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# Comparative evaluation of osseointegration between sandblasted large grit, acid etched (SLA) and calcium phosphate coated implants. A randomized controlled clinical trial

C. JAIN, M. KAUSHIK, A. WADHAWAN, M. AGARWAL, A. ARUN

Department of Periodontology, Subharti Dental College, Meerut, India

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KEYWORDS Implants; Periodontal therapy; Calcium phosphate; Acid etched; CBCT.

## ABSTRACT

**Aim** The surface of a dental implant is the part that is in contact with the bio-environment and the uniqueness of the surface directs the response and affects the mechanical strength of the implant-tissue interface. Additionally, the surface coating promotes bone apposition. This may include mechanical treatments (machining and grit blasting for instance), chemical treatments (acid etching for example), electrochemical treatments (anodic oxidation), vacuum treatments, thermal treatments, and laser treatments. Thus, the purpose of this study was to compare the osseointegration achieved by measuring the implant stability quotient and bone density around sandblasted large grit, acid-etched (SLA) versus calcium phosphate (CaP) coated implants.

**Materials and methods** 20 patients were selected, test group A had SLA implants and test group B had calcium phosphate coated implants. After 4 months, prosthesis was delivered, and the patients were followed up to 9 months. Various clinical and radiographic parameters were recorded.

**Result** 9 months after surgery, high bone density was seen around the calcium phosphate coated implants.

**Conclusion** The bone density in test group B i.e. CaP coated implants, had notably increased, and the increase was statistically significant when compared with test group A.

## INTRODUCTION

Despite the fairly recent rise of oral implantology from a scientific point of view, the history of the evolution of dental implants is a rich and fascinating travelogue through the ages. Since time immemorial, humans have used dental implants in one form or another to replace missing teeth. In the past 20 years, the number of dental implant procedures has increased steadily worldwide, reaching about one million dental implants per year. Oral implantology has come a long way from where it started. The success of dental implants and their rise in dentistry has not been some splendid serendipity but the hard work of countless visionaries. The concept of osseointegration is the cornerstone of successful implant dentistry. The term osseointegration was refined and defined by Brånemark (1) as "a direct structural and functional connection between ordered, living bone, and the surface of a load carrying implant". Implant design, surgical technique, surface topography and chemical composition are the key factors for achieving a fast osseointegration and implant stability over time. The development of novel mechanical and chemical surface modification treatments to improve the osseointegration properties of implants is nowadays a topic of great applicative interest (2).

The surface of a dental implant is the part that is in contact with the bio-environment, and the uniqueness of the surface directs the response and affects the mechanical strength of the implant-tissue interface. Additionally, the surface coating promotes bone apposition. This may include mechanical treatments (machining and grit blasting for instance), chemical treatments (acid etching for example), electrochemical treatments (anodic oxidation), vacuum treatments, thermal treatments, and laser treatments (3). Early in the 1980s, Albrektsson et al. (4) identified implant surface as one of the six important factors for successful osseointegration. Since then, efforts to engineer surface topography and chemistry that improve healing and reduce waiting time between device placement and functional loading have gained momentum in implant dentistry. To date, the existing variety of manufacturing processing techniques is so extensive that attempts to classify surfaces by modification method has become a difficult task (5).

Based on our current knowledge, implant roughness is defined as follows (6).

- Smooth implants are those with a roughness (Sa) of less than 0.5 μm; in oral implants found solely on abutments generally varying between 0.1 and 0.3 μm roughness.
- Minimally rough implants have a roughness (Sa) of between 0.5 to 1.0 μm and are represented by turned Brånemark and Astra Tech™ implants.
- Moderately roughened surfaces vary between 1.0 and 2.0 μm and include almost all modern implants, such as the Astra Tech TiOblast™ and OsseoSpeed™ surfaces, Nobel TiUnite™, Straumann SLA™ and Dentsply Cellplus™ designs.
- Rough implants are those with Sa above 2.0 μm and are exemplified by plasma sprayed devices.

### Methods of surface modifications of implant surfaces

Methods of implant surface modifications are as follows.

- Mechanical methods: grinding, blasting, machining and polishing generally result in rough or smooth surfaces, which can improve adhesion, proliferation and differentiation of cells.
- Chemical methods: chemical treatment with acids or alkali, sol gel, hydrogen peroxide treatment, anodization and chemical vapor deposition are chemical surface modification methods used to alter surface roughness and composition and enhance surface energy.
- Physical methods: plasma spraying, ion deposition and sputtering are some of the physical methods used for implant surface modification (7).

Some techniques add material on the bulk metal; thus, a surface with bumps (convex profile) will be created in contrast to techniques where particles will be removed from the surface, creating pits or pores on the surface (concave profile). The surface treatments of implants may be categorized as follows (8).

1. Subtractive processes:
   - sand blasted acid etched surfaces,
   - etched surfaces,
   - dual etched surfaces,
   - laser microtextured surfaces,
2. Additive processes:
   - hydroxyapatite (HA) and other calcium phosphate coatings,
   - titanium plasma-sprayed (TPS) surfaces,
   - oxidation,
   - sputtering,
   - bioactive coating eg. growth factors, antibiotics, etc.

