

CLINICAL RESEARCH

Digital comparative analysis in three dimensions of two impression techniques for the bilateral distal extension of partially edentulous mandibular arches: A pilot clinical study

Matheel AL-Rawas, BDS, MRESDENT, FRACDS,^a

Johari Yap Abdullah, B.S. & I.T., GradDip ICT, MSc, PhD (Craniofacial Biology),^b

Belal Elmarhoumy, BDS, FRACDS,^c Yanti Johari, BDS, MCLINDENT, FRACDS,^d

Azirrawani Ariffin, BDS, MCLINDENT, MPROS,^e and Adam Husein, BDS, MCLINDENT, FRACDS^f

ABSTRACT

Statement of problem. The stability of mandibular removable partial dentures with bilateral distal extensions may be improved with the controlled tissue support achieved by using the altered cast impression technique, although this process is time-consuming and technique-sensitive.

Purpose. The purpose of this pilot clinical study was to compare casts generated from a conventional definitive impression with casts generated from an altered cast impression using a 3-dimensional (3D) analysis software program.

Material and methods. Three partially edentulous participants with mandibular Kennedy Class I were enrolled, and impressions were made with the 2 techniques and poured in stone. The casts were scanned, aligned, and superimposed by using a 3D analysis software program. Surface deviations were measured to evaluate the differences in displacement induced by the impression on the tissue surface. Five observations were made in 4 different areas on each partially edentulous side. Means from these observations were generated, and the Wilcoxon and Mann Whitney tests were performed for all data to assess the differences between the right and left sides in the same participant and among the 3 participants ($\alpha=.05$).

Results. The casts made from the altered cast impression had an overall mean $\pm$ standard deviation displacement of -0.05 ± 1.25 mm on the right and left sides of the mandibular buccal shelf area. Moreover, the greatest overall difference of about 0.45 ± 0.41 mm occurred on the lingual slope of the residual ridge, and the differences in the other areas were 0.10 ± 0.99 mm (crest of the residual ridge) and 0.16 ± 0.66 mm (buccal slope of the residual ridge). The overall differences varied statistically between significance and nonsignificance for the same participant and among the 3 participants.

Conclusions. A digital comparative analysis of the conventional and altered cast methods of recording the bilateral distal extension areas in partially edentulous participants showed that the altered cast method exhibited more displacement on the buccal vestibule or buccal shelf area compared with other examined areas. The differences between the 2 impression methods in the displacement values among the examined areas were minimal and in close proximity, and such differences may lack clinical significance. (J Prosthet Dent xxxx;xxx:xxx-xxx)

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^aSenior Lecturer, Prosthodontics Unit, School of Dental Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia; and Specialist, Hospital Universiti Sains Malaysia, Kubang Kerian, Malaysia.

^bSenior Lecturer, Craniofacial Imaging Lab, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, Malaysia; and Senior Lecturer, Dental Research Unit, Center for Transdisciplinary Research (CFTR), Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.

^cPostgraduate student, Prosthodontics Unit, School of Dental Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia.

^dAssociate Professor, Prosthodontics Unit, School of Dental Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia; and Associate Professor and Specialist, Hospital Universiti Sains Malaysia, Kubang Kerian, Malaysia.

^eSenior Lecturer, Prosthodontics Unit, School of Dental Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia; and Specialist, Hospital Universiti Sains Malaysia, Kubang Kerian, Malaysia.

^fProfessor, Prosthodontics Unit, School of Dental Sciences, Universiti Sains Malaysia, Kubang Kerian, Malaysia; and Professor, Department of Preventive and Restorative Dentistry, College of Dental Medicine, University of Sharjah, University City, United Arab Emirates.

Clinical Implications

Based on the findings of the present pilot study, the altered cast method does not appear to be clinically better than a conventional definitive impression. The altered cast method requires greater technical sensitivity, higher costs, and more time.

