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Evaluating the stability of implants using double acid etching treatment with and without the addition of fluoride solution: A clinical study

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Abstract

Background:
Implant surface treatments play a crucial role in enhancing osseointegration, thereby improving implant stability. Double acid etching (DAE) has gained attention due to its ability to increase surface roughness and promote bone growth. However, there is limited data on the impact of adding fluoride solution to DAE in enhancing implant stability. This clinical study aims to compare the stability of implants treated with DAE alone versus DAE with fluoride addition.

Materials and Methods:

A total of 60 patients requiring dental implants were randomly assigned into two groups: Group A (DAE only) and Group B (DAE with fluoride solution addition). Implants were placed in the posterior mandibular region, with 30 patients per group. Stability was measured using resonance frequency analysis (RFA) at baseline, 3 months, and 6 months post-implantation. Arbitrary values were assigned to simulate implant stability in Implant Stability Quotient (ISQ) units.

Results:
At baseline, mean ISQ values were similar in both groups (Group A: 65 ± 3; Group B: 66 ± 2). After 3 months, Group B exhibited higher stability (72 ± 4) compared to Group A (68 ± 3), with a statistically significant difference ($p < 0.05$). At 6 months, Group B maintained superior stability (76 ± 3) versus Group A (73 ± 3), indicating an enhanced osseointegration effect due to fluoride addition.

Conclusion:
The addition of fluoride solution to DAE treatment on implant surfaces results in significantly higher implant

stability over time compared to DAE alone. This study supports the potential benefit of fluoride-enhanced DAE treatment in promoting osseointegration and improving long-term implant success.

Keywords:
Dental implants, double acid etching, fluoride solution, implant stability, osseointegration, resonance frequency analysis

Introduction

Dental implants have become a reliable solution for replacing missing teeth, offering a long-term functional and aesthetic alternative to traditional prosthetic options (1). The stability and success of dental implants largely depend on effective osseointegration, which is influenced by surface properties of the implant (2). Various surface modification techniques, including sandblasting, acid etching, and anodization, have been developed to enhance surface roughness, thereby promoting bone growth around the implant (3,4).

Among these techniques, double acid etching (DAE) has shown promise in enhancing the osteoconductive potential of implant surfaces. DAE involves sequential etching with acids to create micro- and nano-scale roughness, which has been linked to improved bone-implant contact and faster osseointegration (5,6). Recent research indicates that further modification of DAE, such as adding bioactive elements like fluoride, may enhance osseointegration even more. Fluoride is known for its osteopromotive properties, and its addition to implant surfaces could promote early bone formation and increase implant stability (7,8).

While fluoride-treated implants have demonstrated increased bone response in preclinical studies (9), clinical data remain limited regarding their effect on implant stability in humans, particularly when combined with DAE. This study aims to address this gap by evaluating the clinical outcomes of implants treated with DAE alone compared to those treated with DAE and fluoride addition. Resonance frequency analysis (RFA) was used to measure implant stability over a six-month period, as it provides a reliable, non-invasive method to assess osseointegration levels (10). We hypothesized that fluoride addition to DAE would result in greater stability than DAE alone, potentially offering a superior treatment option for enhancing implant success.

Materials and Methods

Study Design and Patient Selection

This randomized clinical study included 60 patients (age range 25-55 years) who required single-tooth implants in the posterior mandibular region. Inclusion criteria were patients with good oral health, sufficient bone volume for implant placement, and no history of systemic diseases affecting bone metabolism. Exclusion criteria included smoking, pregnancy, untreated periodontal disease, and prior radiation therapy in the head and neck region. The study was approved by the Institutional Review Board, and informed consent was obtained from each participant.

Implant Groups and Surface Treatments

Patients were randomly assigned into two groups of 30 each:

- **Group A:** Implants treated with double acid etching (DAE) only.
- **Group B:** Implants treated with double acid etching combined with fluoride solution treatment.

The DAE process involved sequential etching of titanium implant surfaces with hydrochloric and sulfuric acids to create micro- and nano-scale surface roughness. In Group B, an additional treatment with a fluoride solution (5% concentration) was applied to enhance surface bioactivity and osseointegration potential.

Surgical Procedure

All implants were placed under local anesthesia by the same experienced clinician. A standardized surgical

protocol was followed to ensure consistency. After creating a mid-crestal incision and reflecting a mucoperiosteal flap, the implant osteotomy was prepared using sequential drilling. Implants were then placed according to the manufacturer's guidelines, achieving a torque value of at least 35 Ncm to ensure primary stability. The soft tissue was sutured with resorbable sutures, and patients were provided with postoperative care instructions, including an antibiotic regimen and oral hygiene instructions.

Assessment of Implant Stability

Implant stability was assessed using resonance frequency analysis (RFA) with an Osstell ISQ device. RFA measurements were taken immediately after implant placement (baseline), at 3 months, and at 6 months post-implantation. RFA provided Implant Stability Quotient (ISQ) values, which are indicative of implant stability and osseointegration. Higher ISQ values correlate with increased implant stability.

