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ORIGINAL ARTICLE

EVALUATING BONE MINERAL DENSITY AND TRABECULAR BONE MICROSTRUCTURE AROUND IMPLANTS BY CBCT

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ABSTRACT

Aim: The purpose of this study is to evaluate Bone Mineral Density (BMD) by Hounsfield Units (HU) and Trabecular Bone microstructure by Fractal Dimension (FD) around dental implants pre-operatively and post operatively by CBCT.

Materials and Methods: Twelve patients with partially edentulous sites of age group between 20 to 50 years with good systemic health were enrolled. Patients are assessed for BMD before (baseline) and after placement of implants (9 months) using analysis by Hounsfield Units (HU) and FractalDimension (FD).

Results: BMD by HU improved from baseline (412.25 ± 105.16) to 9 months (626.58 ± 114). Trabecular Bone Microstructure by FD improved from baseline (0.78 ± 0.06) to 9 months (1.40 ± 0.05). Unpaired t test and paired t test were performed for inter groupand intra group analyses respectively.

Conclusion: Present study was undertaken to evaluate bone changes on implants placed in the suitable edentulous sites. All the implant Osseo integrated without any uneventful healing. The marginal bone loss found was also minimal and found to be statistically non-significant. With the limited sample size it can conclude that fractal analysis holds good for bone architectural analysis.

Key words: Bone Mineral Density, Trabecular Bone Microstructure, Hounsfield Units, Fractal Dimension, Cone Beam Computed Tomography.

INTRODUCTION

Dental implants have become a predictable treatment option for restoring missing teeth. Provides adequate function and esthetics without affecting adjacent hard and/or soft tissue structures. A dental implant is a titanium screw which is placed into bone to replace missing teeth. The implant mimics the root of a tooth in function. It is not only biocompatible, but actually fuses to bone by osseointegration. Osseointegration is a direct structural and functional union between living bone and surface of the load carrying implant.[1] Traditional radiographs like periapical and panoramic

radiography provide adequate information along with neighboring vital structures that must not be violated. However, these radiographic modalities provide a two-dimensional (2D) representation of three-dimensional (3D) structures. Their limited film size, image distortion, magnification, and 2-D view restrictttheir use in some cases. In an effort to overcome this limitation, Cone Beam Computed Tomography (CBCT) has become available for 3D visualization of the craniofacial complex.[2]

CBCT is an essential tool for treatment planning and post-procedure monitoring. By providing highly accurate 3-D images of the patient's anatomy from a single, low-radiation scan, CBCT technology delivers a comprehensive understanding of the patient's jaw and the anatomical structures that provides accurate treatment planning.[3]

Bone Mineral Density (BMD) is the amount of bone tissue in a certain volume of bone. Assessment of jaw BMD may be considered useful in implant planning (Gulsahi et al., 2010).[4] Clinical studies show greater implant survival & osseointegration in mandible than maxilla. This survival is limited by bone quality, i.e. bone density.[5] Bone mineral density is lower in maxillary when compared to mandibular Bone Mineral Density. HU value was used to assess the bone density on the implant site, and the standard value of jaw bone density varies from one individual to other.[6]

Fractal analysis is based on fractal mathematics for describing complex shapes and structural patterns. It indicates a figure's complexity and expressed as "Fractal Dimension" (FD), which measures self-similarity. Trabecular bone has branching pattern that exhibits fractal properties. Therefore, when applied to trabecular bone images on radiographs, this method can be considered as a reflection of trabecular bone micro architecture.[7] In fractal analysis, a box-counting algorithm is mainly used to quantify the trabecular pattern by counting the trabecular bone and bone marrow interface.[8]

MATERIALS AND METHODS

STUDY DESIGN

The objective of this study is to evaluate modalities to measure the peri- implant changes i.e. BMD by HU and Trabecular bone microstructure by FD. The peri- implant changes were assessed using CBCT at baseline and 9 months.

