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Yasmin S. Zidan
Assistant Lecturer of Removable Prosthodontics, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt., dentist.jasmin@yahoo.com

Amany A. Abd El-fattah
Professor of Removable Prosthodontics, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt

Dina M. Kholief
Professor of Removable Prosthodontics, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt.

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Clinical and Radiographic Evaluation of the Effect of Different Denture Bases in Implant Supported Mandibular Overdenture Cases

Yasmin S. Zidan*, Amany A. Abd El-fattah, Dina M. Kholief

Removable Prosthodontics, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt

Abstract

Purpose: To evaluate and compare the effect of CAD/CAM, thermoplastic, and conventional denture bases on denture retention, bone height, and density in implant-supported mandibular overdentures. **Materials and methods:** Eighteen completely edentulous patients were selected, and for each patient, two implants were installed at the canine area of the mandible. After the osseointegration period, abutments were installed over the implants, and the patients were divided into three groups. Group I: Six patients received maxillary and mandibular heat-cured acrylic resin dentures. Group II: Six patients received maxillary heat-cured acrylic resin dentures and mandibular dentures with a thermoplastic denture base. Group III: Six patients received maxillary heat-cured acrylic resin dentures and mandibular denture bases fabricated by CAD-CAM technology. The patients were evaluated clinically and radiographically. **Results:** Regarding denture retention, the highest value was recorded in group (III) followed by group (II) while the lowest value was recorded in group (I). Regarding radiographic assessment, the amount of bone height loss was found to be higher in a group (I) compared to the other two groups. Bone density showed the lowest change in a group (I) compared to groups (II and III). **Conclusion:** Thermoplastic and CAD CAM denture bases showed higher results than conventional dentures as regards denture retention and alveolar bone preservation.

Keywords: CAD CAM denture, CBCT, Implant, Thermoplastic denture

1. Introduction

The quality of life for many edentulous patients has improved since the introduction of osseointegrated dental implants. Overdentures supported by implants have been shown to be a successful treatment option for edentulous patients [1]. The implant-supported overdenture has been shown to have advantages in support, stability, and aesthetics in the treatment of mandibular edentulous patients, including improved masticatory efficiency, decreased anterior bone loss and soft tissue injury, increased patient satisfaction and comfort, and improved patient health [2].

Mandibular overdentures supported by two implants are well-known for their long-term effectiveness and are frequently recommended for the treatment of edentulous patients. Their relative simplicity, minimal invasiveness, good performance, and affordability make them an alternative treatment solution [3].

Bone health is important for maintaining implant health, which is necessary for the longevity of dental implants. The risk factors that can contribute to implant-supported oral prosthesis failure are reduced by regular follow-up and supportive therapy. Bone quality and quantity are important not only for diagnosis, treatment planning, surgical approach, and healing time but also for prosthetic fabrication [4].

Due to its desirable features, such as good aesthetics, exact replication of surface details, absence of toxicity, simplicity of handling and repair, and cost efficiency, polymethyl methacrylate (PMMA) is one of the most frequently applied dental materials in prosthodontics [5]. It does, however, have significant drawbacks, including weak mechanical qualities that

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* Corresponding author. Nasr City, Cairo 11765, Egypt.
E-mail address: dentist.jasmin@yahoo.com (Y.S. Zidan).

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can cause the denture base to fracture or reduce the denture's lifespan [6].

Another denture base material that can be a viable alternative to PMMA is a thermoplastic resin, which has superior flexibility, resistance to flexural fatigue, and impact strength. The thermoplastic denture material is appropriate for a wide range of variable conditions in the mouth, resulting in improved function, stress distribution, and tissue health [7].

Computer-aided design and manufacture (CAD-CAM) has recently been widely used in dentistry with great success. The CAD-CAM system, which has just become commonly available for complete denture manufacturing, is seen as a viable alternative to traditional acrylic resin bases. The advancement of computer-aided technology in the field of complete denture construction is expected to solve issues with traditional complete dentures and make the fabrication process easier [8].

Evaluations of retention between CAD-CAM denture bases and conventional ones, and also between thermoplastic and conventional denture bases were made in previous studies [9,10], revealing that, the conventional one has less accuracy and retention. However, no evaluation between three types of denture bases CAD-CAM, thermoplastic, and conventional denture bases was conducted in one study.

