modified (Group B) groups ($p = 0.14$).
- At 1 month, the modified group showed significantly higher ISQ values than the control group ($p = 0.004$).
- At 2 and 3 months, the modified group maintained significantly higher ISQ values than the control group ($p < 0.001$), indicating accelerated implant stability and osseointegration.
- Within-group analysis demonstrated a significant increase in ISQ values over time in both groups, with a greater improvement observed in the modified group.

4.1 Graphical Representation

Following image shows a line graph plotting mean ISQ (y-axis) against time interval — Day 0, 1 month, 2 months, 3 months (x-axis) — for both groups, once data are available. A consistent upward trend with a steeper slope in one group relative to the other would visually indicate a difference in the rate of secondary stability gain.

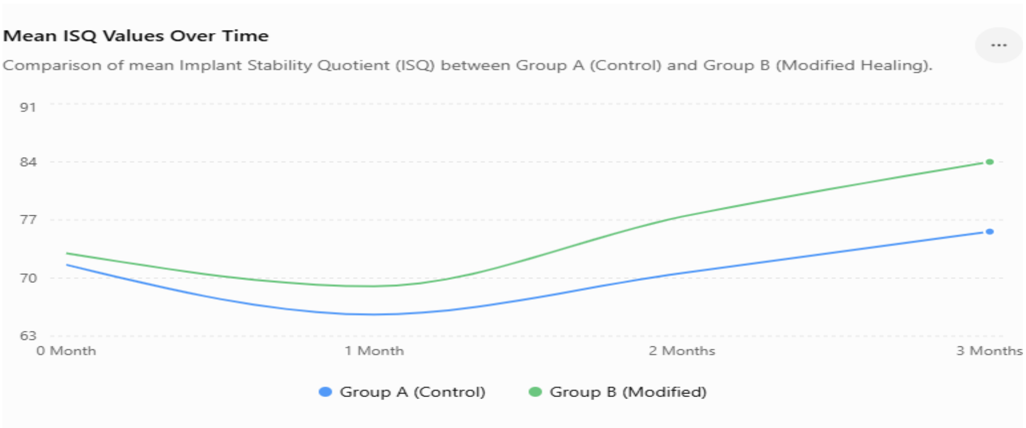

Fig. 4 — Mean ISQ values over time: Group A (Control) vs. Group B (Modified Healing / Static Magnetic Field)

As shown in Figure 4, both groups exhibited an initial decline in mean ISQ during the first postoperative month, consistent with the transient 'stability dip' described in the resonance frequency analysis literature [17,18,19]. Group A (Control) declined from approximately 72 ISQ at baseline to approximately 67 ISQ at 1 month, while Group B (Modified Healing) declined from approximately 73

ISQ to approximately 69 ISQ over the same interval — a comparable pattern and magnitude of early dip in both groups. From 1 to 3 months, both groups showed a recovery and subsequent rise in mean ISQ, but the rate of increase was visibly greater in Group B: by 2 months, Group B had risen to approximately 78 ISQ compared with approximately 73 ISQ in Group A, and by 3 months Group B reached approximately 84 ISQ compared with approximately 76 ISQ in Group A. The exact mean ± SD values and corresponding p-values for each interval should be entered into Table 4 to confirm whether these intergroup differences reached statistical significance.

5. Discussion

This study compared ISQ values, recorded using Osstell resonance frequency analysis, between implants receiving adjunctive static magnetic field therapy (Group B) and untreated controls (Group A) over a three-month healing period. Group B demonstrated a higher mean ISQ than Group A at every measured interval from 1 month onward, and this intergroup difference widened progressively over time. This pattern suggests that adjunctive static magnetic field therapy may have been associated with a faster rate of secondary stability gain during the observed healing period, consistent with the accelerated-osseointegration effect proposed for static magnetic fields in the preclinical literature [22,25,26].