Clinical parameters such as Bone Mineral density, Trabecular Bone Microstructure were assessed at baseline and 9 months. Approval of the study was obtained from the ethical committee of St. Joseph Dental College and an informed consent was taken from all participants before commencement of the study.

STUDY POPULATION

The study population included patients who reported to the department of Periodontics St Joseph dental college during the period April 2017 to April 2018.

INCLUSION CRITERIA

- Patients in the age group of 20 to 45 years.
- Partially edentulous patients.
- Patients showing compliance to maintain good oral hygiene.
- Good systemic health.

EXCLUSION CRITERIA

- Patients with known systemic disease.
- Patients on medication and antibiotic therapy since last 6 months.
- Patients with psychiatric disorders.
- Pregnant or lactating women.
- Smokers.
- Teeth with occlusal interferences and restorations.
- Poor oral hygiene and mobility.

PRE-TREATMENT RECORDS

- Detailed medical and dental history.
- Routine blood investigations.
- Periodontal assessment using clinical parameters.
- Diagnostic casts.
- Periapical, panoramic radiographs and CBCT scan whenever required.
- Clinical photographs (fig1,2).

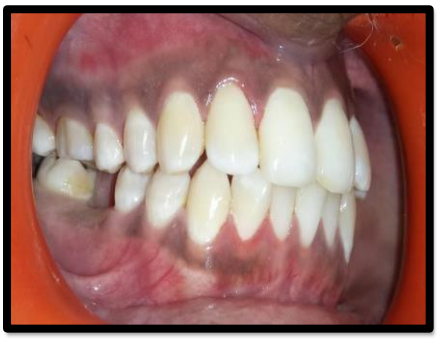

Figure 1. Pre Operative scaling

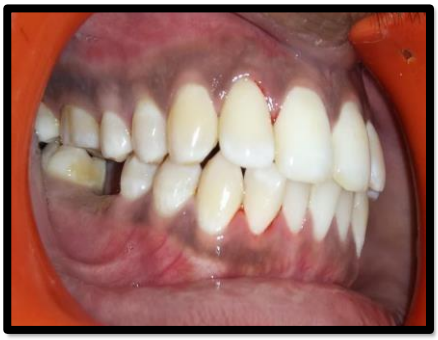

Figure 2. Post Operative scaling

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CLINICAL PARAMETRS

- Hounsfield Units
- Fractal Dimension(fig.3,4).

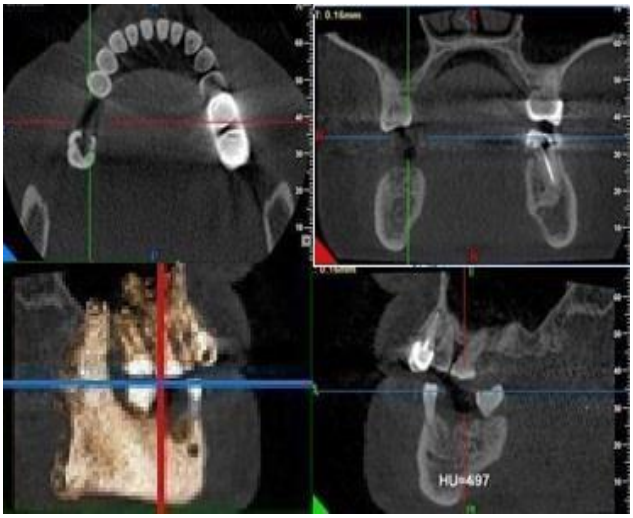

Figure 3. Pre-Operative Hounsfield Units (HU) Value

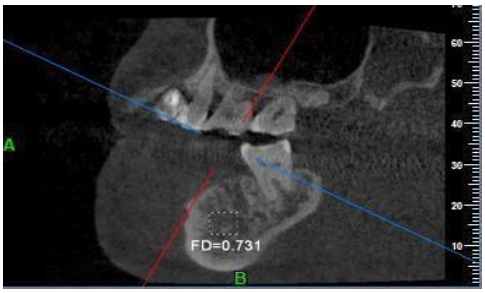

Figure 4. Pre-Operative Fractal Dimension Units(FD

PRESURGICAL PROCEDURE

Prior to commencement written consent was taken. Following initial examination and treatment planning, the selected patients underwent phase 1 therapy. Detailed instructions and plaque control measures were given. Two weeks after phase 1 therapy, patients were subjected to the surgical procedure. Selected patients underwent routine blood investigations and radiographs of the area of interest were taken. On completion of baselineexamination and initial therapy, dental implants were placed at the edentulous sites.