However, the clinical superiority of any of these surfaces has so far not been clearly confirmed by any well designed clinical trial. Thus, the purpose of this study was to compare the osseointegration achieved by measuring the implant stability quotient and bone density around sandblasted large grit, acid-etched (SLA) versus calcium phosphate (CaP) coated implants with the null hypothesis (H0) stating that there is no significant difference between the improvement in bone density of the two test groups using different implant surface coatings.

## MATERIALS AND METHODS

Twenty subjects, 12 males and 8 females (age range 21–50 years, mean age 34.7±6.0 years), were enrolled in the study. The patients were selected, on a consecutive basis, among individuals referred to Out Patient Department, Subharti Dental College and Hospital, Meerut, Uttar Pradesh, in the period between December 2018 and May 2020. The study protocol, questionnaires and informed consent, in full accordance with the ethical principles of the Declaration of Helsinki of 1975, as revisited in 2008, were approved by the Institutional Review Board and received the approval of the Institutional ethic committee. The subjects who agreed to participate in the study signed a written informed consent according to the above-mentioned principles.

All participants met the study inclusion criteria: Systemically healthy individuals (American Society of Anaesthesiologists I or II) with tooth missing in mandibular molar region excluding the third molar, who had good periodontal health with adequate interocclusal clearance and adequate mesiodistal space in edentulous area, reluctant for removable or fixed partial denture. The patients with a history of smoking, compromised healing conditions (e.g., uncontrolled diabetes mellitus, radiotherapy etc.), bone disorders, who could not adequately maintain their oral hygiene or had some temporomandibular disorders were excluded from the study.

### Intra-examiner calibration

A single operator (CJ) performed all the surgeries. A single examiner (MK) evaluated the subjects for clinical parameters presurgically, then at 4 months when the prosthesis was placed and at 9 months from the implant placement, the clinical parameters were examined by a different operator (MA) and another single examiner (AW) evaluated the radiographic parameters presurgically, immediately after implant placement and then 9 months post surgically.

### Presurgical protocol

Following initial examination and treatment planning, the selected patients underwent Phase I therapy. Detailed instructions regarding self-performed plaque control measures were given to signify its importance on the success of the implant therapy. After two weeks, only those patients maintaining optimum oral hygiene were subjected to the surgical procedure.

### Premedication

Patients were given one capsule of Augmentin® 625 mg (Amoxycillin 500mg and potassium clavulanate 125mg) 12 hrs before and one capsule of Augmentin® 625 mg 1hr before the procedure.

## Surgical procedures

After assessing the pre-treatment records (Fig. 1a), the subjects were prepared for implant placement. Strict asepsis was followed during the procedure. After achieving adequate local anesthesia with 4% articaine with epinephrine 100,000, sub-crestal incision was given (Fig. 1b). Crevicular incisions were also extended to the mid buccal and mid lingual region of adjacent tooth. Full thickness flaps were elevated (Fig. 1c). A lance drill was passed through surgical stent to the depth corresponding to the length of implant chosen. Next, intermediate drills of the diameter and length of the implant were used to expand the osteotomy. Then, paralleling pins were used to verify that the desired angulation of the implant is correct. The implant site was generously irrigated with sterile saline to ensure that there are no debris or bone chips left at the base or attached to the vertical walls of the osteotomy site following preparation. The SLA implant (Touareg STM, Adin Dental Implants System LTD., Afula, Israel.) or the CaP coated implant (Touareg OSTM, Adin Dental Implants System LTD., Afula, Israel) depending on the group of the subject, was put into the osteotomy site with an insertion torque of 35 Ncm at the crestal level. Stability of implant was measured by Osstell®. The cover screw was placed using the 0.05" hex driver. At this point the implant was immobile, which ensured primary stability. The flap margins were then repositioned and sutured tension free with a resobable polyglactin 910 suture material (Fig. 1d-f, 2, 3, 4, 5).
Medications were prescribed, Augmentin® 625 mg 8

