An appraisal of bone resorption in completely edentulous diabetic and nondiabetic patients at prospective implant site in anterior mandible using digital volumetric tomography and its correlation with glycemic control: A case–control study

**ABSTRACT**

**Purpose:** The prospective case–control study aimed at comparing bone resorption at prospective implant sites in anterior mandible between diabetic and nondiabetic patients using digital volumetric tomography (DVT) and establishes a correlation between glycemic control and residual ridge resorption.

**Materials and Methods:** Twenty apparently healthy and 20 type 2 diabetic edentulous male patients between the age group of 55–65 years providing with written consent were recruited in the present study. First-time denture wearers were considered who were edentulous for at least 1 year. Glycated hemoglobin (HbA1c) analysis of all individuals were done to affirm the diagnosis and quantify glycemic control. DVT of all the individuals were performed and bone height was determined at 5 prospective implant sites were determined, on the same scans Wical and Swoope method was used to determine the residual ridge resorption on the right and left side of mandible for all the individuals. The data were tabulated and descriptive and analytical statistics were performed to compare bone resorption between diabetic and nondiabetic groups. Pearson’s correlation was carried out to establish correlation between glycemic control and residual ridge resorption.

**Results:** There was no statistical difference between the bone height measurements at prospective implant sites between diabetic and nondiabetic groups. The residual ridge resorption was more in diabetics when compared to nondiabetics, and a significant moderate negative correlation existed between the glycemic control and residual ridge resorption on left ($r = 0.541; P \leq 0.001$) and right ($r = 0.408; P = 0.009$) side of the mandible.

**Conclusion:** It can be concluded from the present study that bone resorption at prospective implant sites is statistically similar in diabetics when compared to nondiabetics. Patients with poor glycemic control show increased residual ridge resorption.

**Keywords:** Digital volumetric tomography, glycated hemoglobin, prospective implant sites, residual ridge resorption, type 2 diabetes

**INTRODUCTION**

According to a WHO Report in 2008, 347 million people suffered from diabetes in the world. Of the total population studied 69.2 million people (8.7% of diabetic population) were Indians. Diabetes remained undiagnosed in 36 million people.[1] The environmental factors include obesity, sedentary lifestyle, urban migration, and rising living standards.[2] The prevalence of diabetes has risen in the low- and middle-income group as compared to high-income groups in the past decade.[1] The prognosis of removable prosthesis is affected by residual
ridge resorption and it depends on quantity and structure of the bone.[3] Residual ridge resorption may progress without apparent symptoms until the patient’s dentures become loose thus shortening the life of prosthesis. Diabetes mellitus is the main endocrine disorder that has been documented to affect the periodontium, bone and calcium metabolism.[3] Implant-supported prosthesis was considered a contraindication in diabetic patients until recently proven that the stability of implant in type 2 diabetic patients directly depends on the HbA1c levels,[4] which on being high warrants poor stability of prosthesis.[4,5] The increasing demand for implant-supported prosthesis in diabetic population has given rise to a need for thorough research on of the various avenues present in implant-supported treatment modalities. Implant-supported prosthesis offer several fold advantages over conventional tissue borne prosthesis. Regardless of the implant system to be used there is a need for preoperative radiographic assessment primarily by orthopantomograph and more definitively with computed tomography (CT).[6] While the panoramic images give two-dimensional images which only help in determining the bone height, CT helps in three-dimensional (3D) imaging which provides a better insight of the buccolingual direction as well.[6] Digital volumetric tomography (DVT) is an imaging modality which produces similar 3D images but at lower radiation doses. DVT produces highly contrasted images of craniofacial structure.[7] Ascertaining the need for exploration in the field of implant as a safer and better option for diabetic patients it is essential to establish guidelines which relates diabetic control and anatomic feasibility at the site of implant placement. The purpose of this study is to compare vertical bone height measurements using DVT, in diabetics and nondiabetics, to assess the amount of residual ridge resorption at prospective implant site and to correlate it with glycemic control.