IMPLANT MATERIALS

- Self-tapered threaded implants were used.
- Minimum dimensions - 3.3mm in diameter and 9.5mm long. Maximum dimensions - 4.5mm in diameter and 11mm long.
- Crown placed- metal ceramic.

SURGICAL PROCEDURE

Local anesthesia (1:80000 lignocaine) is administered at the site where implant is tobe placed.The sequenceof implant placement is(fig.5-8)-

1. Initial marking of the implant site with a round bur.
2. Use of a 2-mm twist drill to establish depth and align the implant.
3. Guide pin is placed in the osteotomy site to confirm position and angulation.
4. Pilot drill to increase diameter of the coronal aspect of the osteotomy site.
5. Final drill used is the 3-mm twist drill to finish preparation of the osteotomy site.
6. Countersink drill is used to widen the entrance of the recipient site and allow forthe sub crestal placement of the implant collar and cover screw.
7. Implant is inserted into the prepared osteotomy site with a handpiece.
8. The cover screw is placed and soft tissues are closed with 3-0 suture.

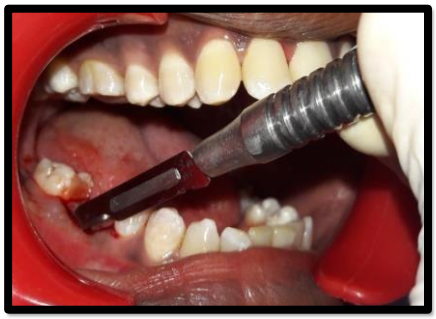

Figure 5. Mid crestal incision given

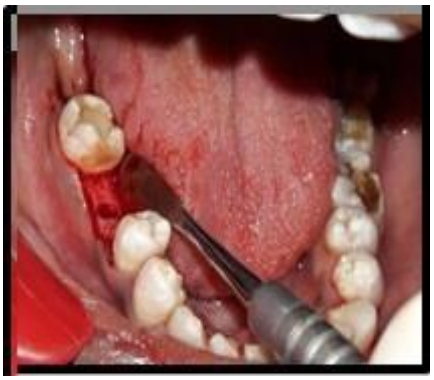

Figure 6. Full thickness mucoperiosteal flap elevatedand Osteomy site prepared

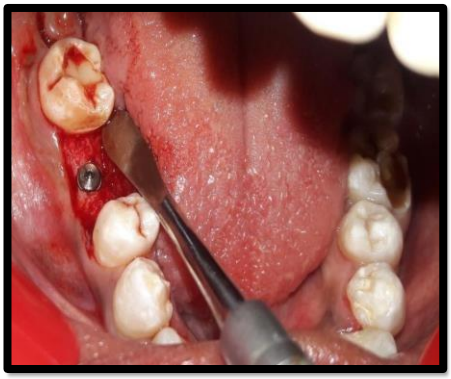

Figure 7. Implant placement done

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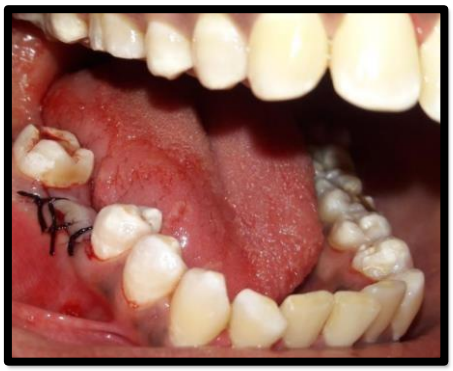


Figure 8. Mucoperiosteal flap approximation doneusing silk sutures

POSTOPERATIVE CARE

All patients were prescribed Amoxicillin 500 mg thrice daily for 5 days and a combination of Ibuprofen 400mg and Paracetamol 325mg thrice daily 3days. They were also instructed to rinse with 10 ml of Chlorhexidine gluconate (0.2%) mouthwash twice daily for two weeks.