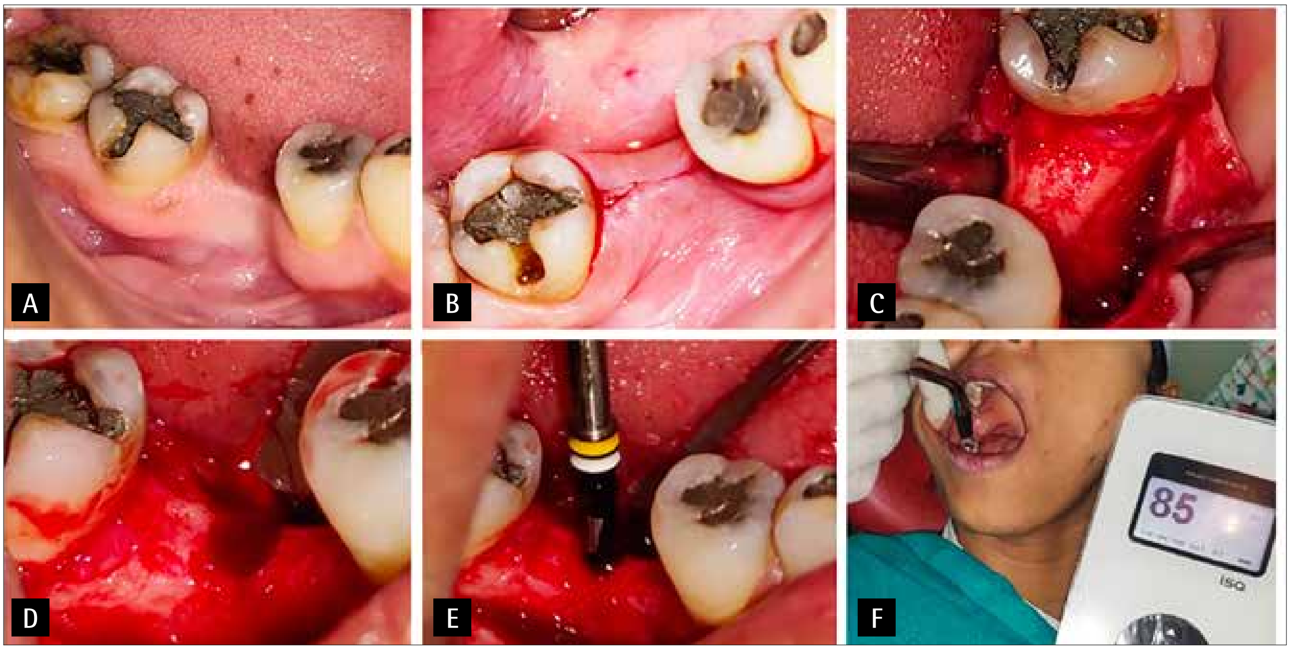



FIG. 1 A: Pre-op. B: Incision. C: Full thickness mucoperiosteal flap reflected. D: Osteotomy prepared. E Osteotomy parallelism. F ISQ Value at baseline.

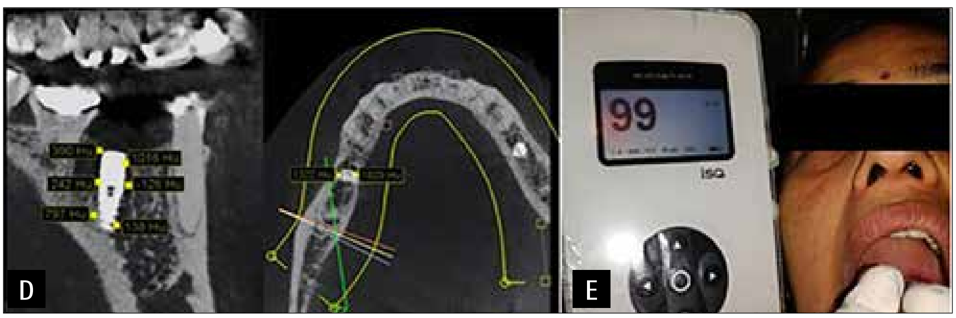




FIG 2 A: Implant with cover screw.
B: Sutures placed.
C: Gingival former at 4 months.
D: Bone density in HU at baseline.
E: ISQ at 4 months.

hourly for 5 days with aceclofenac, paracetamol and serratidopeptidase combination 8 hourly for 3 days. The patients were asked to rinse with chlorhexidine 0.2% twice a day for the next 7 days. Patients were recalled in 7 days to assess healing and a CBCT was done to establish the baseline bone density.

After 4 months of implant placement, second stage surgery was initiated. Mid crestal incision was placed over implant, and soft tissue was reflected sufficiently. Cover screw was removed, gingival former/ temporary healing abutment was attached to the implant and gingival tissue was sutured around it for 15 days. After the formation

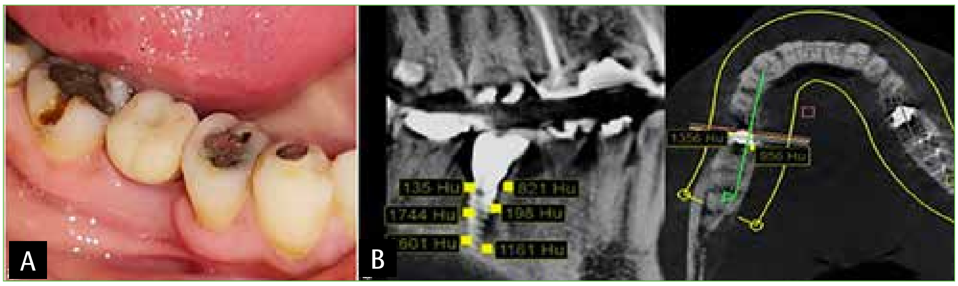



FIG 3 A: Final prosthesis.
B: Bone density in HU at 9 months.