MATERIALS AND METHODS

This prospective case–control study was conducted at the Department of Prosthodontics, Sharad Pawar Dental College, Datta Meghe Institute of Medical Science (DMIMS) (Deemed to be University). Approval for study was obtained from Institutional Ethics Committee (DMIMS) Ref no-DMIMS (DU)/IEC/2017-18/6689 and it was carried between October 2017 and April 2019. The sample size of 20 per group was determined by method of difference of means. The power of the study was 80%.

\[ N = 2 \sigma ^2 (Z)' + Z' \sigma / \Delta^2 \]

A total of 40 elderly completely edentulous patients (age group of 51–60 years) were included in the study. The patients were segregated in the study group (n = 20) which had the inclusion criteria as consenting patients who gave a history of diabetes (confirmed by HbA1c levels ≥6.5), first time denture wearers (determined radiographically and patient case history). Patients free of any other systemic disorders which affect bone metabolism. The control group had all the inclusion criteria except that the patients were not type-2 diabetes. The study and the procedures involved were explained to the patients in a language they understood before beginning of the procedure. Routine health check-up was carried out to insure the absence of any other systemic diseases. For the determination of glycemic control HbA1c investigation was done at Acharya Vinoba Bhave Rural Hospital (DMIMSU Sawangi). The blood samples were processed by immunoturbidimetry method using autoanalyzer within 2 h of collection. The results were tabulated, and stratified according to the following levels [Table 1].[5,8]

The bone height at the prospective implant sites was measured using DVT (Phillips AlluraXper FD20 3D RA, Digital subtraction Angiography unit [the Netherlands] s 5600 with exposure parameters of 80 kVP, 10 mA, and 4–5 s with Field of View-12” 270° rotation) of the anterior mandible of all the 40 individuals. The patients were positioned in the DVT machine according to the standard protocol of the department of radiodiagnosis. To measure residual ridge resorption the interforaminal region of mandible was sectioned into five equal sections of bone which were considered as prospective implant sites, labeled A, B, C, D, and E [Figure 1a and b], starting from the patient’s right side. Seven height measurements were made for each patient on the viewing software (3D Rotational Angiography Imaging software). Two measurements were made at the left and right mental foramen region from lower border of the mandible to the crest of the alveolar ridge (MC/[R/L]) and distance of the lower border of the mandible to the lower border of the mental foramen (MF/[R/L]) [Figure 2]. Two parallel lines are drawn 6 mm anterior to the mental foramen and the acquired region is measured and is split into five equidistant regions, namely A’, B’, C’, D’, E’ from the right side of the patient to left. Ridge height measurements were made at the geometric center of these five regions and were named as A, B, C, D, E [Figure 3a-e]. Alveolar bone resorption was

| Table 1: Glycated haemoglobin values stratified under glycaemic control |
|---------------------------------|-----------------|
| **Glycated haemoglobin**        | **HbA1c levels (%)** |
| Nondiabetics                    | ≤6.5            |
| Well controlled diabetics       | 6.6-8.0         |
| Moderately controlled           | 8.1-10          |
| Uncontrolled                    | ≥10.1           |

HbA1c: Glycated hemoglobin
calculated using Wical and Swoope method which predicted the height of the atrophied mandible which is three times the distance between the lower border of the mandible and the lower border of mental foramen. Ortman et al.\(^9\) classified RRR into three classes depending on the ratio obtained using the Wical and Swoope method [Table 2].

Descriptive statistical analysis was done after analyzing the normality of the data. Parametric test was used to analyse the normality of data. The independent sample t-test was used to check mean differences. The level of significance was kept at \(P < 0.05\). The correlation between the residual ridge resorption and glycemic control was measured by Pearson’s correlation test.