Postoperative instructions given are as follows:

1. For first 3 hours after operation, avoid taking hot liquids for the first 24 hours.
2. Do not brush over the surgical site.
3. During the first day, apply ice pack intermittently on face over the operated area.
4. If unusual pain or bleeding from the operated sites seen, asked to report to the hospital immediately.

POSTSURGICAL PROTOCOL

Patients were recalled 24 hours after the surgery to evaluate signs of postoperative complications. After 7 days sutures were removed and the area was irrigated with saline. The patients were advised to use extra-soft brushes for mechanical plaque control to maintain good oral hygiene. The patients were again instructed to rinse with chlorhexidine mouthwash twice daily for another one week. All the 30 patients were kept under a recall program for loading after 9 months.

PROSTHODONTIC PHASE

In both the groups, delayed loading was done. Cover screws were removed and healing abutments were placed after 3 months in the mandibular implants and after 6 months in the maxillary implants. After 15 days of placement of the abutments, abutment level closed tray putty impressions were taken and given for crown fabrication (fig 9-12).

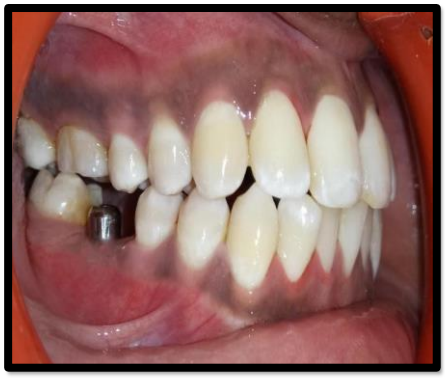


Figure 9. Healing abutments placed

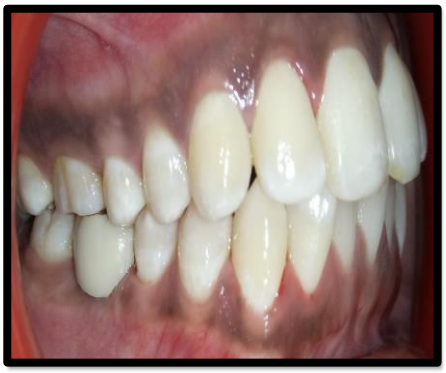


Figure 10. Prosthesis place

Figure 11. 9 Months Post Operative Hounsfield

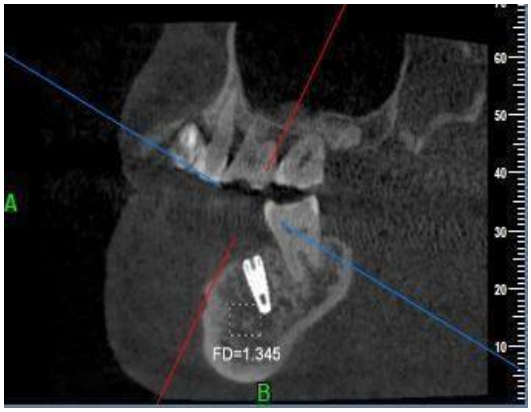


Fig: 12 9 Months Post Operative Fractal Dimension Units (FD)