Another study reported that thermoplastic flexible dentures have higher values than conventional ones in the preservation of supporting structures over mandibular-retained implant cases. Explained that, through the fact that, the thermoplastic denture base directly transmits the stresses to the underlying structure better than a conventional one [11].

The authors of the present study have not come across any studies that compared the effect of CAD/CAM, thermoplastic, and conventional denture bases regarding bone height loss and density changes in implant-supported mandibular overdentures. So, the purpose of this study was to evaluate the retention, bone height loss, and density changes in the mandibular distal area for different denture bases (CAD/CAM, Thermoplastic, and Conventional) used in patients with implant-supported mandibular overdentures.

The null hypothesis was that there would be no significant differences between the three types of denture bases regarding retention, bone height loss, and density changes.

2. Material and methods

2.1. Patient's selection

According to the sample size calculation [12] (A power analysis was performed using G*Power software (v3.1.9.2) to calculate the sample size. The power value was 90%, and the level of significance was 0.05. The results showed an effect size of $f = 1.66$, no centrality parameter of 33.22, and a critical F value of 4.066). Eighteen completely edentulous patients were selected from the Out-Patient Clinic of the Removable Prosthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University. All the procedures were explained to each patient, and informed consent was signed. Research ethical approval was obtained (REC-PR-22-01).

The patients were selected to be males, and their ages ranged from 55 to 65 years old. Their residual ridges were covered by firm mucosa with no signs of inflammation or ulceration. They had a class I Angle's ridge relationship, normal salivary flow, and normal viscosity, free from any diseases that may affect wound healing or adversely affect the surgical operation of dental implants or jaw bones, and were cooperative.

2.2. Clinical and radiographic examination

Oral tissues were checked for signs of inflammation or ulceration, including the remaining edentulous ridge, tongue, cheeks, lips, and palate. The ridge was also examined for any irregularities and/or bony undercuts. Each patient had preoperative panoramic radiographs, to ensure there were no remaining roots, cysts, abscesses, or other pathological abnormalities. A cone beam radiograph was conducted to determine the availability of bone height and buccolingual width for implant placement. Bone quality was also assessed, particularly at the implant sites that were considered.

2.3. Surgical procedures

The proposed implant sites were selected to be the canine regions (bilaterally). The sites were identified by the metallic balls attached to the radiographic stent and were evaluated for sufficient bone height and width. After the radiographic procedure was completed, the radiographic template was modified to be a surgical stent by the removal of metallic balls. The surgical stent was seated on the ridge to ensure proper alignment of the osteotomy sites, and bleeding points on each side of the jaw were formed with dental probes under local anesthetic. The removal of punched tissue was done at the bleeding spots generated by the surgical stent using a tissue punch with a speed of 50 rpm/70 ns and irrigation (included in the surgical kit dentium system, Superline dentium, USA).

Drilling was made with care using an initial pilot drill at 1000 rpm/45 n, followed by a final drill at 500 rpm/70 ns until the desired depth and width were reached (12 mm length and 3.6 mm width). To verify that both implants will be positioned correctly, paralleling rods were placed into the osteotomy sites. The silicon stopper was used to remove the implants from the inner vial, and the implants were then secured to the placement head. Implants were placed in osteotomy sites using a superline drill with a speed of 50 rpm/70 ns. The ratchet was then used to slowly twist each implant clockwise.

The procedure was repeated until resistance was felt, indicating that the crestal bone level had been attained. With a hex driver, the cover screws were tightened to the implants. For the next two weeks, patients were given instructions on medication, dental care, maintenance, and a soft diet. The second-stage procedure was conducted under local anesthesia after three months. The surgical template was used to locate the implant site. Over the implant fixture, a tissue punch was formed, the covering screws were removed, and dome-shaped abutments (dual dentium abutment, USA) were inserted 2 mm above the gingival margin.

2.4. Patient grouping

Simple randomization method was used to divide the patients into three groups. Group I: Six patients received maxillary and mandibular heat-cured acrylic resin dentures. Group II: Six patients received maxillary heat-cured acrylic resin dentures and mandibular dentures with a thermoplastic base. Group III: Six patients received maxillary heat-cured acrylic resin dentures and mandibular denture bases fabricated by CAD-CAM technology.

