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FUNCTIONAL RELINING VERSUS DIGITAL ALTERED CAST OF SELECTIVE PRESSURE IMPRESSION TECHNIQUES USING DIGITALLY FABRICATED DISTAL EXTENSION FRAMEWORKS: PERI-ABUTMENT BONE HEIGHT CHANGES (PART 1)

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ABSTRACT

Aim of the study: To estimate the impact of using two various impression techniques on peri-abutment bone height changes in mandibular Kennedy Class I partially edentulous patients using digitally fabricated distal extension frameworks (3D printed).

Materials and Methods: A total of twenty patients with mandibular Kennedy Class I partially edentulous arches were involved in this study from the outpatient clinic at the Faculty of Dentistry, Mansoura University. Patients were rehabilitated with maxillary complete dentures and mandibular removable partial dentures fabricated on digitally constructed framework (3D printed) using two different impression techniques. Functional relining impression technique and digital altered cast of targeted pressure impression technique. Peri-abutment bone height changes were examined at insertion ,6months and 12 months after insertion employing cone beam CT.

Results: There was a statistically insignificant difference in peri-abutment bone loss among functional relining group and digital altered cast group, these results suggest that both fabrication methods yielded similar amounts of peri-abutment bone loss over time. However, when examining the progression within each group, paired t-tests displayed a statistically significant rise in bone loss from T0 to T12 (p-values ≤0.05), indicating a progressive pattern of abutment bone resorption independent of the fabrication method. This finding suggests that time is a more influential factor in bone loss than whether relining or digital techniques are used.

Conclusion: Considering the limitation of this research, it is evident that, when fabricating removable partial dentures with distal extension bases, the digital altered cast impression technique proves to be a promising approach, demonstrating similar outcomes to functional relining in preserving the alveolar bone surrounding abutment teeth. Furthermore, it is a simplified technique that contributes to the reduction of both laboratory steps and clinical chairside time.

KEYWORD: CAD/CAM, Digital Partial denture, SLS, Digital altered cast, abutment alveolar bone loss

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INTRODUCTION

Mandibular Kennedy Class I cases are considered challenging in prosthodontic rehabilitation due to the absence of posterior abutments, the dual support from both soft tissue and teeth, and the increased torque transmitted to the terminal abutments. These factors can lead to adverse effects on the abutment teeth and contribute to residual ridge resorption [1].

One of the critical steps to improve the long-term prognosis of distal extension removable partial dentures is capturing a functional impression of the edentulous ridge. Among the various impression approaches, selective pressure (altered cast technique) and functional relining techniques have been widely utilized to enhance soft tissue support. [2]

For distal-extension removable partial dentures (RPDs), a functional selective pressure impression of the residual ridge is strongly preferred over mucostatic anatomic impressions [3].

A functional reline is carried out following the fabrication of the removable partial denture to achieve a precise adaptation between the denture base and the remaining alveolar ridge. This technique allows the partial denture to be fabricated from a framework based on a single impression, producing a stable prosthesis with well-extended borders. Besides being straightforward, this method is less technique-sensitive for the clinician, it also enhances patient well-being and reduces the requirement for frequent adjustment visits. [4]

The application of CAD-CAM technology in the manufacture of RPD frameworks has significantly increased due to the limitations associated with conventional casting methods. Modern digital manufacturing enables the production of RPD frameworks through two principal approaches: subtractive (milling) and additive (3D printing) techniques, which represent the two primary CAD/CAM fabrication methods. [5, 6].

Utilizing laser-sintering technology instead of traditional casting offers several advantages, including enhanced framework quality and reduced production costs, potentially making treatment more affordable and available to a broader audience [7].

Furthermore, cobalt-chromium (Co-Cr) alloys manufactured via laser-sintering demonstrate superior dimensional accuracy, improved fatigue resistance, and enhanced mechanical characteristics compared to cast alloys, owing to their improved homogeneity and small grain size. Additionally, laser-sintered and cast Co–Cr alloys exhibit comparable biocompatibility. Consequently, RPD frameworks fabricated through laser-sintering may offer notable clinical advantages, particularly with respect to fit accuracy and mechanical durability [8].

Using the digitally modified cast, the definitive RPD framework can be efficiently designed and manufactured through the CAD-CAM technique. [9]

The study aims to assess and compare two selective pressure impression techniques—functional relining and digitally altered cast—for fabricating mandibular distal extension removable partial dentures with digitally produced frameworks. The comparison will be based on measurements of alveolar bone height changes.