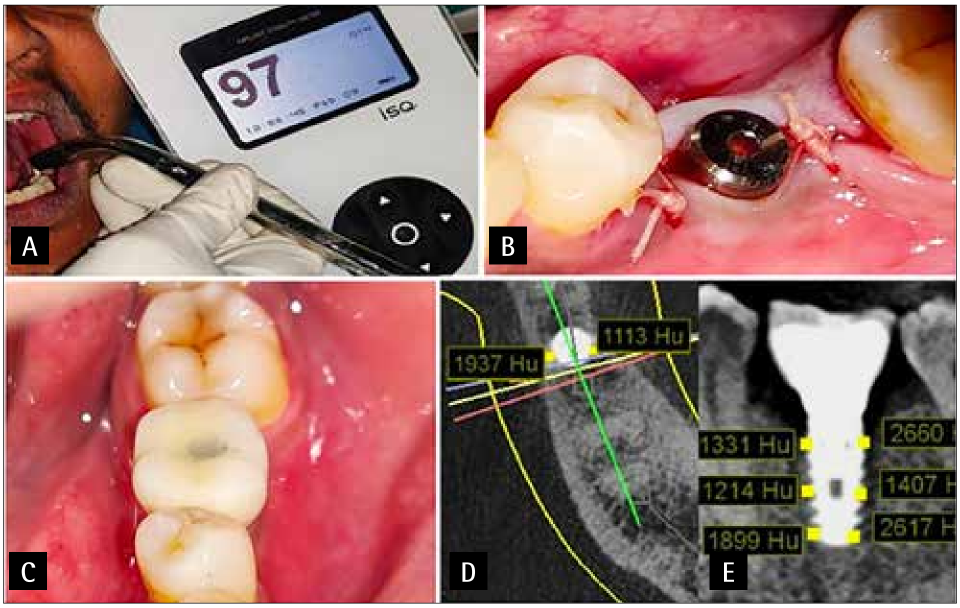
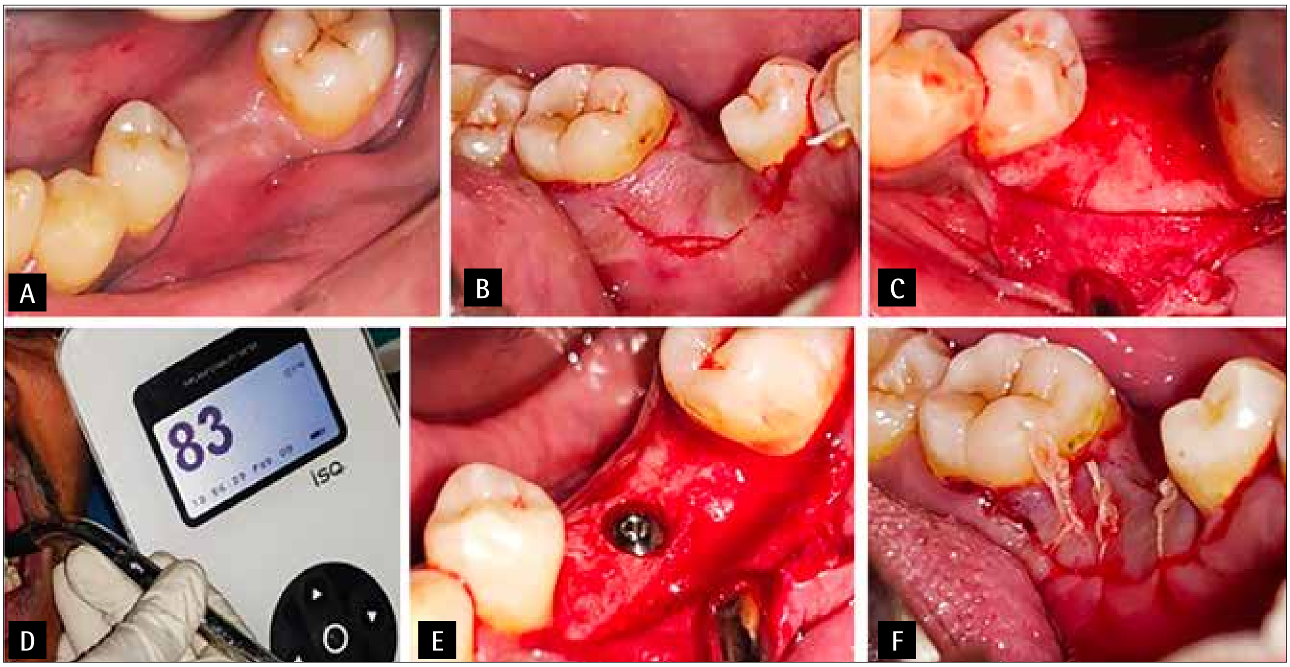



FIG 4 A: ISQ at 4 months.
B: Gingival former at 4 months.
C: Final prosthesis.
D: Bone density in HU at baseline at 9 months.

FIG 5 A: Pre-op. B: Incision.
C: Full thickness mucoperiosteal flap reflected. D: ISQ value at baseline. E: Implant placed.
F: Sutures.



of a gingival collar, the former was replaced by a screw retained porcelain fused to metal crown.
All the patients were reviewed after implant placement at 4 months and 9 months with evaluation of all clinical and radiographic parameters.
Also, patients were reinforced with oral hygiene instructions at every visit.

### Clinical parameters

The clinical parameters evaluated were the following.

1. Oral Hygiene Index-Simplified (Green and Vermillion, 1964) (9),
2. Modified Plaque Index (Mombelli et al., 1987) (10).
3. Modified Gingival Index (Apse et al., 1991) (11).
4. Modified Sulcular Bleeding Index (Mombelli et al., 1987) (10).
5. Keratinized Mucosa Index (Cox et al., 1987) (12).
6. Probing Depth will be recorded at 4 sites around implant (mesial, distal, buccal and lingual) using UNC 15 periodontal plastic probe.
7. Implant Stability Quotient by RFA using Osstell® device.