2.5. Prosthetic procedures

2.5.1. Construction of complete dentures

Group I (conventional heat-cured acrylic resin, Acrostone, England):

Conventional complete dentures were constructed for all patients following the conventional steps. The denture was subsequently delivered to the patient after being examined for retention, stability, extension, articulation, and ease of insertion and removal. The patient was given instructions on good oral hygiene and denture care at home.

Group II (Thermoplastic denture base):

The steps of preliminary impression, secondary impression, maxilla–mandibular relationship, and try-in were made following the conventional steps. The maxillary denture was fabricated conventionally from heat-cured acrylic resin, and the thermoplastic (Flexiplast, Bredent, Germany) mandibular denture was fabricated by using an injection molding technique. After finishing and polishing, the denture was delivered to the patient who, was given the same instructions as group I.

Group III (CAD-CAM denture base):

The steps of preliminary and secondary impressions were made as in group I. The master cast has been duplicated. The original master cast was used for scanning with a 3D optical scanner, and the duplicated master cast was used for the fabrication of occlusion rims, as well as the maxilla-mandibular relation record, which was completed in the clinic and submitted to the lab in the traditional fashion. After fixing the lower master cast on a plate within the scanner with its labial surface facing the scanner, it was scanned with a 3D optical scanner (Next CAD software, USA), and a 3D virtual model of the casts was formed as represented by (Fig. 1).

The lower denture borders were traced using the depth of the visible virtual cast as a guide, as well as the cast's previously created borders. The scanning of the lower master cast and the recording of the maxilla-mandibular were converted into a standard tessellation file (STF). The existing mandibular plane was then defined in CAD software, followed by a diagnostic tooth arrangement in the same CAD software. The virtual edentulous ridge was used to define denture base extension, and a virtual denture base of three mm thickness was generated. The lab was asked to make a fully functional try-in out of a monolithic PMMA puck (Rosbach, Germany), which was then tried in the patient's mouth to assess vertical dimension, occlusion, aesthetics, and phonetics. The accepted virtual diagnostic tooth arrangement and denture foundation were accepted designs that were exported as two separate STL files and put into support and build preparation software.

A pink photo-polymerized resin for the denture base (Next Dent base, USA) and tooth-colored resin for artificial teeth were loaded into the machine tank. The printing procedure started with an order, and it took two to 3 h to complete. A soft-tissue-colored photo-polymerizing resin (Next Dent, USA) was used to attach the printed tooth arrangement to the printed denture base. In an ultrasonic cleaner, the printed denture was rinsed twice in a 96% ethanol solution. A 3-min initial rinse was followed by a 2-min second rinse in a new clean ethanol solution. Finally, the patient's denture was finished, polished, and delivered as represented by (Fig. 1).

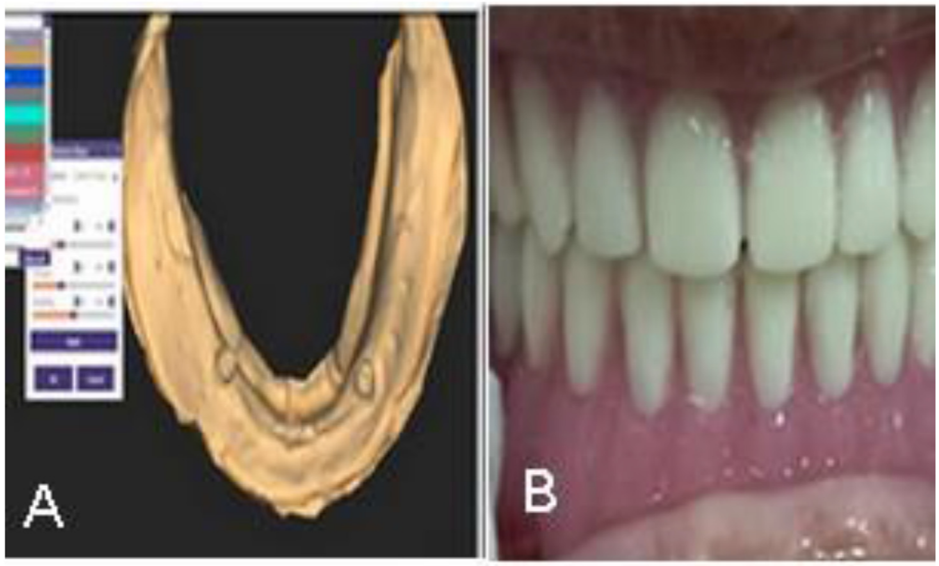

Fig. 1. (A) Photograph showing a 3D virtual model of the lower cast (B) Maxillary heat cured, mandibular 3D printed denture base at insertion time.