MATERIAL AND METHODS

Twenty healthy male individuals were recruited for the research, with age range from (50-60) years old from the clinic of prosthodontic department, Faculty of Dentistry, Mansoura University. All participants were thoroughly briefed on the study's objectives and the prosthodontic procedures involved. They signed written consent permitted by the Ethical Committee of Mansoura University Dental Research (No. A0104023RP). (Clinical trial registration number: NCT06082609). Based on the following criteria: All patients had completely edentulous maxillae opposing mandibular Kennedy Class I arches, with the first premolar serving as the last abutment and exhibiting healthy periodontal and bone support. The selected patients should have skeletal Angles class I maxillo-mandibular relationship. Mandibular canines with well-developed cingulum and abutment teeth must have healthy periodontal and bone support with no pronounced degree of mobility and crown root ratio not less than 1:2. patients with severe soft tissue undercuts and systematic diseases that may impact bone changes should be excluded.

Sample size calculation

The sample size was determined with reference to a prior study that evaluated changes in alveolar bone height in mandibular removable partial dentures using two different impression techniques. According to the results reported by Nejatidanesh et al., assuming a power of 80% ($\beta = 0.20$) to identify a consistent effect size of bone loss and a significance threshold of 5% ($\alpha = 0.05$), the minimum necessary sample size was calculated as 10 patients per group. Therefore, the total sample size was set at 20 patients.

Using a computer-based Excel program, the examiners employed balanced randomization to allocate the patients evenly into two groups, with ten participants in each. This method helps ensure that both groups have similar baseline characteristics before any treatment is administered. Group I included ten participants who received mandibular removable partial denture made with functional relining impression technique. Group II included ten participants who received RPD constructed using digital altered cast of selective pressure impression technique. Only a single investigator, who was not involved in the selection or treatment of the patients, had access to the randomization sequence.