Removable partial dentures (RPDs) are a treatment option for partially edentulous patients.¹ However, RPDs with bilateral distal extensions are challenging because of the support from 2 distinctly different oral structures, the teeth and the residual ridges.^{2,3} A successful RPD should not put undue stress on the remaining natural teeth or residual ridge. However, abutment tooth mobility and residual ridge resorption can occur if support from the teeth and soft tissues is not optimized.^{4,5}

Soft tissues should be recorded as accurately as possible,^{6,7} with the best possible RPD support and extension^{8–10} to optimize stability and treatment outcomes. In bilateral distal extension RPDs, tissues are susceptible to displacement when occlusal load is applied. Displacement is a result of movement of the mucosa as well as bone resorption and of decreased resistance to vertical and horizontal stresses.^{2,11} A functional impression has been advocated^{4,11,12} in which the teeth are recorded in their anatomic form and the mucosa that covers the ridge is recorded in its functional form^{2,3} by using a variety of methods and materials.^{13–17} The popular altered cast impression technique (ACIT) has been reported to be the most reliable,^{11,12} and a functional impression of the mucosa is made under regulated pressure with a custom tray added to the cast metal framework.¹¹ Improved stress distribution, less food impaction, decreased rotation of the abutment teeth, and preservation of oral tissues have been cited as benefits of the ACIT.^{11,12} The approach enables the prosthesis to receive support from both the teeth and the denture base but has the disadvantage of requiring more patient visits; nevertheless, it is a beneficial procedure.¹¹ The principles of controlled tissue support have been reported to be most effectively satisfied by the ACIT,^{2,3,12,18–22} with more displacement or pressure being exerted on the buccal vestibule or buccal shelf area.^{23–25}

Conventional impression procedures, such as unmodified impressions and casts, have typically not been recommended for distal extension RPDs; yet, the ACIT has been reported to not be widely used in clinical practice.^{26,27} The ACIT has been reported to provide significant vertical support and movement differences, but doubts have been expressed about the clinical

significance of such a technique.^{3,19–22} Abt et al⁵ stated in their Cochrane review that inadequate information was available about whether RPDs produced using ACIT performed better than other RPDs. Disadvantages of the ACIT included the possibility of making errors in the technical implementation, additional expense and time, and a perceived lack of value.^{26,27} Digital comparative pilot research is needed on the differences that may be found between the impressions produced through the various methodologies.

Digitized devices and software programs have been used to assess dimensional changes.^{28–31} When 2 surfaces are brought into alignment with one another for 3-dimensional (3D) comparison, the deviation difference between them is determined by the shortest distance between each point on one surface and another. The use of this approach yields findings in the form of colored maps and bars.^{28,31}

This pilot study aimed to use a 3D analysis software program using superimposition technology to compare the cast generated from an ACIT to the cast generated from a conventional definitive impression (CDI) method and to determine if the ACIT was beneficial for patients provided with the bilateral distal extension RPDs. The null hypothesis was that no difference would be found between the 2 impression techniques when comparing both sides of the edentulous ridge in the same participant and among the 3 participants.

MATERIAL AND METHODS

This pilot study involved a 3D digital comparison between 2 impression techniques. A sample size was calculated by using a software program (G*power version 3.1.9.6; Heinrich-Heine-Universität Düsseldorf), assuming an effect size of 0.5, $\alpha=.05$, and $\beta=.80$. A total of 28 participants would have been needed. For this pilot study, 10% of the total sample size³² was required (3 participants). One man and 2 women (mean age=51 years) of Malay ethnicity seeking prosthodontic treatment were recruited from the Malaysian population. The inclusion criteria were partially edentulous individuals with bilaterally missing mandibular molars (mandibular Kennedy Class I) with moderate to severe ridge resorption on both sides requiring the fabrication of RPDs with at least 1 indirect retainer on the canine and/or lateral incisor. The participants had healthy soft tissues, were free from local and systemic disease, and had no masticatory or motor system disorders. The exclusion criteria were those with Kennedy Class II or with only mandibular central incisor teeth present. The investigation was carried out between May 2022 and February 2023. One experienced clinician (M.A.) was

responsible for managing the 3 participants. Ethical approval had been obtained from the Ethics and Research Committee, reference number USMKK/PPP/JEPeM (259.3[2]). Informed consent was obtained from all participants.