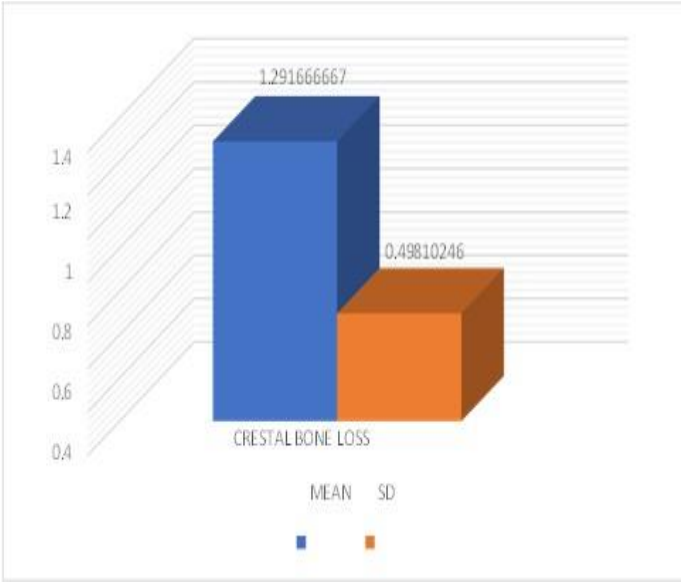
RESULTS

The mean crestal bone loss at base line was 4.5 ± 0.2 and the mean crestal bone loss at 9 months was 5.2 ± 0.4. When the pre operative mean was compared with 9 months post operative mean, it yielded a p value of 0.09, which was not statistically significant (P > 0.05).

Table 1. Mean, standard deviation and test of significance for crestal bone loss at baseline and 9 months post operatively.

	BASELINE		9 MONTHS		BONE LOSS OCCURED		P value
CRESTAL BONE LOSS	MEAN	SD	MEAN	SD	MEAN	SD	
	4.5	0.223	5.2	0.425	0.7	0.202	0.09

Statistical Analysis: Paired t Test. P value was > 0.001 meaning statistically non- significant



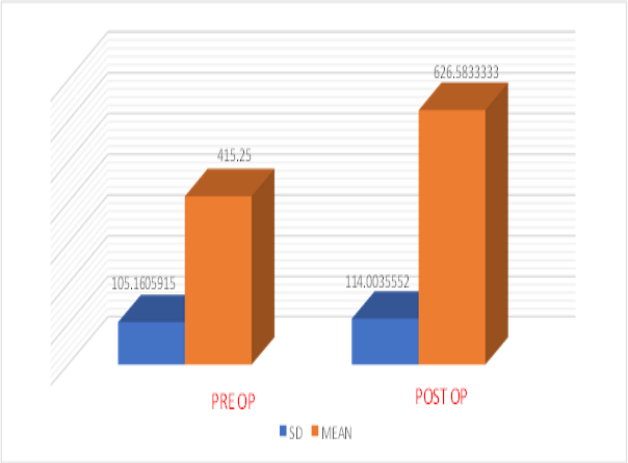
GRAPH 1. Mean crestal bone loss at 9 months post operatively

Table 2. Mean, standard deviation and test of significance for Bone Mineral Density by Hounsfield Units at baseline and 9 months post operatively.

	BASELINE		9 MONTHS		Mean Diff from pre op & 9months		P value
HOUNSFIELD UNITS	MEAN	SD	MEAN	SD	MEAN	SD	
	415.253	105.1606	626.583	114.003	211.33	8.8424	0.004 ** S

Statistical Analysis: Paired t Test. **S: Statistically highly significant.

Inference- The mean bone mineral density (HU) at base line was 412.25 ± 105.16 and the mean bone mineral density (HU) at 9 months was 626.58 ± 114. When the pre operative mean was compared with 9 months post operative mean, it yielded a p value of 0.004, which was statistically significant (P < 0.05).



GRAPH 2. Comparison of mean Bone Mineral Density by Hounsfield Units at baseline and 9 months post operatively

Table 3. Mean, standard deviation and test of significance for Trabecular bone microstructure by Fractal Dimension at baseline and 9 months post operatively.

	BASELINE		9 MONTHS		Mean Diff from pre op & 9months		P value
HOUNSFIELD UNITS	MEAN	SD	MEAN	SD	MEAN	SD	
	415.253	105.1606	626.583	114.003	211.33	8.8424	0.004 ** S

Statistical Analysis: Paired t Test. **S: Statistically highly Significant.