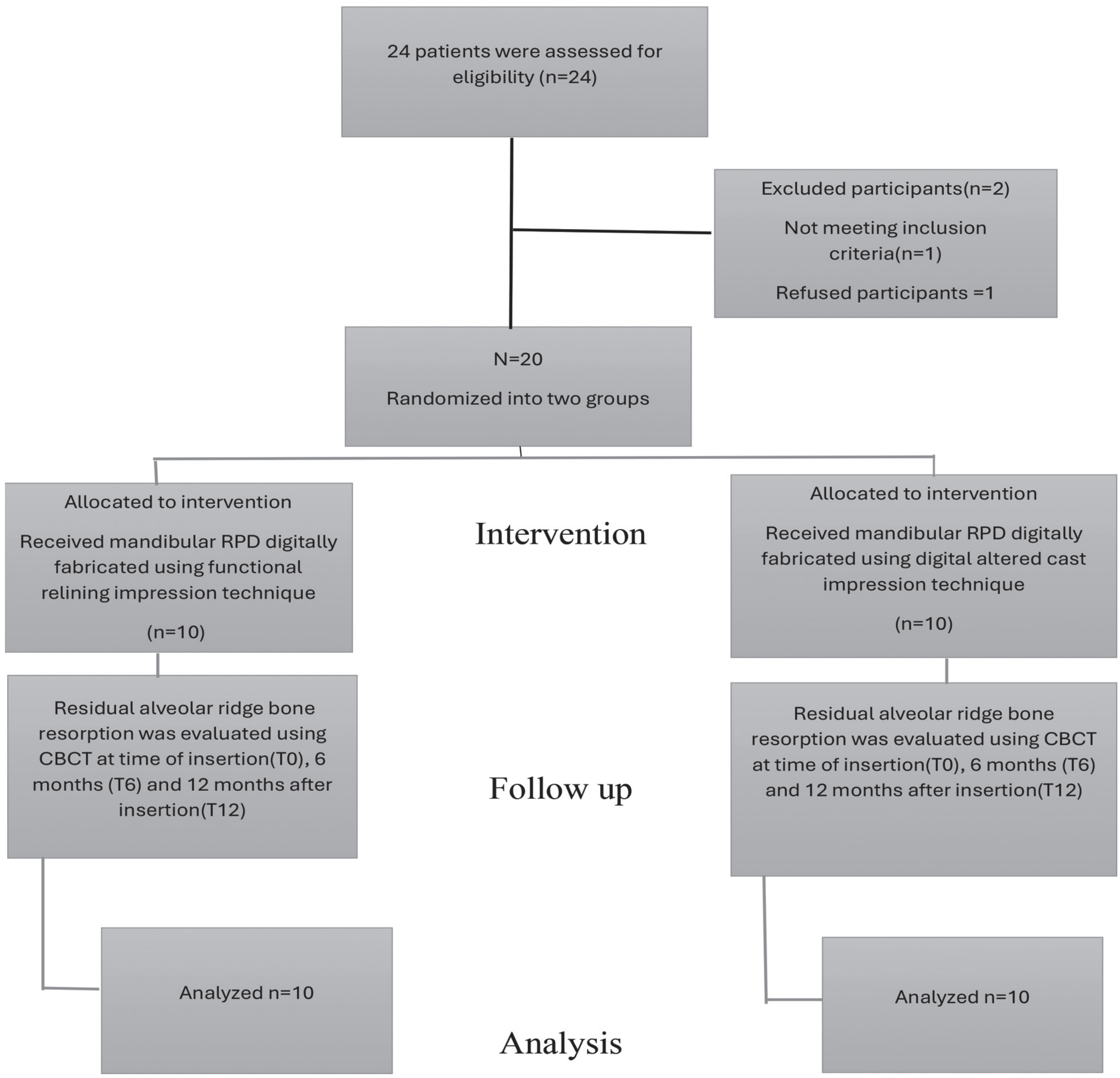
Digital framework construction

Intra oral primary scanning for mandibular arch was done for all patients using intraoral scanner (medit I700 intraoral scanner, Seol, south Korea) (Fig. 1a), then data exported as (STL) format and loaded into the CAD software (Dental system 3shape software). Digital design and surveying of frameworks featuring a lingual bar major connector, RPA direct retainers on the first premolars, and cingulum rests extending from minor connectors as indirect retainers on both canines. Mouth preparation was done according to the determined digital design. Final digital scanning was done to produce virtual master casts using (3shape dental software). After secondary surveying, the preparation of virtual definitive cast was performed including: all unwanted undercuts were filled and smoothed into flat surfaces. A retentive undercut of 0.02 mm was selected for engagement by the clasp arm's retentive terminal. To create relief beneath the saddle, the STL data of the mesh-retainer part was adjusted by lifting it 0.5 mm occlusally. Additional relief was provided under the inferior border of the lingual bar and along minor connectors crossing the gingival margin. (Fig. 1b) The Standard Tesselation Language (STL) file was then sent to a 3D printer (Rapid shape D30, Germany). A stereolithographic resin pattern of the framework was made employing rapid prototyping technology, after which resin try-in was done intra-orally. Fabrication of cobalt-chromium RPD framework by exporting the STL file to a SLM direct metal printing machine (VULCANTECH VM120, Germany) to print 3D frameworks of the same design (Fig. 1c). A CoCr alloy powder (WALL COLMONY, CoCr, 3D Systems) was used, as suggested by the SLM machine manufacturer. The printed framework was refined by sandblasting and diamond burs fitted on the 3D printed cast, then polished. Try-in of metallic RPD framework intraorally. (Fig. 1d)

According to the final mandibular impression, all patients were equally and randomly assigned to two groups in the following manner:

Functional reline group: the finished RPD was relined using functional relining impression technique.

Digital altered cast group: RPD fabricated using digitally obtained altered cast.


24 patients were assessed for eligibility (n=24)
Excluded participants(n=2)
Not meeting inclusion criteria(n=1)
Refused participants =1
N=20
Randomized into two groups
Allocated to intervention
Received mandibular RPD digitally fabricated using functional relining impression technique
(n=10)
Intervention
Allocated to intervention
Received mandibular RPD digitally fabricated using digital altered cast impression technique
(n=10)
Residual alveolar ridge bone resorption was evaluated using CBCT at time of insertion(T0), 6 months (T6) and 12 months after insertion(T12)
Follow up
Residual alveolar ridge bone resorption was evaluated using CBCT at time of insertion(T0), 6 months (T6) and 12 months after insertion(T12)
Analyzed n=10
Analysis
Analyzed n=10