**RESULTS**

The data are presented in mean and standard deviation. The normality of continuous data was analyzed by the Shapiro–Wilk test. As the data followed normal distribution, parametric test was used to analyze the data. The independent sample t-test was used to check mean differences. The level of statistical significance was kept at \(P < 0.05\). The mean age of diabetic group was 56.15 years and non-diabetic group was 55.8 years.

The mean HbA1c value of nondiabetic individuals was found to be 4.67 ± 0.72 with a range of 3.30–5.90 and of diabetic patients was 8.38 ± 1.36 with a range of 6.90–11.50 [Table 3].

There was no statistically significant difference between bone height measurements at prospective implant sites for diabetic and nondiabetic individuals [Table 4].

The mean ORI values of the left side were compared between diabetic and nondiabetic individuals. It was found that there was no statistically significant difference \( (P = 0.092, 95\% \text{ confidence interval [CI]}: −0.03–0.43) \) in mean ORI values of the left side between diabetic and nondiabetic patients; however, this was not the case with right side. Statistically significant difference \( (P = 0.018, 95\% \text{ CI}: 0.04–0.44) \) in mean ORI values of right side was found between diabetic and nondiabetic patients. The mean ORI values of right side were significantly greater in nondiabetic individuals \( (2.12 \pm 0.32) \) compared to diabetic patients \( (1.87 \pm 0.30) \) [Table 5].

The correlation between HbA1c values and ORI (left and right) was evaluated. It was revealed that a medium or moderate negative correlation was present between ORI left and HbA1c value \( (r = −0.541; P ≤ 0.001) \) and also between ORI right and HBA1C \( (r = −0.408; P = 0.009) \) [Table 6].

**DISCUSSION**

Implant-supported complete denture is preferred over conventional complete denture due to their benefits in terms of...
Mistry, et al.: Evaluation of residual ridge resorption in diabetic and non-diabetic patients at prospective implant sites

Table 4: Comparison of bone height at prospective implant site (height at A, B, C, D, and E) in diabetic and nondiabetic patients

| Variables       | Groups    | n  | Mean | SD  | SE  | MD     | 95% CI | t    | P*    |
|-----------------|-----------|----|------|-----|-----|--------|--------|------|-------|
| Height at A     | Nondiabetic| 20 | 16.98| 2.12| 0.47| 0.27   | -0.90-1.45| 0.472| 0.639 |
|                 | Diabetic  | 20 | 16.70| 1.50| 0.33|        |        |      |       |
| Height at B     | Nondiabetic| 20 | 20.33| 1.73| 0.38| 0.62   | -0.50-1.75| 1.123| 0.268 |
|                 | Diabetic  | 20 | 19.70| 1.78| 0.39|        |        |      |       |
| Height at C     | Nondiabetic| 20 | 21.22| 2.28| 0.51| 0.97   | -0.32-2.26| 1.521| 0.137 |
|                 | Diabetic  | 20 | 20.25| 1.71| 0.38|        |        |      |       |
| Height at D     | Nondiabetic| 20 | 18.59| 2.24| 0.50| 0.56   | -0.61-1.74| 0.965| 0.340 |
|                 | Diabetic  | 20 | 18.03| 1.33| 0.29|        |        |      |       |
| Height at E     | Nondiabetic| 20 | 17.33| 2.42| 0.54| 1.17   | -0.12-2.46| 1.833| 0.075 |
|                 | Diabetic  | 20 | 16.16| 1.51| 0.33|        |        |      |       |

*P value derived from independent sample t-test; P<0.05. SD: Standard deviation, SE: Standard error, CI: Confidence interval, MD: Mean Deviation