2.6. Patient's evaluation

2.6.1. Clinical evaluation

Denture retention was measured at the time of delivery, six months, and nine months later. Denture resistance to vertical displacement (i.e., retention) was measured using a digital force meter (Ebalance, China) by pulling on a metal hook located in the geometric center [13] of each mandibular denture as follows the patient was instructed to sit up in an upright position. A 2 mm diameter hole in the midline between the two lower central incisors served as the measurement point. After that, the mandibular denture was placed in the patient's mouth, as represented by (Fig. 2).

The mandibular denture was then inserted inside the patient's mouth. The patient was asked to sit comfortably with his head on the chinrest and the occlusal plane parallel to the floor of the room. The chinrest was connected to a solid metal rod with a movable pulley at its end.

The measurements were taken with nylon thread. The first end of the nylon was tied into a metal ring that was inserted into the gap between the central incisors. The other end of the nylon thread was threaded through the movable pulley's external grooved surface and attached to the digital force meter's hook. The force meter pulled the thread away from the patient, and the dislodging forces were upward at 45° to the occlusal plane towards the moving pulley. The force meter was vertically pulled until the denture was raised. The retention of the denture was determined by measuring the force in Newton. For each patient, three recordings were obtained each time, and an average was generated, tabulated, and statistically analyzed at the time of denture insertion and after 6 and 9 months for groups I, II, and II.

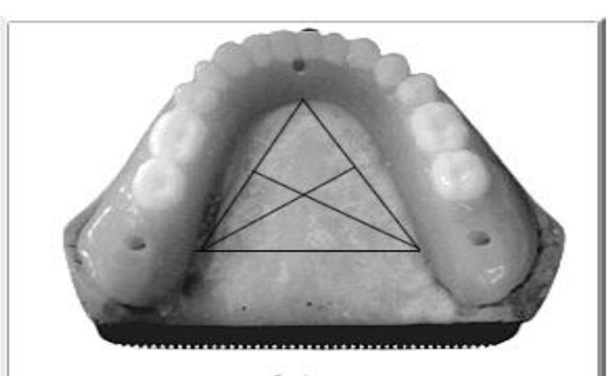

Fig. 2. Geometric center of the mandibular denture.

2.6.2. Radiographic evaluation

At the panoramic pictures of Cone-beam computerized tomography (PICBCT) taken after overdenture implantation (baseline), six and twelve months later, the bilateral posterior regions of the residual ridges were assessed. The scan was performed with the same CBCT machine and software (CAT Vision, USA). For all patients, the scan parameters were standardized (16 × 8 cm FOV, 10.11 mA, 120 kVp). The panoramic photos were created using a ‘curve tool‘ that bisects the alveolar ridge. The photos were standardized in terms of level and width. DICOM files were used to save the images. The Gonion angle point, mental foramen, and alveolar crest were all established in the literature as landmarks that permit a repeatable measurement protocol [14] hence, they were used to ensure standardization of the images.

The initial landmark was the point of intersection of the implant-axis mandibular border (IMB), which was formed by intersecting the anticipated implant-axis with the mandible's lower margin (The second landmark was found to be the anatomically defined Gonion angle point (G). From IMB to G, a baseline (B) was established. The third landmark on the PICBCT was point (A), which represents the alveolar crest of the ridge, and finally point F, which represented the mental foramen (Fig. 3).

On both sides of the mandible, a line representing residual ridge height was drawn from point A through point F and perpendicular to line GIMB, with AR for the right side and AL for the left side. Two lines were measured, and the average value was determined. By subtracting the radiographic mandibular height on the follow-up from the mandibular height on the initial, the changes in bone height at the measurement points were calculated. Resorption was indicated by a negative value. The bone density along the two lines was recorded in Hounsfield units (HU), and the mean value was then calculated, tabulated, and statistically analyzed.