### Radiographic parameters

CBCT scan (Orthophos SL, Galileos- Sirona, CS 9300 Scanner®) was done to assess the facial, lingual, mesial and distal bone density around the implant. A total of three CBCT were taken.
First CBCT was taken before the implant placement, for diagnosis and treatment planning and then at baseline (at the time of implant placement), and at 9 months post implant placement.
The images obtained from CBCT evaluation were used to assess the bone density changes around the implants in Hounsfield Units (HU) using specialized software (Blue Sky Bio; Grayslake III).
For recording bone density, the axial section was used and bone density was recorded by dividing implant into three parts lengthwise and the bone density was recorded at midpoint of each divided section. For all the four aspects, bone density was recorded at baseline and 9 months.

### Statistical analysis

The data regarding the clinical parameters and radiographic parameters were tabulated and subjected to statistical analysis by applying the following tests.

1. Mean.
2. Standard Deviation (S.D.).
3. Paired student's t-test.
4. Unpaired 't' test.

## RESULTS

Healing proceeded without major complications at either of the test sites with minimal postoperative discomfort. No implant loss was registered during the entire period of observation in the 20 subjects.
The clinical measurements' data for both the test groups are listed in Table 1, 2.
The paired and the unpaired t tests were not statistically significant (P>0.05) for OHI-S, mPI, mGI, sulcular bleeding index, keratinized mucosa index, probing depth and ISQ.
The paired t test was not statistically significant (P>0.05) for bone density measurement in either groups, but the unpaired t-test for test group B was statistically significant (P<0.05) in facial, lingual, buccal and lingual sides.

## DISCUSSION

In our society of appearance, teeth must be white and the dentition harmonious. The face is widely regarded as

| S. No. | Parameters | duration (months) | Mean difference | P-value - unpaired "t" test | | |
|---|---|---|---|---|---|---|
| 1 | OHI-S | 0-4 | **0.04** | 0.065 | p>0.05 | (N.S.) |
| | | 4-9 | **0.07** | 0.546 | p>0.05 | (N.S.) |
| | | 0-9 | **0.12** | 0.357 | p>0.05 | (N.S.) |
| 2 | Modified Plaque Index | 4-9 | **0.03** | 0.862 | p>0.05 | (N.S.) |
| 3 | Modified Gingival Index | 4-9 | 0.11 | 0.328 | p>0.05 | (N.S.) |
| 4 | Modified Sulcular Bleeding Index | 0-4 | 0.07 | 0.251 | p>0.05 | (N.S.) |
| | | 4-9 | **0.17** | 0.173 | p>0.05 | (N.S.) |
| | | 0-9 | **0.10** | 0.331 | p>0.05 | (N.S.) |
| 5 | Probing Depth | 4-9 | 0.03 | 0.729 | p>0.05 | (N.S.) |
| 6 | Keratinized Mucosa Index | 0-4 | **0.10** | 0.548 | p>0.05 | (N.S.) |
| | | 4-9 | **0.10** | 0.724 | p>0.05 | (N.S.) |
| | | 0-9 | **0.20** | 0.347 | p>0.05 | (N.S.) |
| 7 | Implant Stability Quotient | 0-4 | **1.40** | 0.302 | p>0.05 | (N.S.) |

TABLE 1 Using paired "t" test at different time intervals for Oral Hygiene Index, Modified Sulcular Bleeding Index and Keratinized Mucosa Index for both test groups.

| Parameters | Duration (months) | Mean difference | P-value - unpaired "t" test | | |
|---|---|---|---|---|---|
| Facial | 0-9 | 166.70 | 0.001 | p<0.05 | (S) |
| Lingual | 0-9 | 108.23 | 0.011 | p<0.05 | (S) |
| Mesial | 0-9 | 118.53 | 0.001 | p<0.05 | (S) |
| Distal | 0-9 | 56.83 | 0.008 | p<0.05 | (S) |

TABLE 2 Using unpaired "t" test for bone density measurement on various aspects for both the test groups.

a symbol of "self", and the smile as a window into one's personality. Teeth participate primarily as one of the main attributes of smile, and loss of teeth may result in significant disabilities that can profoundly disrupt social activities.

Uncemented endosseous implants have become the most valuable alternative to dental prostheses supported by remaining teeth or adjacent oral soft tissues. After more than four decades of continuous tireless research, dental implantology is now a well-recognized therapeutic advancement in the treatment of partial or complete teeth loss. The technique is reliable and suppresses the use of fixed or removable dentures, which invariably alter the supportive adjacent teeth after a short or medium period of use (13).

The manufacturers have developed a number of specific processes to improve the rate of osseointegration and the long-term biomechanical anchorage of the implant on the bone matrix. An increasing number of surface modifications are being introduced to improve bone-implant contact.

Despite a majority of studies comparing 'machined' surfaces with new rough surfaces or coated surfaces, it is not clear whether, in general, one surface modification is better than another. With this in mind, the present study was conducted to compare and evaluate, clinically and radiographically, the osseointegration between sandblasted large grit, acid etched and calcium phosphate coated implants.

During the course of the study, none of the implants in either group failed claiming a success rate of 100%. These results are in accordance with the studies done by Cochran et al. (14) where the 1-year implant success rates for the sand blasted acid etched implants were 99.4% in the posterior mandible and 100% in posterior maxilla and Grunder et al. (15) where the cumulative postloading implant survival rate was 100% for both anterior and posterior implants.