Table 5: Comparison of Ortman’s Resorption Index (left and right side) between diabetic and nondiabetic patients

| Variables       | Groups    | n  | Mean | SD  | SE  | MD     | 95% CI | t    | P*    |
|-----------------|-----------|----|------|-----|-----|--------|--------|------|-------|
| ORI left        | Nondiabetic| 20 | 2.09 | 0.38| 0.08| 0.19   | -0.03-0.43| 1.731| 0.092 |
|                 | Diabetic  | 20 | 1.89 | 0.33| 0.07|        |        |      |       |
| ORI right       | Nondiabetic| 20 | 2.12 | 0.32| 0.07| 0.24   | 0.04-0.44| 2.472| 0.018*|
|                 | Diabetic  | 20 | 1.87 | 0.30| 0.06|        |        |      |       |

*P-value derived from independent sample t-test; *Significant at P<0.05. ORI: Ortman’s Resorption Index, SD: Standard deviation, SE: Standard error, CI: Confidence interval, MD: Mean Deviation

Table 6: Correlation between glycated hemoglobin values and Ortman’s Resorption Index (left and right)

| Variables       | n  | r     | P*    |
|-----------------|----|-------|-------|
| ORI left        | 40 | -0.541| <0.001*|
| ORI right       | 40 | -0.409| 0.009*|

*P value derived from Person’s correlation test; *Significant at P<0.05. ORI: Ortman’s Resorption Index

of satisfaction, quality of life, and biting force.[10] The McGill’s consensus statement implies that mandibular conventional denture must be no longer be the primary treatment option for rehabilitation of mandibular edentulous ridge.[11] The population considered in the study is that of edentulous diabetic patients. According to the WHO, diabetic population is a growing challenge with an estimated 7.8% of total population between the age group of 20–70 years.[1] Of the overall diabetic population 95% are suffering from NIDDM diabetes.[12] Implant therapy is a relative contraindication in diabetic patients, reasons attributed are increased hyperglycemia inhibits activity of osteoblasts and alters response of parathyroid hormones as well as increased osteoclastic activities, decreased collagen synthesis during healing and callus formation, bone matrix is negatively affected and there is decreased accumulation of extracellular matrix.[13-17] Literature supports that clinical outcomes in patients with well-controlled type-II diabetes are positive and encouraging.[18,19]

The rate of residual ridge resorption is 0.5–1% per year after the 1st year of extraction.[20] The stable rate of resorption is the reason for selection of patients who were edentulous for at least 1 year. Systemic factors such as osteoporosis caused by juvenile rheumatoid arthritis, osteogenesis imperfecta, hyperparathyroidism, Cushing’s disease and vitamin deficiencies secondary to malabsorption play an important role in RRR when compares to local factors,[21-22] they define the final rate and extent of the resorption process post cessation of effect of local factors (i.e., 1 year), this was the premise of choosing subjects which were not suffering from any other systemic illness. To avoid gender-based differences, only male subjects were considered for study.[23-25] HbA1c analysis was performed on all individuals and individuals in the diabetic group were selected according to the American Diabetes Association (ADA) criteria of HbA1c levels of >6.5.[8] The importance of knowledge of mandibular anatomy is essential for planning implant therapy in terms of implant position, prosthesis selection, and cantilever length.[26,27] For a mandibular anterior region to provide predictable support to the implant a minimum of 9 mm of height is required.[26,27] As a general rule, the anterior interforaminal region can be divided into five equal parts for the placement of five implants. These regions are A, B, C, D, E from right to left side of the mandible[26-27] Apostolakis et al. framed a recommendation that 100% safety margin can be achieved when the most distal implant is placed at a distance of 6 mm from the anterior border of the mental foramen.[28] DVT is an imaging technique which produces similar 3D images to CT but at a dosage of radiation similar to panoramic radiography and at a lower cost.[29,30] DVT provides highly contrasted images of craniofacial structures.[7] With low dose protocol for implants there is risk reduction of 50%–60% with DVT.[30] Freedom from superimposition, distortion, minimal errors in
linear measurement, low dosage of radiations, and economic feasibility were the reason for selection of volumetric imaging modality for the present study.