2.7. Statistical analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution and using Kolmogorov–Smirnov and Shapiro–Wilk tests. The data showed a normal distribution so they were analyzed using one-way ANOVA followed by Turkey's post hoc test for intergroup comparisons. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.1 for Windows.

3. Results

All follow-ups and there were no dropouts and none of the implants failed.

3.1. Clinical evaluation

The descriptive statistics of retention values through the three follow-up periods within the same group were based on repeated ANOVA tests followed by post hoc tests for multiple comparisons through the three follow-up periods. The mean values and standard deviation (SD) of the denture retention (in Newton) for different groups are presented in (Table 1).

For **Group (I)**: There was a significant difference between values measured at different intervals ($P < 0.001$). The highest value was measured at baseline (7.00 ± 1.29) followed by 6 months (5.85 ± 0.64) while the lowest value was found at 9 months (5.10 ± 0.80). Statistical analysis using the ANOVA test revealed that values measured at baseline were significantly higher than values measured at other intervals ($P < 0.001$). **Group (II)**: There was no significant difference between values

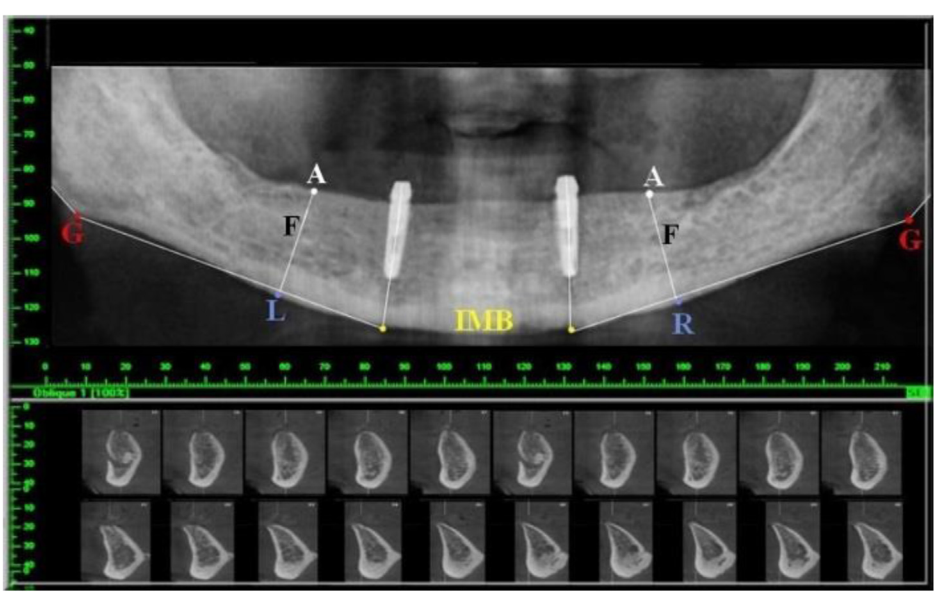

Fig. 3. A photograph showing traced panoramic image of CBCT Scan of the mandible.

ORIGINAL STUDY

Table 1. *Mean values and standard deviation (SD) of denture retention for different groups.*

Interval	Denture retention (mean ± SD)			P value
	Group (I)	Group (II)	Group (III)	
At delivery	7.00 ± 1.29[a C]	12.50 ± 1.51[c B]	15.03 ± 1.10[c A]	<0.001[a]
After 6 months	5.85 ± 0.64[b C]	13.85 ± 1.09[a B]	15.33 ± 1.11[a A]	<0.001[a]
After 9 months	5.10 ± 0.80[c C]	13.12 ± 1.72[b B]	15.07 ± 1.06[b A]	<0.001[a]

Different small letters in each column indicate significant differences in each group. Different capital letters in each row indicate a significant difference between the three groups.
[a] Significant ($P \leq 0.05$) ns; non-significant ($P > 0.05$).

measured at different intervals ($P = 0.257$). The highest value was measured at 6 months (13.85 ± 1.09) followed by 9 months (13.12 ± 1.72) while the lowest value was found at baseline (12.50 ± 1.51). **Group (III)** There was no significant difference between values measured at the different intervals ($P = 0.551$). The highest value was measured at 6 months (15.33 ± 1.11) followed by 9 months (15.07 ± 1.06) while the lowest value was found at baseline (15.03 ± 1.10).