Plaque is considered an important etiological factor in peri-implantitis. So various indices have been recorded during the course of this study to observe their relationship with the success and failure of the implants. OHI-S, mPI, mGI, sulcular bleeding index, though improved, were not statistically significant for either of the test groups (Fig. 7, 6, 8).

Suboptimal oral hygiene may lead to greater tissue damage around implants within alveolar mucosa than around implants within keratinized tissue. Hence, once the implant crown has been placed, the importance of reinforcing oral hygiene measures in a patient increases manifolds. In the present study, the mean OHI-S values decreased overtime but the result was not statistically significant. The reduction seen in the recorded values showed that the patients maintained their oral hygiene during the course of the study.

The importance of keratinized mucosa around implants has not been proven in longitudinal studies, but the absence of keratinized mucosa around implants seems to increase the susceptibility of plaque-induced peri-implant tissue destruction. In our study the mean differences of keratinized mucosa index scores at baseline was $2.8 \pm 0.92$ and $2.64 \pm 0.9$ at 9 months for test group A and $3.18 \pm 0.7$ at baseline and $3 \pm 0.54$ at 9 months for test group B (Fig. 6) showing no statistical difference in either of the groups. Similar results have been reported by Morris et al. (16) in their study of the comparison of periodontal-type around SLA and HA-coated implants where they compared the clinical parameters around implants and concluded that the width of keratinized tissues remained relatively constant over time for the implant types, with no significant difference.

Implant stability plays a vital role in successful osseointegration. It may be described as the capacity of the implant to withstand loading in axial, lateral and rotational directions. Various methods have been suggested in literature to measure implant stability. The experimented resonance frequency analysis system was commercially produced as Osstell® (Integration Diagnostic Ltd., Goteborg, Sweden). RFA uses the principle of resonance frequency, in which, when a frequency of audible range is repeatedly vibrated onto an implant, the stronger the bone implant interface, the higher the frequency. This technology was proven to be capable of characterizing alterations in implant stability during early healing, and is sensitive enough to identify differences in longitudinal implant stability based on bone density at the implant recipient site (17).

None of the test groups had a statistically significant increase in the implant stability while in the study done by Łukaszewska-Kuska et al. (18) comparing SLA and calcium phosphate coated implants, statistically significant differences were noted for the measurements made for the HA coated implants ($p = 0.006$), while for the grit blasted implants the increase in the ISQ values

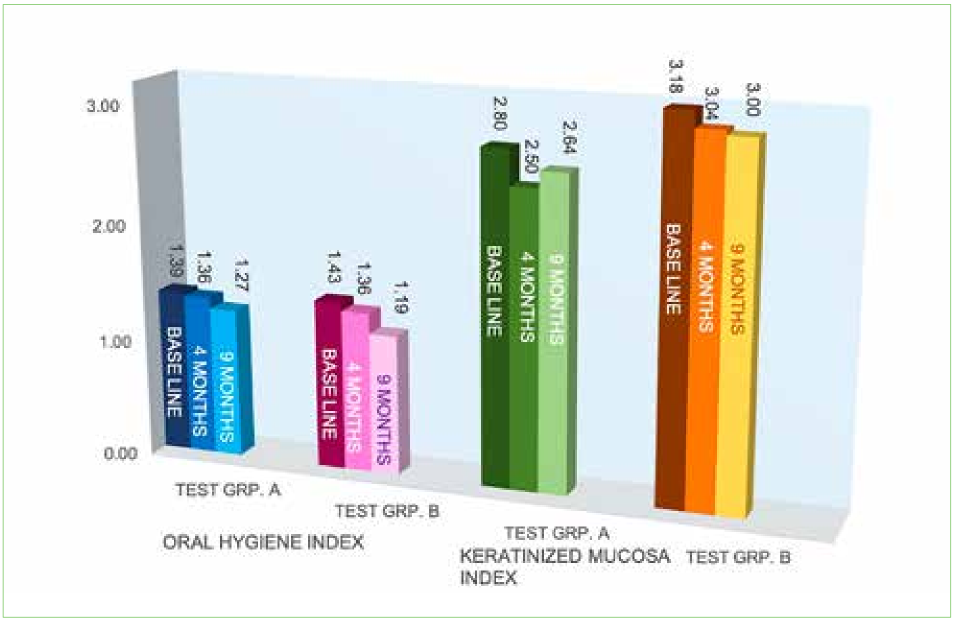



FIG 6 Bar diagram showing Oral Hygiene Index and Keratinized Mucosa Index at different time points for the test groups A and B.