The placement of 2–5 implants[11] in the anterior mandibular region decreases the rate of RRR,[19] improves quality of life of the patient,[21] and a consensus can be reached that placement of implant is possible in anterior region when the available bone height is at least or more than 11 mm. In the present study, no subject in any group showed mean height less than the prescribed height <11 mm. Many studies have evaluated height parameter at various implant sites, some have measured it at the midline,[6,21] at edentulous sites,[6,32‑34] some have measured it near the premolar region[8,43] and designed an index which classified the resorption into mild (≥2.34), moderate (1.67–2.33), and severe (≤1.66).[8] Studies have shown that the bone resorption near the midline of the mandible is lesser as compared to distal areas[21,38‑40] this is in concurrence with the present study. Al‑Jabrah, in 2011, compared residual ridge resorption in diabetic and nondiabetic patients, the mean mandibular resorption in diabetic group was found to be double in amount (35.8%) as when compared to nondiabetics (18%).[31] Kenawy et al.[32] in 2017, compared bone resorption and bone density between diabetic and nondiabetic patients and found no significant difference between bone quantity, there was decreased bone density in diabetic patients.[33] Taylor et al., in 1998, tested and proved the hypothesis that noninsulin‑dependent diabetes mellitus patients have a higher progression of residual ridge resorption.[42] the present study supports these findings as the ORI was found to be lower in diabetic patients as compared to nondiabetics.

The ADA has recommended HbA1c as a likely tool to diagnose diabetes instead of the fasting blood glucose criteria[8,43] In a study reported by Antony in 2016, where residual mandibular bone height was correlated with HbA1c levels revealed that with deteriorating glycemic control there is deterioration of bone height.[29] A panoramic radiographic study was carried out by Tadiparthi and Sujatha in 2016 reported that residual ridge resorption was higher in diabetic patients especially in the right and left premolar region.[29] From the above discussion, it can be deduced that glycemic control is a potent predictor of bone resorption. Regarding Co‑relation between HbA1c levels and residual ridge resorption a moderate negative correlation −0.541 for right side and −0.408 for left side was found between ORI and HbA1c Values, which suggests that poor glycemic control negatively affect bone resorption, this is in consensus with the findings of Gómez‑Moreno et al., in 2014 and Taylor et al., in 1998.

In the present study, there was no statistical difference between the height parameters at prospective implant sites between diabetic and nondiabetic patients; however, the width parameter was not factored in due to the plausible problems it poses in standardization. The residual ridge resorption showed a moderate negative correlation with glycemic control. In spite of the effort to establish a homogenous study group, it was not possible to exclude all factors which affect the progression, morphology, rate of residual ridge resorption. Nutritional deficiencies, morphological differences of the mandibular ridge, masticatory patterns, deleterious habits could not be homogenized as it is difficult to quantify them in a meaningful manner.