Comparing the three groups showed that, there was a statistically significant difference among the groups at all follow-up periods of the study, where the highest values were recorded for group (III), followed by group (II), and the lowest values were recorded for group (I).

3.2. Radiographic evaluation

The mean values and standard deviation (SD) of the bone height loss (mm) and bone density changes (HU) for different groups are presented in (Table 2).

3.2.1. Bone height loss (mm)

Observation of the results revealed that the mean value of bone height loss increased over time. Statistical analysis using the ANOVA test revealed that in **Group (I),** the value measured at 0–12 months (0.40 ± 0.05) was significantly higher than the value measured at 0–6 months (0.21 ± 0.02) ($P < 0.001$). In **Group (II),** the value measured at 0–12 months (0.21 ± 0.03) was significantly higher than the value measured at 0–6 months (0.11 ± 0.05) ($P = 0.002$). In **Group (III),** the value measured at 0–12 months (0.21 ± 0.03) was significantly higher than the value measured at 0–6 months (0.12 ± 0.05) ($P = 0.009$).

Comparing the three groups by Post hoc test, it was found that group (I) showed significantly higher values than the other groups along the two interval periods of the study.

3.2.2. Bone density change (HU)

Observation of the results revealed that the mean value of the bone density change increased over time. Statistical analysis using the ANOVA test revealed that in **Group (I),** the value measured at 0–12 months (223.23 ± 6.41) was significantly higher than the value measured at 0–6 months (119.51 ± 6.77) ($P < 0.001$). For **Group (II):** the value measured at 0–12 months (258.47 ± 2.83) was significantly higher than the value measured at 0–6 months (144.78 ± 6.32) ($P < 0.001$). In **Group (III):** the value measured at 0–12 months (248.23 ± 3.32) was significantly higher than the value measured at 0–6 months (132.98 ± 3.07) ($P < 0.001$).

Comparing the three groups by post hoc test it was found that group (I) showed significantly lower values than other groups along the two-time interval periods of the study.

4. Discussion

The null hypothesis that there would be no differences in retentive force or bone height and density changes among the three types of denture bases

Table 2. *Mean values and standard deviation (SD) of the bone height change (mm) and bone density change (HU) at the two-time interval for all three groups.*

Interval	Bone height loss (mm) (mean ± SD)			P value
	Group (I)	Group (II)	Group (III)	
0–6 months	0.21 ± 0.02[b A]	0.11 ± 0.05[b B]	0.12 ± 0.05[b B]	0.002[a]
0–12 months	0.40 ± 0.05[a A]	0.21 ± 0.03[a B]	0.21 ± 0.03[a B]	<0.001[a]
Interval	**Bone density change (HU) (mean ± SD)**			**P value**
	Group (I)	**Group (II)**	**Group (III)**	
0–6 months	119.51 ± 6.77[b B]	144.78 ± 6.32[b A]	132.98 ± 3.07 [b A]	<0.001[a]
0–12 months	223.23 ± 6.41[a B]	258.47 ± 2.83[a A]	248.23 ± 3.32[a A]	<0.001[a]

Different small letters in each column indicate significant difference within each group. Different capital letters in each row indicates significant difference between the three groups.
[a] Significant ($P \leq 0.05$) ns; non-significant ($P > 0.05$).

(CAD/CAM, thermoplastic, and conventional) was rejected.

In group I, conventional acrylic denture base material was used as a control because it is the most commonly used material for conventional dentures [6]. In group II, A thermoplastic denture base was utilized because it has more flexibility, more resistant to flexural fatigue, and has better impact strength [7]. In group III, CAD/CAM denture base was used. Due to the problems of the milling method, which include excessive loss during milling, high maintenance costs of the equipment, major time loss during the production process, and high maintenance costs of the equipment, the CAD/CAM technology used for fabrication of the final dentures in this study was 3D printing. The advantages of 3D printing include the ability to manufacture desired prostheses and models with a minimal amount of material and the ability to create many products at once [15,16].