Two impression techniques were used: the CDI and the ACIT. The CDI of the mandibular arch was made by using an acrylic resin custom tray of spaced design (Vertex Trayplast; Vertex-Dental by 3D Systems) with tray adhesive (Caulk; Dentsply Sirona) and monophase type II silicone impression material (EXAMIX; GC) loaded in the custom tray after border molding with modeling plastic impression compound (Tracing sticks; Kemdent). The CDI was sent to a dental laboratory technician, and a Type IV dental stone (Nok Stone; Lafarge Prestia) cast was made and scanned before proceeding with the fabrication of the cast cobalt chromium framework and the ACIT procedure.

The ACIT was made once the fit of the cast cobalt chromium framework had been verified. An acrylic resin custom tray of a close-fitting design (Vertex Trayplast; Vertex-Dental by 3D Systems) was attached to the mandibular cast metal framework, and this tray was then border molded. The ACIT was made with type II monophase silicone impression material (EXAMIX; GC) after tray adhesive (Caulk; Dentsply Sirona) had been applied. While making an impression, finger pressure was applied only to the framework rests that contacted the teeth.

The cast was altered in the laboratory. Two main saw cuts were made with a stainless-steel round diamond saw (365DF Diamond Disk; Hager and Meisinger) attached to a laboratory straight handpiece. Grooves were placed in the cut surfaces of the cast to aid in the retention of the additional stone. The framework was completely seated on the cast before it was fixed in place with sticky wax (Sticky Wax Yellow; Kemdent). The definitive impression was beaded and boxed in the usual manner¹¹ and poured with Type IV die stone (Nok Stone; Lafarge Prestia).

The dental stone casts were scanned using a portable laser scanner (Next Engine Desktop 3D Scanner, model 2020i; NextEngine Inc) to generate virtual casts in standard tessellation language (STL) format. The files were imported into a surface-matching software program (Geomagic Control X 2021; 3D Systems), and the CDI virtual cast (reference data) and the ACIT virtual cast (measured data) were compared after the ACIT STL files had been 3D superimposed onto the CDI files. Three alignment methods were used sequentially: transform alignment by points, best fit alignment, and then transform alignment by using the rotation and translation functions.

Three-dimensional comparisons and calculations were made by determining the shortest distance between

each point on one surface and another of the virtual casts at 4 different areas of the bilateral distal extension of the partially edentulous mandible (Fig. 1). Area 1 was the buccal vestibule area, delineated from the frenum area anterior to the premolar region and continuing from the first premolar area to the first molar area. Posterior to the first molar area, the delineation should have become shorter in the retromolar pad area.²⁵ The buccal slope, crest, and lingual slope of the residual ridge were represented by areas 2 through 4, respectively. Each of these areas was chosen because of the specific tissue support these areas provide to the denture.

Concerning the colored maps and bars in Figures 2 and 3, the 3D comparison in the analysis software program depicted a color-coded bar displaying a range between -1 and 1 . Positive deviation is represented by the colors yellow, orange, and red, whereas negative deviation is indicated by the various hues of blue. A positive deviation indicated that less displacement was used when making the ACIT, while a negative deviation indicated the reverse.

In each area, 5 observations were made of the deviation or displacement values between the surfaces of the superimposed virtual casts. The means of the 5 deviation values in the 4 areas were measured to evaluate the differences on the virtual surfaces (tissue surfaces).

Statistical analysis was performed using a software program (IBM SPSS Statistics, v26.0; IBM Corp). Means and standard deviations were calculated, and the Wilcoxon test was applied to assess the differences between the right and left sides of the same participant. The Mann Whitney test was applied to assess the differences between the right and left sides among the 3 participants ($\alpha=.05$).