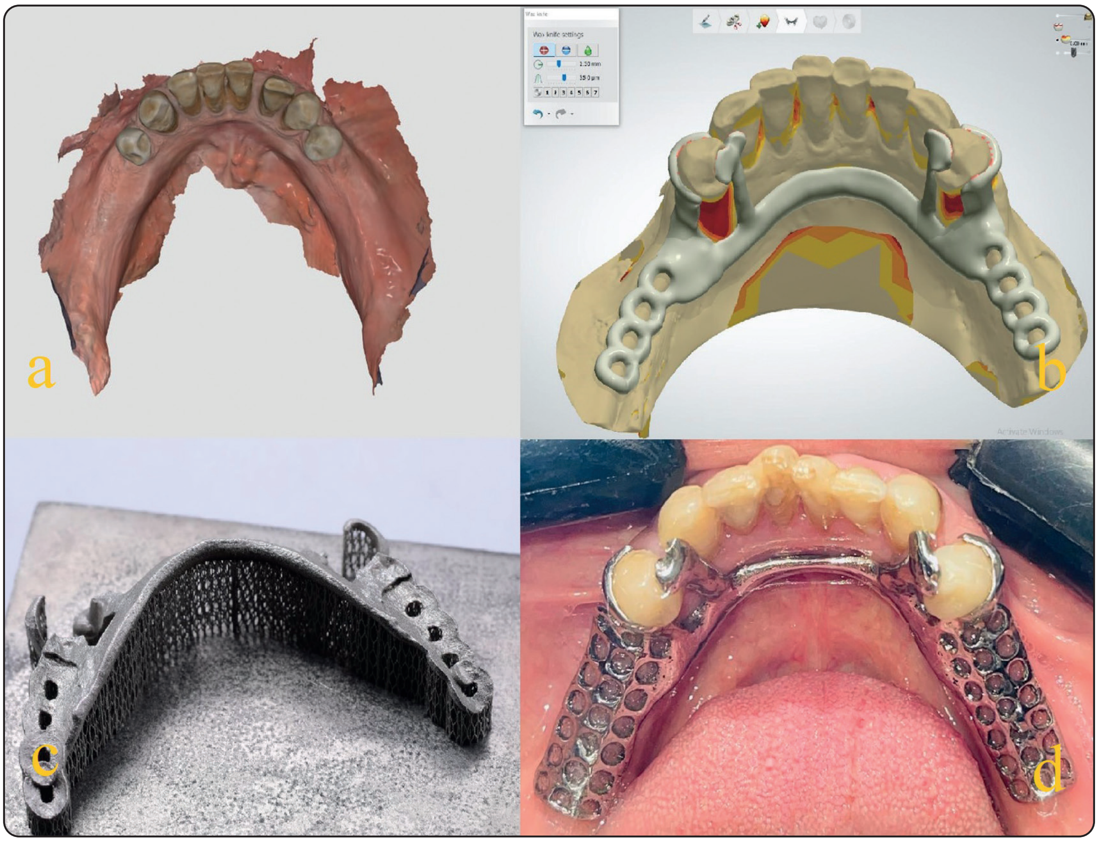


Fig. (1) Steps for digital RPD metal framework construction

Functional relining of conventionally processed RPD (functional reline group):

After duplication of the 3D printed cast in extra hard stone, bite blocks were attached to the meshwork of metal frameworks to register maxillomandibular relations. Then RPD was conventionally processed. 1-2 mm tin foil spacer in edentulous area of the duplicated cast was placed before processing to provide space for relining impressions material. The finished removable partial denture was then relined using zinc oxide eugenol-free impression material (cavex outline, cavex , Netherland, Holland), while making sure that rests and indirect retainers were fully seated in place. Then denture relining was processed.

Digitally obtained altered cast:

The following steps were used to apply the selective pressure impression technique: Custom tray was affixed to the framework, Border molding of the tray then Zinc oxide eugenol-free impression material was prepared following the manufacturer's guidelines, loaded tray was fully inserted into the patient's mouth, ensuring all rests and indirect retainers were fully seated as the impression material reached its final set (Fig. 2). Using the IOS software, the distal extension area of the denture base corresponding to the site of the altered cast impression was deleted from the original scan used in the fabrication of the RPD framework (Fig. 3a). With the IOS (intraoral scanner), scan the labial and buccal aspects of the teeth, and then scan the altered cast impression and the RPD framework in situ (Fig. 3b). Then, scan the finished impression (intaglio surface) extra orally (Dental Desktop; 3Shape A/S). (Fig. 3c)

Scan was exported as an STL file and opened in an open-source software (medit link). The cameo