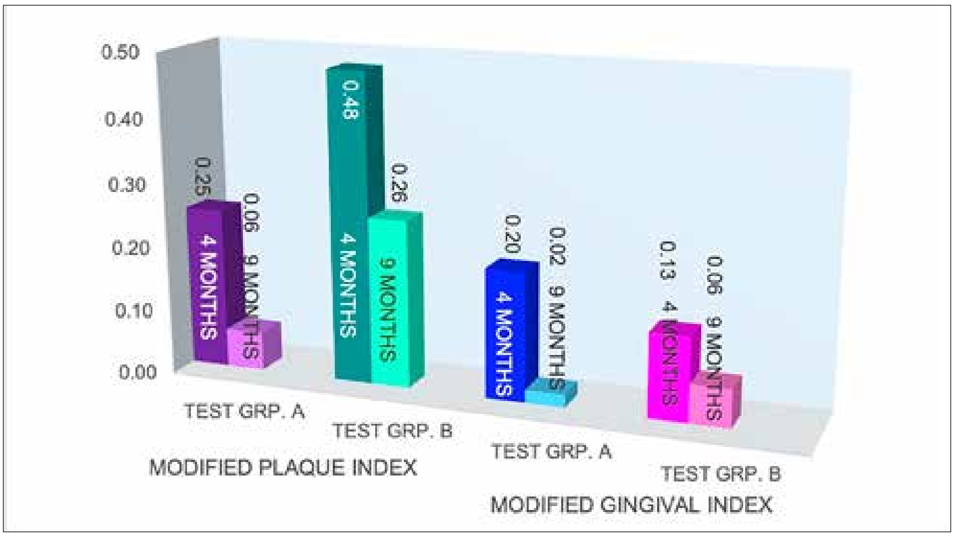



FIG 7: Bar diagram showing Modified Plaque Index and Modified Gingival Index at different time points for the test groups A and B.

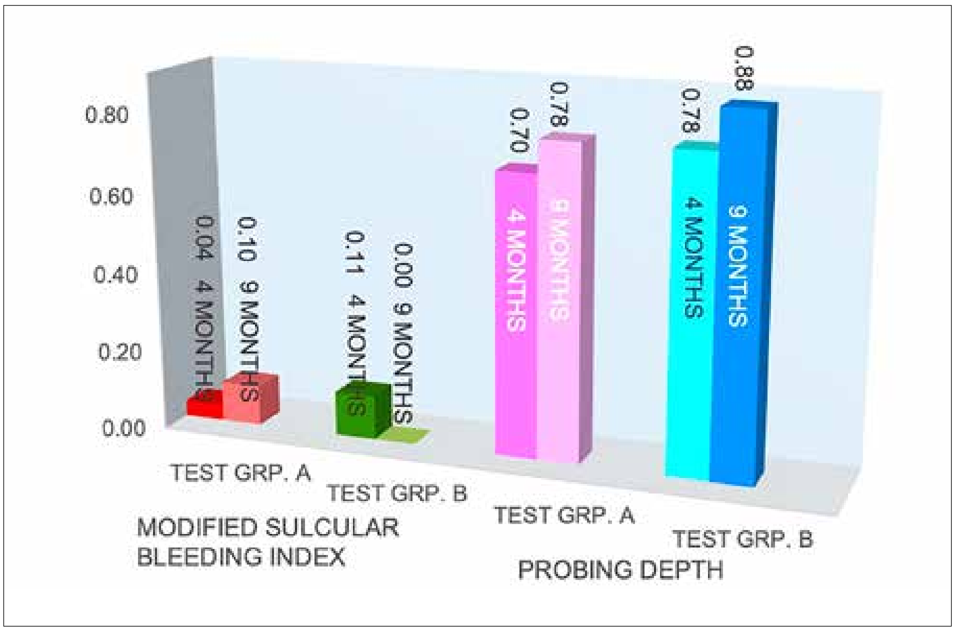
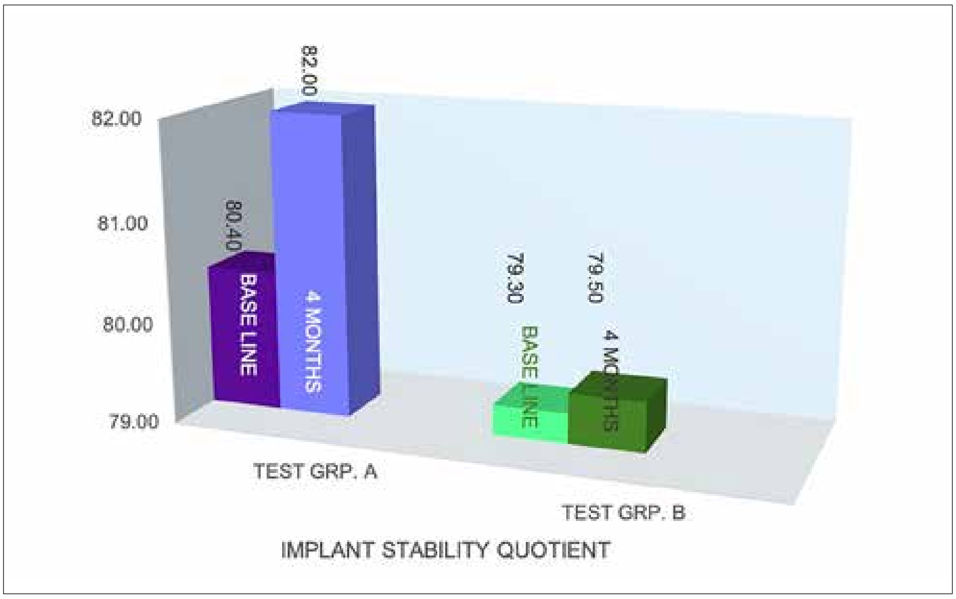



FIG 8 Bar diagram showing Modified Sulcular Bleeding Index and Probing Depth at different time points for the test groups A and B.