**CONCLUSION**

It can be concluded from the present study that bone resorption at prospective implant sites is statistically similar in diabetics when compared to nondiabetics. The residual ridge resorption is more in diabetics when compared to nondiabetics, and patients with poor glycemic control show increased residual ridge resorption.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Roglic G, World Health Organization, editors. Global Report on Diabetes. Geneva, Switzerland: World Health Organization; 2016. p. 86.
2. Kaveshwar SA, Cornwall J. The current state of diabetes mellitus in India. Australas Med J 2014;7:45‑8.
3. Abdulhadi LM. Residual ridge resorption in completely edentulous patients influenced by pathophysiologic factors. Dentika Dent J 2009;14:29‑36.
4. Gómez‑Moreno G, Aguilar‑Salvatierra A, Rubio Roldán J, Guardia J,
Gargallo J, Calvo-Guirado JL. Peri-implant evaluation in type 2 diabetes mellitus patients: A 3-year study. Clin Oral Implants Res 2015;26:1031-5.
5. Oates TW, Dowell S, Robinson M, McMahan CA. Glycemic control and implant stabilization in type 2 diabetes mellitus. J Dent Res 2009;88:367-71.
6. Ural C, Bereket C, Sener I, Aktan AM, Akpinar YZ. Bone height measurement of maxillary and mandibular bones in panoramic radiographs of edentulous patients. J Clin Exp Dent 2011;3:e5-9.
7. Bhattacharjee MS, Baliga S, Vimbute P. A digital volumetric tomography (DVT) study in the mandibular molar region for miniscREW placement during mixed dentition. Dent Press J Orthod 2015;20:55-60.
8. Gillett MJ. International expert committee report on the role of the A1C assay in the diagnosis of diabetes. Diabetes Care 2009;32:1327-34.
9. Ortmann LF, Hausmann E, Dunford RG. Skeletal osteopenia and residual ridge resorption. J Prosthodont Dent 1989;61:321-5.
10. Kurkut A, Bertoli E, Frazer R, Pinto-Sinai G, Fuentetabar Hidalgo R, Studds J. A systematic review of studies comparing conventional complete dentures and implant retained overdenture. J Prosthodont Res 2018;62:1-9.
11. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Gerodontology 2002;19:3-4.
12. Greenberg M, Glick M, Becker B. Burkert’s Oral Medicine, Diagnosis and Treatment. 10th ed. Hamilton: Mealey; 2003. p. 563-77.
13. Dubey RK, Gupta DK, Singh AK. Dental implant survival in diabetic patients; review and recommendations. Natl J Maxillofac Surg 2013;4:142-50.
14. Santana RB, Xu L, Chase HB, Amar S, Graves DT, Trackman PC. A role for advanced glycation end products in diminished bone healing in type 1 diabetes. Diabetes 2003;52:1502-10.
15. Kayal RA, Tsatsas D, Bauer MA, Allen B, Al-Sebaei MO, Kakar S, et al. Diminished bone formation during diabetic fracture healing is related to the premature resorption of cartilage associated with increased osteoclast activity. J Bone Miner Res 1998;22:560-8.
16. Liu R, Bal HS, Desta T, Krothapalli N, Alyassi M, Luan Q, et al. Diabetes enhances periodontal bone loss through enhanced resorption and diminished bone formation. J Dent Res 2006;85:510-4.
17. Weiss RE, Gorn AH, Nimni ME. Abnormalities in the biosynthesis of cartilage and bone proteoglycans in experimental diabetes. Diabetes 1981;30:670-7.
18. Peled M, Ardekian L, Tagger-Green N, Gutmacher Z, Machtei EE. Dental implants in patients with type 2 diabetes mellitus: A clinical study. Implant Dent 2003;12:116-22.
19. Javed F, Romanos GE. Impact of diabetes mellitus and glycemic control on the osseointegration of dental implants: A systematic literature review. J Periodontol 2009;80:1719-30.
20. Carlsson GE, Persson G. Morphologic changes of the mandible after extraction and wearing of dentures. A longitudinal, clinical, and X-ray cephalometric study covering 5 years. Odontol Revy 1967;18:27-54.
21. Springe B, Sladjina A, Soboleva U, Lejniaks A. Bone mineral density and mandibular residual ridge resorption. Int J Prosthodont 2014;27:270-6.
22. Devlin H, Ferguson MW. Alveolar ridge resorption and mandibular atrophy. A review of the role of local and systemic factors. Br Dent J 1991;170:101-4.