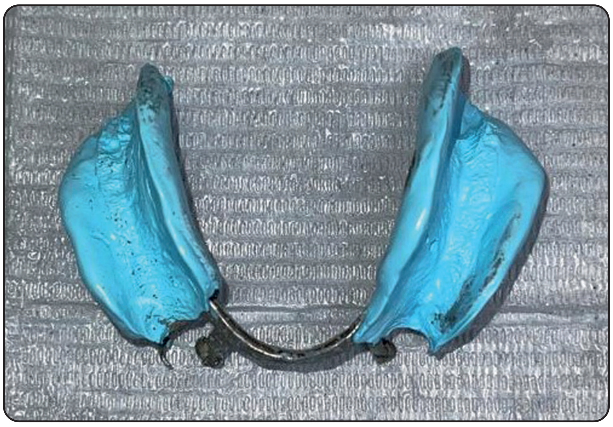


Fig. (2) Altered cast impression with ZOE impression material

surface of the impression scan was imported and distal extension section was removed. Next, 'Invert Normals' command was applied to the modified cast impression area, which flips the active surface of the STL file (Fig. 3d). This process generates a digital cast of the impression, which is then digitally merged with the tooth cast to form the final definitive cast (Fig. 4). The resulting model was fabricated using additive manufacturing. (Fig. 5a)

3D printing of digital altered master cast was done then final RPD was constructed the same way as group (I) without relining. Duplication of the digitally printed altered cast in extra hard dental stone was done to be used during processing in relining group. (Fig. 5b)

Evaluation of alveolar bone height changes:

Cone beam CT was employed to assess the alveolar bone height changes around abutment immediately following denture insertion (T0), six months (T6) and 12 months following insertion (T12). CBCT scan of the edentulous mandible was done with a standardized head position.

All CBCTs were performed by the same operator using the same imaging device at 90k Vp,3.2mA, with a volume pixel (voxel) size of 0.2 mm to

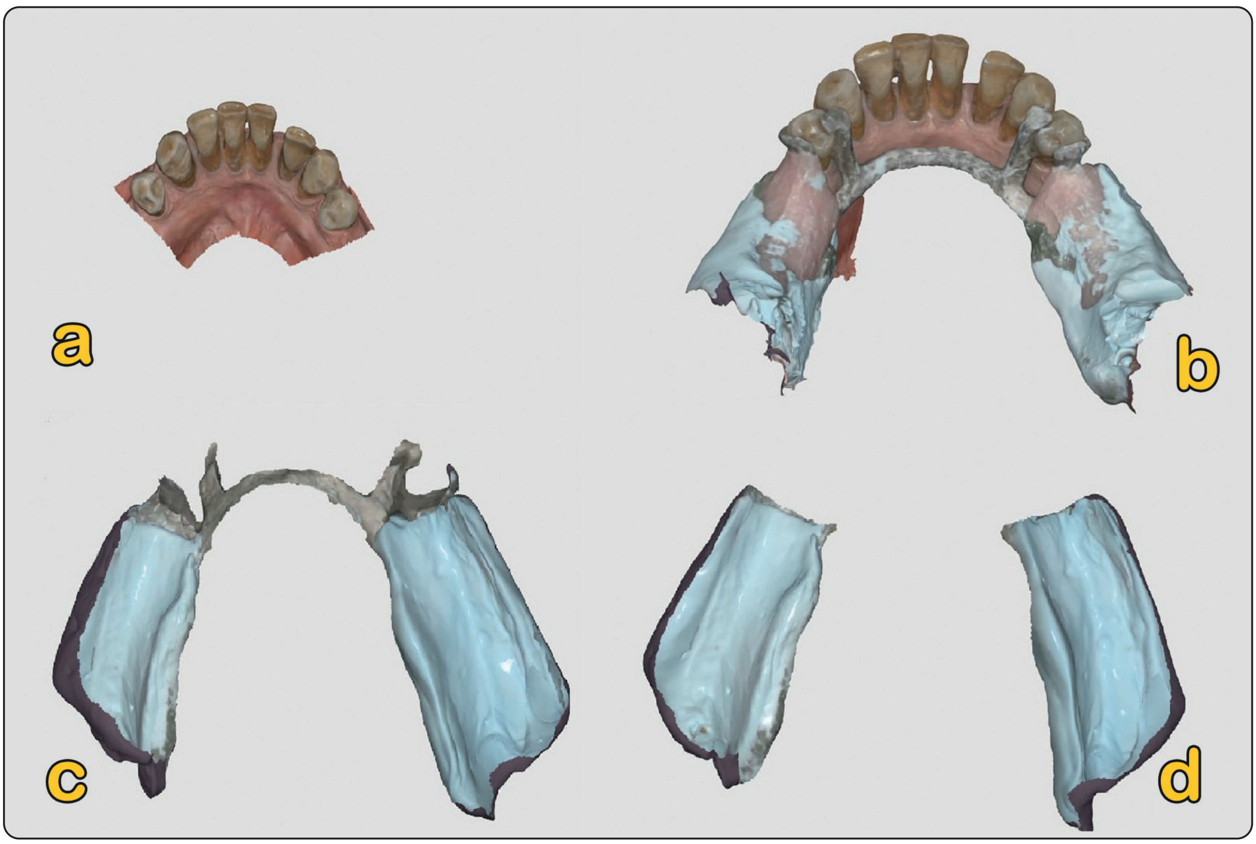


Fig. (3) Separate scans for the teeth and posterior free end saddle to be merged together to obtain digital altered cast