Mandibular denture retention was measured using a digital force meter at the time of delivery, six months, and nine months later. Because intraoral factors such as the presence of saliva are considered, *in vivo*, retention measures are preferred [13].

The bone height of the mandible was measured using a technique that had been established and employed in previous studies [14,16] to evaluate the progress of bone loss. The implants acted as fixed markers with more clearly defined anatomical landmarks, improving the accuracy of the technique and avoiding distortion and magnification problems. The position of the mental foramen in relation to the superior and inferior borders of normal mandibles appears to be a more helpful reference landmark, with enough reliability to justify its use in clinical research [17]. Cone-beam computed tomography was employed in this study instead of panoramic radiography to avoid the effects of distortion and magnification and produce more accurate and reliable measurements. It is also characterized by the faster collection of the data set for the entire field of view [18].

The results of the current study revealed that in the assessment of denture retention, there was a significant difference among different groups. The highest value was found in the group of CAD/CAM denture bases (III), followed by the group of flexible denture bases (II), while the lowest value was found in the group of conventional denture bases (I). Proper denture retention requires adaptation and precision of the denture base to the tissue-bearing area, and minimal processing distortion is required for good mucosal adaptation [19,20]. Factors such as time-consuming waxing up, investment, and wax removal, as well as deformation of heat-cured acrylic resin, all reduce the degree of adaption and accuracy of denture bases in traditional denture base fabrication techniques [6].

The present study's findings were close to those of the previous one [9], which revealed that CAD/CAM printed dentures showed statistically higher retention than conventional ones. The advancement of CAD software has made it feasible to quickly identify the cross-section of a program's intended region. It was reported that the highest values of retention were enlisted with the overdenture made from thermoplastic acrylic resin than conventional one which may be due to high interfacial surface tension recorded values of thermoplastic acrylic resin. Strong tension increases the retention of the prosthesis in place [10].

In this study, the amount of bone height loss in the mandibular residual ridge was found to be significantly higher in group (I) than in the other two groups. This could be due to the combination of polymerization shrinkage and distortion of denture bases caused by thermal stresses in the conventional processing technique, which affect the adaptation and accuracy of the denture base to the underlying tissues, causing a microgap and increasing force transmitted into the tissues [21,22].

This was in agreement with several authors [23,24] who reported that when compared to conventional dentures, flexible dentures displayed viscoelastic behavior, which improves function and patient comfort. As for the CAD/CAM denture bases, the dentures were found to be more dimensionally stable than traditional denture bases, hence preserving denture adaption to underlying tissues [9] and consequently preserving the supporting bone. Results of this study have shown that bone height loss significant with time in all study groups this is could be attributed to increased mechanical stresses that may cause fatigue, microdamage, and bone resorption [25].

The slight increase in bone density changes in the three groups registered in the present study was in accordance with a previous study [26]. The increase in bone density readings during follow-up periods of overdenture wearers may be attributed to the increased load of the strain forces of the masseter muscle due to the increase in the vertical relationship, as well as the beginning of chewing activity in patients with new dentures. This was in agreement with an author who stated that the degree of strain forces in the place of masticatory muscle attachment to the bone may change with a complete denture, affecting bone density values [27].

The highest changes in bone density were significantly found in groups (II) and (III), while the lowest change was found in group (I). This could be due to the fact that the rigidity of conventional heat-cured acrylic resin transferred more harmful stresses to the underlying tissue than the flexible one [28]. Also, the accuracy and adaptation of CAD-CAM dentures make stress distribution under the denture base better than conventional ones [9]. Although bone density changes were significant with time in all study groups, there was an increase in all groups in time intervals, which indicates favorable bone reaction, as bone responds positively to the applied load by building additional support through the arrangement of its trabecular pattern and heavy cortical lamina dura [29]. It was recognized that an increase in the working load results in an increase in bone mass without exceeding the biological load-bearing capacity of the alveolar bone [30,31].

4.1. Conclusion

Within the limitations of the follow-up periods and the number of patients, from the measured parameters of this study, it can be concluded that: Thermoplastic and CAD-CAM denture bases showed higher results than conventional dentures as regards denture retention and alveolar bone preservation. However, more clinical studies with longer follow-up periods and greater sample sizes are necessary to reach more decisive conclusions.

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Conflicts of interest

There are no conflicts of interest declared by the authors.

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