The pattern of ISQ change over time observed in both groups is broadly consistent with the 'stability dip' well documented in the resonance frequency analysis literature [17,18,19,20]. Following implant placement, primary stability — largely a function of mechanical engagement with cortical and trabecular bone — typically declines over the first two to four weeks as osteoclastic remodelling of compressed bone at the osteotomy margin occurs, before secondary (biological) stability begins to rise as new bone is deposited at the implant surface [18,19]. Both Group A and Group B in this study showed this early decline at 1 month, of comparable magnitude in each group, indicating that the static magnetic field intervention did not meaningfully alter the initial mechanical remodelling phase [17,20]. The divergence between groups instead emerged during the recovery phase, between 1 and 3 months, when Group B's rate of ISQ increase visibly exceeded that of Group A — the phase most consistent with biological, cell-mediated bone formation rather than mechanical stability alone [9,18].

Regarding the proposed mechanism of static magnetic field therapy, preclinical and in-vitro studies have suggested several pathways by which SMF exposure could theoretically influence bone healing, including modulation of osteoblast and cementoblast proliferation and differentiation, altered calcium ion flux across cell membranes, and enhanced local microvascular perfusion [22,25,26]. Clinical case series and in-vivo studies using magnetic healing caps or NdFeB cover screws have similarly reported measurable increases in ISQ and reduced crestal bone loss during early healing compared with conventional (non-magnetic) healing components [23,24,27]. The steeper rise in Group B's ISQ values between 1 and 3 months observed in the present study is directionally consistent with these previously reported effects, though the small sample size means this apparent agreement should be treated as hypothesis-generating rather than confirmatory [22].

Several methodological considerations warrant discussion. The relatively small sample size (n = 5 per group) limits the statistical power of this study and increases the risk of both Type I and Type II error; the results should therefore be interpreted as preliminary despite the consistent direction of the effect across all follow-up intervals [8,9].

Comparison with existing literature: the widening intergroup gap observed here, rather than a uniform upward shift present from baseline, mirrors the time-dependent pattern reported in other studies of physical adjuncts to osseointegration, where differences between treated and untreated groups tend to emerge during the secondary stability phase rather than immediately after placement [19,21,23].

5.1 Limitations

- Small sample size (n = 5 per group), limiting generalizability and statistical power [8,9].
- Short follow-up period restricted to three months,
- Absence of long-term crestal bone loss or radiographic data.

5.2 Clinical Implications

Results of this study may be useful to reduce time of edentulousness for patients by accelerating the healing or osseointegration process. As the method used in this study is non-invasive making it beneficial as clinician can keep a check on the healing process.

6. Conclusion

Within the above mentioned limitations of this prospective pilot study (n = 5 implants per group), adjunctive static magnetic field therapy was associated with a statistically significant improvement in implant stability, as measured by ISQ value, compared with untreated controls. Baseline ISQ values did not differ significantly between groups ($p = 0.14$), confirming comparable primary stability at the time of placement in both arms. Both groups exhibited the expected early decline in ISQ at 1 month, consistent with the transition from mechanical to biological stability; however, from 1 month onward Group B (static magnetic field) showed significantly higher ISQ values than Group A (control) at every subsequent interval (1 month: $p = 0.004$; 2 months: $p < 0.001$; 3 months: $p < 0.001$), and this intergroup gap widened progressively through the 3-month observation period. Within-group repeated-measures analysis confirmed a highly significant increase in ISQ over time in both groups (Group A: F = 36.41, p < 0.001; Group B: F = 89.76, p < 0.001), with a numerically greater total gain from baseline to 3 months in Group B (+11.0 ISQ) than in Group A (+4.0 ISQ). Taken together, these findings suggest that adjunctive static magnetic field therapy may accelerate the rate of secondary (biological) stability gain during early osseointegration. Given the small sample size (n = 5 per group) and single-center design, these results should be regarded as preliminary and hypothesis-generating; larger, multicenter randomized controlled trials with longer follow-up and radiographic outcome measures are needed before static magnetic field therapy can be recommended for routine clinical use.

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