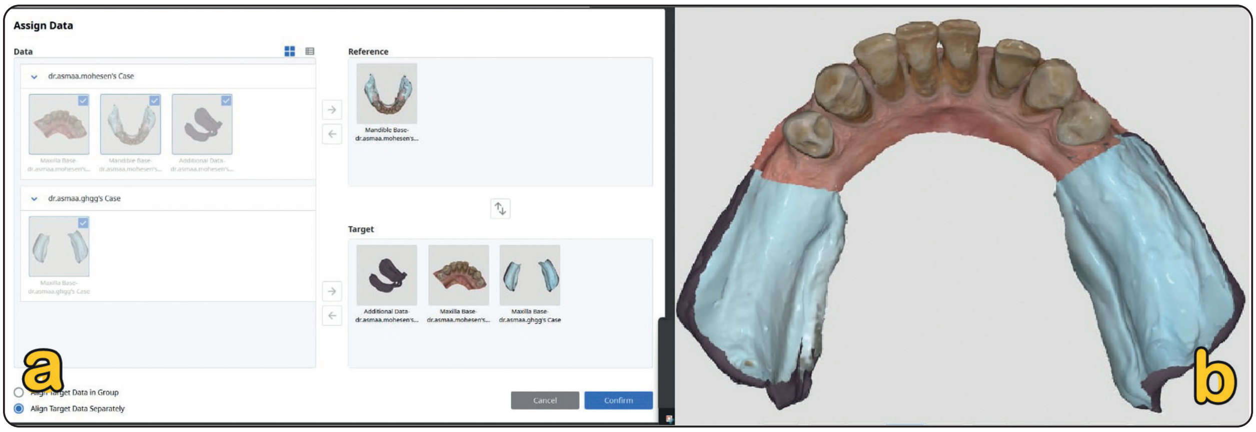


Fig. (4) Digital altered cast was obtained by merging anterior and posterior scans together

ensure high resolution imaging. The images were saved in DICOM format for further processing. CBCT scans were analyzed using Ondemand3D™ software (CyperMed Inc., Seoul, South Korea). One investigator was responsible for analyzing CTs and performing the measurements.

The abutment bone height changes were measured in mm as follows

Two lines were drawn. The first line (vertical line) running with the long axis of the abutment tooth (the first premolar), the second line was perpendicular to the first one passing through the

Fig. (5) Digital altered cast was printed, duplicated then partial denture was constructed conventionally