FIG 9 Bar diagram showing implant stability quotient at different time points for the test groups A & B.




was not significant (p = 0.15). Andersson et al. (19) acknowledged a correlation between bone quality and primary stability measured by Osstell® device. They noted the ISQ value of 74.0 ± 18.4 after 9 months of placement in SLA implants, and the value was not statistically significant as observed in the current study (Fig. 9). Yokota et al. (20) reported similar results in accordance with the current study claiming a higher primary stability for the calcium phosphate coated implants.

A successful implant depends on patient-related (e.g., bone volume and density) and procedure-related parameters (e.g., design, diameter and length of implant, surgical procedure). There may be some flexibility in implant design and surgical techniques, but parameters such as bone density cannot be modified by the operator. The term "bone quality" encompasses many broad concepts of bone including physiology, mineralization, and morphology.

When helical CT is used, bone density can be obtained in HU. For CBCT, however, there is no standard unit, it represents the greyscale of the area of interest. Hasan et al. (21) and Isoda et al. (22) conducted a study where they correlated the values of CT, CBCT and ISQ. The density values obtained by the CBCT device were confirmed to correspond reasonably with those estimated using helical CT and those were further correlated with the implant stability quotient.

In the present study, the bone density values were measured and compared by taking a CBCT immediately after implant insertion and then at 9 months. Even though the implant stability quotient values were not statistically significant for either of the groups, the bone density values expressed a remarkable improvement in the test group B at 9 months. The p-value was significant for all the 4 aspects of the implant. Kim et al. (23) observed similar results when comparing the bone density around SLA implants and calcium phosphate coated implants. The bone density around the calcium phosphate coated implants increased significantly. Rizo-Gorrita et al. (24) reported a higher bone implant contact and bone density in accordance with the present study in calcium phosphate coated implants when compared to SLA implants.

In the present study as well, it could be appreciated that the calcium coated implants had a better response in terms of bone healing and bone deposition. The bone density was more around the test group B implants, and it was statistically significant in the 9 month follow up. McGlumphy et al. (25) did a 7 year prospective study on the functional loading of HA-coated implants where they reported an accelerated healing time and a higher implant stability, which was attributed to the biomimetic calcium phosphate coatings over the implants. Similarly, Binahmed et al. (26) reported a 8-10 year follow up of the calcium phosphate coated implants and their successful osseointegration. In a randomized controlled multicenter study, Jeffcoat et al. (27) compared calcium phosphate coated threaded and titanium threaded dental implants over a 5-year period. The CaP coated threaded implants were associated with cumulative survival rates of 97.7% and the titanium dental implants with 95.2% (P < .06).

The superiority of calcium phosphate coatings lies in their potential for adsorbing large amounts of fibronectin and vitronectin on the surface, which increases the osteoblast adhesion and bone formation. Calcium phosphate also increases osteoblast proliferation, which increases the bioactivity of the coatings. Calcium ions enable the formation of a biochemical bond between the implant and the bone, which results in faster and more intense osseointegration (28).

Phosphate groups, on the other hand, provide potential chemical bonding sites for calcium ions and for the hydroxyapatite of the bone matrix during biological mineralization, and are responsible for biochemical interaction between the implant and the bone (29). Poulos et al. (30) reported similar findings in their histologic study of calcium phosphate coatings in implants, which explains the increased bone density around the calcium phosphate coated implants in the present study.

In the present study the implant used in test group B had RBM additive treatment on its surface. Resorbable Blast Media (RBM) surface treatment is based on high-speed particle blasting, using the resorbable bioceramics. RBM particles do not penetrate too deep into the titanium surface and are removed by a mild acid as opposed to the SLA implants where concentrated acids are used, and sometimes dual etching is required to remove the alumina particles from the surface of the implants. Gonshor et al. (31) discuss the success rates of the RBM implants which are in accordance with the present study, where 100% implant survival was seen.

The clinical and radiographic evaluation of the calcium phosphate coated surfaces from baseline to 9 months showed a marked improvement in the bone density and implant stability, which was statistically significant when compared to the sandblasted, acid etched implant surface. However, this study had some limitations. The sample size was limited to 20 subjects with 20 edentulous sites. A larger sample size would give more meaningful results. Histological evaluation was not done due to ethical considerations. Conducting histological studies would be helpful to clarify the mechanism of primary stability and bone deposition around the calcium phosphate coated implants.

## CONCLUSION

With a long history of dental implantology and ever since modern dental implants were introduced more than 40 years ago, the development of the ideal implant has been a major research subject in the field, thereby changing the practice of implant dentistry. Through research, dental implant technology has been constantly improving, evolving in the recent years, providing patients with unparalleled levels of effectiveness, convenience, and affordability.

In the current study, after clinically and radiographically evaluating the SLA and CaP coated implants, there was an increase in the overall bone density around both the implant groups, though it was not statistically significant in test group A, i.e. SLA implants. The bone density in test group B i.e. CaP coated implants, had notably increased, and the increase was statistically significant when compared with test group A. Thus, within the limitations of the current study, it may be inferred that calcium phosphate coated implants are superior to the subtractive sandblasted large grit acid-etched implant surfaces in improving the primary stability and bone density at the implant site.

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### Conflict of interest

No potential conflict of interest relevant to this article was reported.

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