RESULTS

The results of the deviation of the ACIT (measured data) virtual casts superimposed on those of the CDI

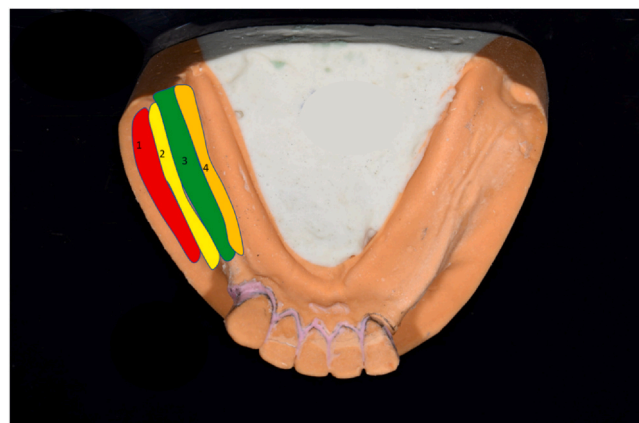


Figure 1. Four studied areas in distal extension partially edentulous mandibular arch.

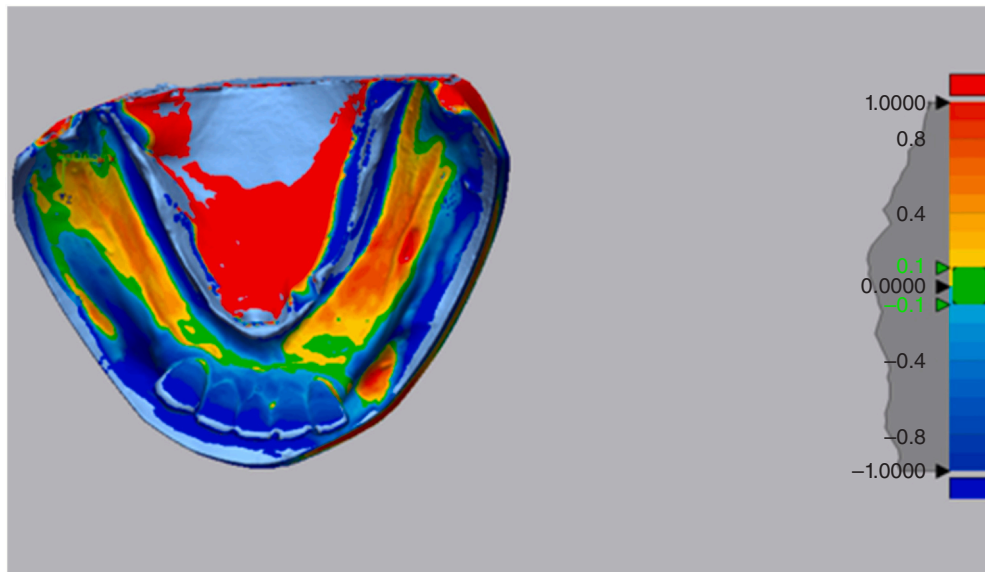


Figure 2. 3D comparison with color-coded areas and color-coded bar with deviation range between 1 and -1 mm.