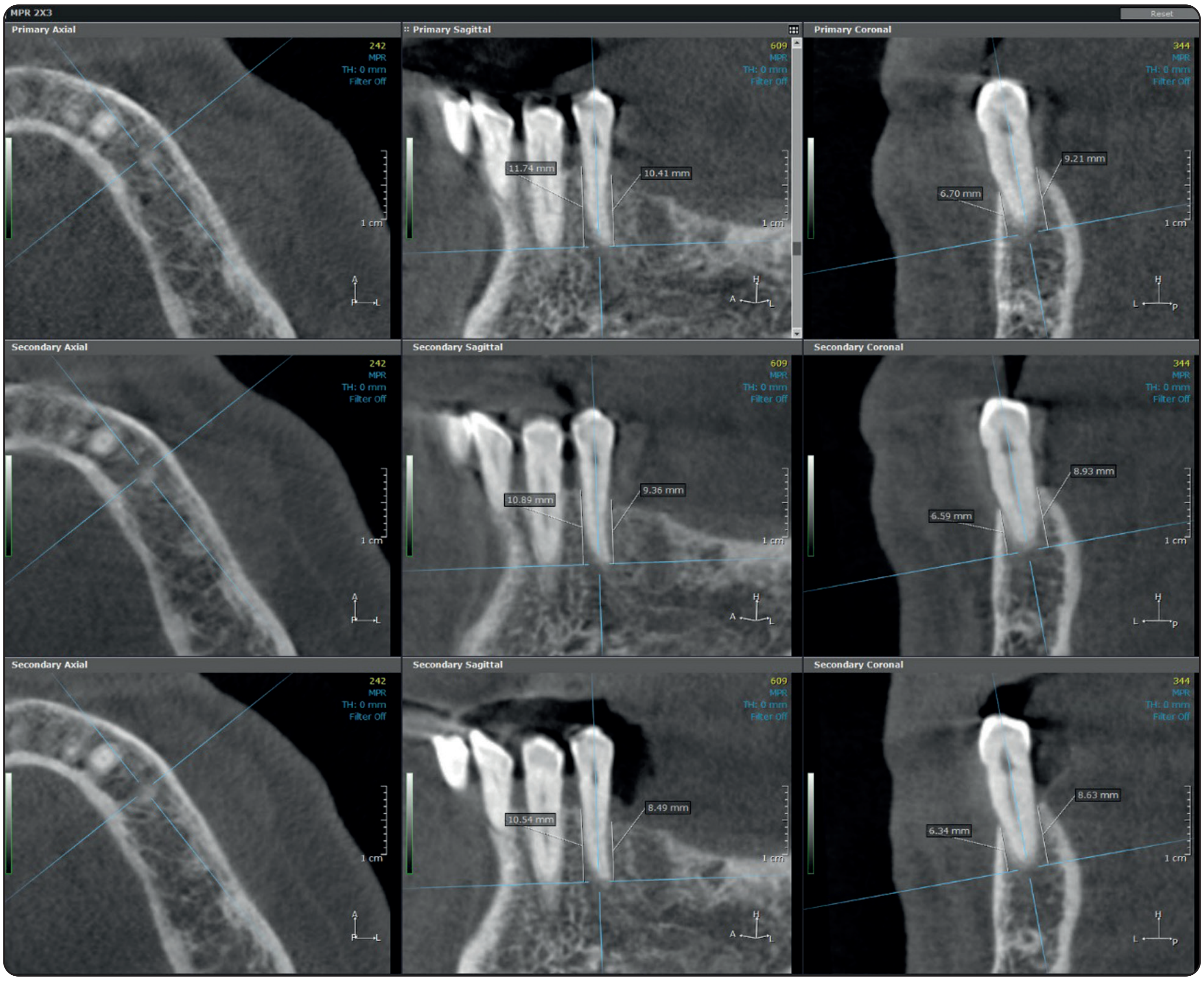


Fig. (6) Evaluation of alveolar bone loss around abutments using cbct scan

apex of the abutment roots. Using the ruler function of the software, the vertical distance was measured between the crest of the alveolar ridge and the apex of the abutment mesially, distally, buccally and lingually at T0, T6 and T12. The mean readings of these measurements were calculated (Fig. 6). The abutment alveolar bone loss in 1st 6 months was calculated by subtracting the mean of T6 from the mean of T0 (representing T_{0-6}), and the 2nd month was calculated by subtracting the mean of T12 from T6 (T_{6-12}). The abutment alveolar bone loss after 12 months (T_{0-12}) equals the sum of $T_{0-6}+T_{6-12}$

Statistical analysis

Data were analyzed utilizing the Statistical Package for the Social Sciences (SPSS), Windows Standard Version 24. The normality of the data was assessed employing the Shapiro-Wilk test. Continuous variables with a normal distribution were expressed as mean ± standard deviation (SD). Two independent groups were compared applying the independent t-test, while comparisons within paired groups were carried out using the paired t-test. Spearman's correlation was applied to assess associations among continuous variables. A p-value of ≤ 0.05 was interpreted as statistically significant.

The smaller the p-value, the higher the statistical significance of the findings.

RESULTS

Comparison of abutment bone loss between the Relining and Digital groups across three time points—T0, T6, T12 showed that at each interval, no statistically significant differences were identified across the two groups, as p-values >0.05. These results suggest that both fabrication methods yielded similar amounts of abutment bone loss over time.

However, when examining the progression within each group, paired t-tests displayed a statistically significant rise in bone loss from T0 to T12 (p-values ≤0.05), indicating a progressive pattern of ridge resorption independent of the fabrication method. This finding suggests that time is a more influential factor in bone loss than whether relining or digital techniques are used.