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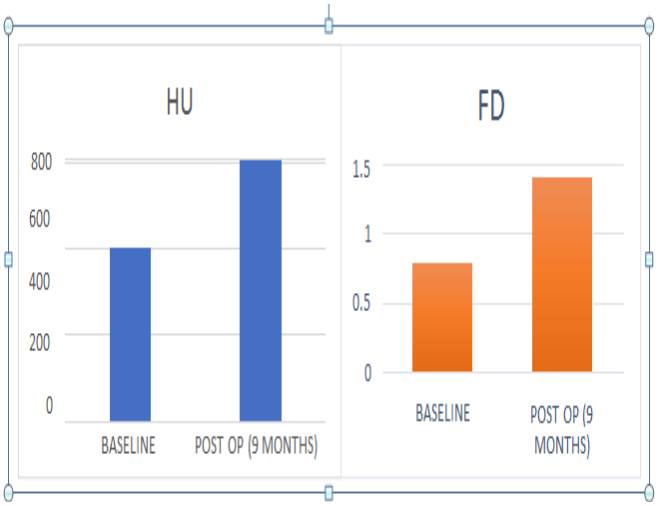
Inference- The mean Trabecular Bone Microstructure (FD) at base line was 0.78 ± 0.06 and the mean Trabecular Bone Microstructure (FD) at 9 months was 1.40 ± 0.05.When the pre operative mean was compared with 9 months post operative mean, it yielded a p value of 0.001, which was statist ically significant (P < 0.05).

GRAPH 3. Comparison of mean Trabecular bone microstructure by Fractal Dimension at baseline and 9 months post operatively.

Table 4. Mean, standard deviation and test of significance for Bone Mineral Density by Hounsfield Units and Trabecular bone microstructure by Fractal Dimension at baseline and 9 months post operatively.

	BASELINE		9 MONTHS		P value
	Mean	SD	MEAN	SD	
HOUNSFIELD UNITS(HU)	415.253	105.1606	626.583	114.003	0.004 * S
FRACTAL DIMENSION (FD)	0.781917	0.068182	1.40125	0.058518	0.001 ** S

Inference-The mean bone mineral density (HU) at base line was 412.25 ± 105.16 and at 9 months was 626.58 ± 114. When the pre operative mean was compared with 9 months post operative mean, it yielded a P value of 0.004, which was statistically significant (p < 0.05). The mean trabecular bone microstructure (FD) at base line was 0.78 ± 0.06 and at 9 months was 1.40 ± 0.05.When compared it yielded a P value of 0.001, which was statistically significant (P < 0.05). In comparison, Fractal Dimension Analysis showedhigh significance than Hounsfield units.



GRAPH 4: Mean inter group comparison of Bone Mineral Density by HU and Trabecular bone microstructure by FD at baseline and 9 monthspost operatively.

DISCUSSION

The Implant-Tissue interface is an extremely dynamic region of interaction. The process of osseointegration involves an initial interlocking between alveolar bone and the implant body and later, biological fixation through continuous bone apposition andremodelling. This entire process is followed by changes in Bone Mineral Density and Trabecular bone microstructure. Cone Beam Computed Tomography (CBCT) is an essential 3-dimensional tool for measuring the bone mineral density. It is measured in terms of Hounsfield units.

Trabecular bone microstructure which is measured in terms of fractal dimensions is a method for describing complex shapes, structural pattern and also to estimate microstructure of bone tissue and trabecular pattern and is expressed numerically as fractal dimension. The debate on which method (BMD or FD) is accurate in recording the changes has always been a matter of concern for periodontists when placing implants.

Thus, the purpose of this study was to compare and evaluate Bone Mineral Density (BMD) by Hounsfield Units (HU) and Trabecular Bone microstructure by Fractal Dimension (FD) analysis around implant cases pre-operatively and post operatively.

Bone mineral density, most important parameter, can be measured using hounsfield units.