23. Canger EM, Celenk P. Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients: Residual ridge resorption. Gerodontology 2012;29:17-23.
24. AlSheikh HA, AlZain S, Warusy A, AlMukaynizzi F, AlThomali A. Mandibular residual ridge height in relation to age, gender and duration of edentulism in a Saudi population: A clinical and radiographic study. Saudi Dent J 2019;31:258-64.
25. Tadiparthi DJ, Sujatha D. Evaluation of vertical bone heights of maxillary and mandibular residual ridges among edentulous diabetics by digital orthopantomograph. Int J Cur Res 2016;8:5.
26. Kendrick S, Wong D. Treatment options for the edentulous mandible. Dent Today 2009;28:72, 74-6.
27. Misch CE. Contemporary Implant Dentistry. St. Louis: Mosby Elsevier; 2008.
28. Apostolakis D, Brown JE. The anterior loop of the inferior alveolar nerve: Prevalence, measurement of its length and a recommendation for interferosial implant installation based on cone beam CT imaging. Clin Oral Implants Res 2012;23:1022-30.
29. Bianchi SD, Lojacoana A. 2D and 3D images generated by cone beam computed tomography (CBCT) for dentomaxillofacial investigations. In: CAR’S ’98-Proceedings of the 12th International Symposium and Exhibition: Computer Assisted Radiology and Surgery. Amsterdam: Elsevier; 1998. p. 792-7.
30. Ziegler CM, Woerthe R, Brief J, Hassfeld S. Clinical indications for digital volume tomography in oral and maxillofacial surgery. Dentomaxillofac Radiol 2002;31:126-30.
31. Carlsson GE. Responses of jawbone to pressure. Gerodontology 2004;21:65-70.
32. Antony L. Role of HbA1C levels and anti diabetic medication on crown/root ratio of maxillary/mandibular abutment teeth and on residual mandibular bone height among young Saudi University diabetic and non diabetic students in King Khalid University, Kingdom of Saudi Arabia. Research Journal of Recent Sciences 2016;5:7.
33. Kenawy S, El Beshlawy D, Dahaba M, Mushira M. Quantitative and qualitative maxillary jaw bone assessment using computed tomography of a diabetic and non-diabetic sample Egyptian population. Int J Adv Res 2017;5:2113-26.
34. Shilpa BS, Vasudevan SD, Bhongade ML, Baliga V, Pahare VV, Dharse PV. Evaluation of survival of 8 mm-length implants in posterior resorbed ridges: A pilot study. J Indian Soc Periodontol 2018;22:334-9.
35. Quirynen M, Mraiwa N, van Steenberge D, Jacobs R. Morphology and dimensions of the mandibular jaw bone in the interforaminal region in patients requiring implants in the distal areas. Clin Oral Implants Res 2003;14:280-5.
36. Olson JW, Shernoff AF, Tarlow JL, Colwell JA, Scheetz JP, Bingham SA. Dental endosseous implant assessments in a type 2 diabetic population: A prospective study. Int J Oral Maxillofac Implants 2000;15:811-8.
37. Wical K, Swoope C. Studies of residual ridge resorption. Part I. Use of panoramic radiographs for evaluation and classification of mandibular resorption. J Prosthodont Dent 1974;32:7-12.
38. Ural C, Bereket C, Sener I, Aktan AM, Akpinar YZ. Bone height measurement of maxillary and mandibular bones in panoramic radiographs of edentulous patients. J Clin Exp Dent 2011;3:e5-9.
39. Kalk W, de Baat C. Some factors connected with alveolar bone resorption. J Dent Res 1989;17:162-5.
40. Xie Q, Wolf J, Ainao A. Quantitative assessment of vertical heights of maxillary and mandibular bones in panoramic radiographs of elderly dentate and edentulous subjects. Acta Odontol Scand 1997;55:155-61.
41. Al-Jabrah O. Association of type 2 diabetes mellitus with the reduction in bone mineral density. Area Dent 2015;26:1031-5.
42. Al-Delaimy WK, Schmitz KH, Mokdad AH, Dube SR, Serdula MK, Gortmaker SL, et al. Contribution of obesity to the prevalence of diabetes mellitus among US adults. JAMA 2003;290:2466-77.
43. Sherwani SI, Khan HA, Ekhzaimy A, Masood A, Sakharlkar MK. Significance of HbA1c test in diagnosis and prognosis of diabetic patients. Biomark Insights 2016;11:95-104.