Comparison of abutment bone loss between the Relining and Digital groups across three time points—T0, T6, T12

Abutment Bone Loss	Relining group (n=10)	Digital group (n=10)	Test of significance	p value
T_{0-6} Mean ± SD	0.22±0.06	0.22±0.07	t=0.004	0.997
T_{6-12} Mean ± SD	0.27±0.03	0.26±0.01	t=0.134	0.895
T_{0-12} Mean ± SD	0.49±0.07	0.49±0.08	t=0.049	0.961
Paired t test	P1=0.049* P2≤0.001* P3≤0.001*	P1=0.039* P2≤0.001* P3≤0.001*		

*t: Independent t test, *significant p≤0.05, p1:(T_{0-6} Vs. T_{6-12}), p2:(T_{0-6} vs. T_{0-12}), p3:(T_{6-12}vs. T_{0-12}).*

DISCUSSION

The findings showed minimal total abutment alveolar bone resorption when evaluating the first and second six-month periods in both groups (I and II), likely due to the restricted apical movement of the abutment teeth. This can be attributed to the technique of impression used to record distal extension in both groups were functional impressions which are widely recognized as a crucial factor in achieving the most optimal prognosis for the distal extension denture. To best ensure tissue support, various functional impression techniques have been advocated. [10-11] The absence of distal abutments results in reduced mechanical support for the prosthesis, placing greater functional load on the residual ridge leading to torsional stresses on abutments. This uneven distribution of occlusal forces is considered a primary contributor to alveolar bone resorption [12].

The selected impression technique is crucial in determining the initial adaptation and tissue support of the denture base, which directly influences how functional forces are transmitted. The altered cast technique is widely recommended for distal extension RPDs as it aims to capture the edentulous ridge under functional conditions, improving the fit of the denture base and reducing torque on the abutment teeth [13]. Because occlusal forces on a tooth-tissue-supported RPD must be evenly distributed between the abutments and the ridge tissues, a single-impression master cast cannot accomplish this. Instead, a dual-impression technique is employed to create a corrected cast. This method captures the teeth in their anatomic shape while recording the residual ridge soft tissues in their functional state [14]. The mucofunctional concept (a physiologically based philosophy) can be realized through two approaches: relining the denture base after fabrication or taking a mucocompressive impression that captures the tissues in their loaded state [15]. Following the relining process, load distribution was partially transferred to both the supporting tissues and the abutment teeth. This procedure influenced the transmission of forces through both direct and indirect retainers through the major and minor connectors. The findings highlight the significance of direct relining as a straightforward and effective method, especially when compared to the more complex altered cast impression technique. Therefore, it should be considered an essential step in all distal extension mandibular RPD.[16]

These explanations are align with previous study of Sajjan C. [13], who stated that the altered cast technique enhances support by accurately capturing the functional form of the ridge, leading to more balanced load distribution between teeth and tissues, thereby reducing torque and minimizing stress on abutments. This dual support reduces the stresses transmitted to the abutment teeth, thereby minimizing the incidence of torque. Consequently, this technique offers several potential advantages, improved stress distribution, including preservation of the residual ridges, and reduced torque on the abutment teeth.

Additionally, the study revealed that time, rather than the specific impression method, was a more significant factor influencing abutment and ridge resorption. There was significant abutment and ridge resorption independent of the fabrication method whether functional relining or digital altered cast techniques were used.

These results correspond with preceding studies that have demonstrated that alveolar bone resorption begins immediately after tooth loss and progresses rapidly for approximately 10 weeks, subsequently by a slower yet continuous resorption process thereafter [17]. The most effective way to minimize this resorption is to preserve the residual alveolar ridge through various forms of prosthetic rehabilitation. Additionally, the application of tooth-supported dentures has been shown to effectively reduce the resorption rates [18].

Bone resorption has been noted in both RPD wearers and non-wearers, as evaluated through mandibular height and width measurements, with edentulous sites showing greater resorption relative to dentate sites. This observation aligns with prior research findings [17, 19, 20]. However, most previous studies have examined bone resorption by evaluating dentate and edentulous groups or denture users and non-users across various participants or specimens. As a result, functional stimulation may contribute to bone resorption rather than preserving the edentulous area, suggesting it could be just as significant as the pressure from dentures. Additionally, the pressure applied by removable partial dentures (RPDs) on the edentulous regions of the alveolar bone may accelerate resorption in RPD wearers relative to non-wearers [21].

CONCLUSION

Considering the limitation of this research, it is evident that, when fabricating removable partial dentures with distal extension bases, the digital altered cast impression technique proves to be a promising approach, demonstrating similar outcomes to functional relining in preserving the alveolar bone surrounding abutment teeth. Furthermore, it is a simplified technique that contributes to the reduction of both laboratory steps and clinical chairside time.

Declarations

Ethics approval and consent to participate

The patients were fully informed about the purpose and procedures of this study and provided written informed consent. The study was approved by the local ethical committee of the Faculty of Dentistry, Mansoura University (No. A0104023RP) and retrospectively registered at ClinicalTrials.gov *(ClinicalTrials.gov Identifier:* NCT06082609*)*.

Consent for publication

Not applicable

Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest to declare.

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