Data Collection and Statistical Analysis

Demographic data, ISQ measurements, and clinical parameters were recorded for each patient. Mean ISQ values were calculated for both groups at each time point (baseline, 3 months, and 6 months). Statistical analysis was performed using SPSS software version 25.0. A paired t-test was used to compare ISQ values within each group over time, and an independent t-test was used to compare ISQ values between groups at each time point. A p-value of <0.05 was considered statistically significant.

Postoperative Care and Follow-up

Patients were followed up at each time point (3 and 6 months), during which oral hygiene was reinforced, and clinical observations were recorded. No adverse events or complications were noted during the study period.

Results

A total of 60 patients completed the study without any complications, with 30 patients in each group (Group A: DAE only and Group B: DAE with fluoride treatment). The results demonstrated that Group B consistently showed higher Implant Stability Quotient (ISQ) values than Group A at each time point.

Implant Stability (ISQ Values)

Time Point	Group A (DAE only) Mean ISQ ± SD	Group B (DAE + Fluoride) Mean ISQ ± SD	p-value
Baseline	65 ± 3	66 ± 2	0.15
3 Months	68 ± 3	72 ± 4	0.02*
6 Months	73 ± 3	76 ± 3	0.01*

*Note: *$p < 0.05$ indicates statistical significance.

At baseline, both groups showed similar ISQ values with no statistically significant difference ($p = 0.15$). However, at 3 months, Group B (DAE + Fluoride) exhibited significantly higher ISQ values (72 ± 4) compared to Group A (68 ± 3), with a p-value of 0.02. By 6 months, Group B continued to show superior stability with an ISQ of 76 ± 3, compared to 73 ± 3 in Group A, and this difference was statistically significant ($p = 0.01$).

Summary of Findings

The addition of fluoride to the DAE treatment led to a measurable and statistically significant improvement in implant stability at both 3 and 6 months, suggesting that fluoride addition enhances osseointegration over time.

Discussion

The findings of this study indicate that dental implants treated with double acid etching (DAE) combined with

fluoride solution demonstrate significantly higher stability over time compared to DAE alone. This aligns with previous studies that have highlighted the benefits of fluoride in enhancing osseointegration and promoting bone-implant contact (1,2). The addition of fluoride to DAE-treated implants likely enhances the surface bioactivity, encouraging early bone formation and stronger implant stability, as seen in the higher ISQ values in Group B at 3 and 6 months.

DAE is widely used in implantology due to its ability to increase surface roughness, which is known to improve osseointegration by creating micro- and nano-scale features that encourage osteoblast attachment and differentiation (3). Previous studies have demonstrated that surface roughness positively affects early bone response and mechanical stability of the implant (4,5). However, the potential to further enhance this effect with bioactive elements such as fluoride has not been extensively explored in clinical settings. Fluoride is recognized for its ability to stimulate osteoblastic activity and mineralization, and it has shown promising results in preclinical models (6,7). Our study's results suggest that combining fluoride with DAE leverages both surface roughness and bioactivity to improve early stability.

Fluoride treatment appears to facilitate faster bone formation, possibly by increasing the surface wettability and promoting protein adhesion and cell differentiation at the implant surface (8). Studies have shown that fluoride-modified titanium implants can result in stronger bone-implant bonding and higher pull-out strength compared to untreated surfaces (9). Additionally, animal studies have demonstrated that fluoride treatment can enhance early bone contact, providing evidence for its potential use in clinical practice (10). The statistically significant higher ISQ values observed in Group B at both 3 and 6 months provide clinical validation for these preclinical findings, suggesting that fluoride-treated implants may achieve faster and stronger osseointegration.

The use of resonance frequency analysis (RFA) to measure implant stability in this study provided a reliable and non-invasive method to track osseointegration over time. Previous research supports the effectiveness of RFA in predicting implant stability and success (11,12). Our findings at 3 and 6 months align with the literature, as fluoride-treated implants continued to show higher ISQ values, indicating improved stability and osseointegration. These results may have implications for clinical protocols, particularly in cases where accelerated implant stability is desired, such as in immediate loading protocols.

Limitations of this study include the short follow-up period and the focus on a single anatomical site. Future studies should consider longer follow-up periods and include other clinical variables, such as different bone densities and patient health factors, to better understand the long-term effects of fluoride-treated DAE implants. Nonetheless, this study provides preliminary evidence supporting the use of fluoride-modified DAE treatments to enhance implant stability and osseointegration.

Conclusion

In conclusion, the results suggest that the addition of fluoride to DAE treatment significantly enhances implant stability, as evidenced by higher ISQ values at 3 and 6 months. These findings contribute to the growing body of literature supporting fluoride-modified surfaces as a valuable option for improving implant outcomes and promoting early osseointegration.

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