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The units are based on a linear scale defined only by two points: the attenuation of dry air, set at) 1000 HU, and the attenuation of pure water, set at 0 HU.After the 9 months follow-up it was found that bone mineral density (HU) at base line was 412.25 ± 105.16, while at 9 months was 626.58 ± 114. The bone mineral density increased considerably after implant placement which states the physiological changes that have occurred in the bone to be healthy.

The mean bone density was highest in the anterior mandible followed by the anterior maxilla, the posterior mandible, and the posterior maxilla. The mean bone density recorded in the present study was higher than the studies reported previously by Y. Hao et al. 2014[9], this could be because of the physiological differences between the living bone and the cadaver bone. This increase in bone mineral density is due to the reactive bone formation that occurs around the implant for Osseo- integration. It was also stated by Farre-Pages et al 2010 that HU can be used as a diagnostic parameter to predict possible implant stability. The results in the present are in correlation with the studies performed by Kyou Hiasa et al. in 2016, Stoppie et al. 2011, Farre-Pages et al. 2010 and L.J. Fuh[10] 2010.

Fractal Dimensions has some advantages when compared with hounsfield units such as lower radiation dose, shorter acquisition time, and reduced costs. HU should be better understood as “relative” density rather than “true” density. This relative density is determined by CT numbers, which represent the total X-ray attenuation of different body tissues. Thus, the comparative evaluation between bone mineral density (HU) and trabecular bone microstructure was considered. The trabecular bone micro structure (FD) at base line was 0.78 ± 0.06 and at 9 months was1.40 ± 0.05. The trabecular bone micro structure has also improved from baseline to 9 months after implant placement indicating osseointegration. The results are in the accordance studies done by Bollen et al., 2013[11]. Bone quality can improve around a functional osseointegrated dental implant due to the positive bone stimulation, the more bone that is present at an implant site, the better the possibility for implant success. Mechanical injury to bone results in an increase of its volume and density as stated by Yan Hua 2008[12].

This effect, however, as stated by Branemark et al. 1964 and Slotte et al. 2003. Hounsfield units and Fractal dimensions could record physiological changes occurring in the bone around implant. HU represents the relative bone density of the jaw bone in a calibrated gray-level scale. In accordance to the studies done by *Y. HAOet al 2014* stated that the anterior mandible bone density (HU) > anterior maxilla (HU) and posterior mandible (HU) > posterior maxilla.

In accordance to the studies done by Yan Hua 2008 stated thatfractal analysis is one of the most suitable method for texture analysis. Beam hardening and heel effect are the two phenomenon that gives the accurate results of trabecular bone microstructure by fractal analysis. Beam hardening is a phenomenon resulting from the increase of mean energy of the X ray beam when passes through an object. Heel effect is a phenomenon that causes a angular distribution of the X ray beam intensity. Trabecular bone micro texture analysis thus plays a vital role in bone quality assessment by micro architectural composition. However, further clinical trials with larger sample size and longer duration are required to determine the study.

CONCLUSION

In conclusion the present study was undertaken to evaluate bone changes on implants placed in the suitable edentulous sites. All the implants have osseointegrated without any uneventful healing. The oral hygiene measures followed properly showed successful implants without peri-implantitis. The marginal bone loss found was also minimal and found to be statistically non- significant. With the limited sample size it can concluded that fractal analysis holds good for bone architectural analysis. However, the study has certain limitations. Limited number of patients and shorter follow up period may have contributed to the lack of any detectable significance between the groups. Longer follow up with larger sample size is necessary to study the efficiency of the material in attaining a predictable treatment outcome.

DECLARATION

Ethics approval

Obtained from the St.Joseph Dental College and Hospital, CEC/20/2018-19 **Consent to participate:** Obtained from all the study participants

Patient consent for publication

Obtained

Acknowledgments

Not applicable

Conflicts of interest and financial disclosures

The author declares that he has no conflict percent and there was no external source of funding for the research in question

Sources of Funding

This research received no external funding (self-funding).

Availability of data and materials

From the Institution

Clinical trial registry number

Not applicable

Prospero registry number

Not applicable

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