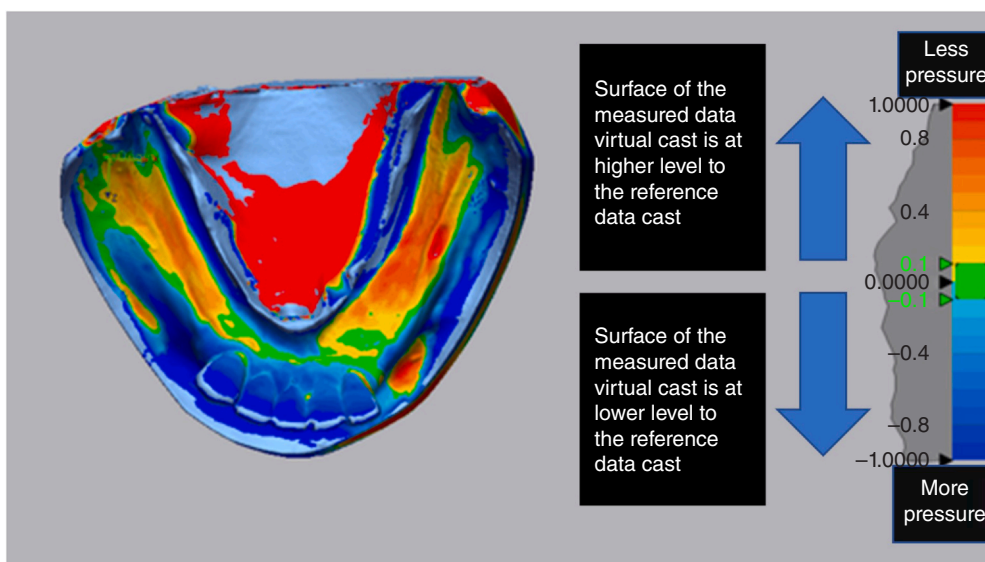


Figure 3. Details on reading and collection of deviation results.

(reference data) are shown in Table 1. In the surface-matching software program (Geomagic Control X; 3D Systems), the results of the 3D analysis, with a color bar indicating whether the values of the ACIT caused more or less displacement compared with the reference data values, are shown in Fig. 2. Values above the surface of the reference data in the 3D level were coded with yellow, orange, and red, which refers to less

displacement or pressure on the mandibular tissues, while values below the surface of the reference data were coded with different shades of blue, which refers to more displacement or pressure being applied to the mandibular tissues by the ACIT (Fig. 3). The ACIT achieved higher displacement values with an overall mean $\pm$ standard deviation of -0.05 ± 1.25 mm in area 1 (buccal shelf area/buccal vestibule) compared with the

Table 1. Mean and standard deviation of displacement or deviation values of superimposed virtual casts

CDI vs ACIT Superimposed Casts	Buccal Shelf Area (Area 1)				Buccal Slope of Residual Ridge (Area 2)				Crest of Residual Ridge (Area 3)				Lingual Slope of Residual Ridge (Area 4)			
	Mean (mm)	SD	Mini- mum (mm)	Maxi- mum (mm)	Mean (mm)	SD	Mini- mum (mm)	Maxi- mum (mm)	Mean (mm)	SD	Mini- mum (mm)	Maxi- mum (mm)	Mean (mm)	SD	Mini- mum (mm)	Maxi- mum (mm)
P1 R side	0.12	0.11	-0.03	0.23	-0.22	0.46	-0.74	0.23	0.22	0.18	-0.05	0.41	0.47	0.16	0.20	0.63
P1 L side	-1.09	0.75	-1.94	-0.39	-0.27	0.21	-0.62	-0.09	0.26	0.47	-0.24	1.04	0.43	0.28	0.11	0.73
P2 R side	-0.73	1.83	-3.11	0.91	0.09	1.24	-1.78	1.20	-0.75	2.29	-2.75	0.77	0.70	0.84	-0.59	1.43
P2 L side	0.57	0.24	0.31	0.88	0.76	0.19	0.55	1.04	0.75	0.28	0.48	1.09	0.15	0.27	-0.25	0.44
P3 R side	0.96	0.75	0.03	1.96	0.55	0.46	0.06	1.31	0.20	0.17	0.01	0.39	0.27	0.16	0.02	0.48
P3 L side	-0.17	1.73	-2.63	1.68	0.11	0.14	-0.08	0.23	-0.05	0.05	-0.10	0.03	0.68	0.25	0.47	1.11
overall	-0.05	1.25	-3.11	1.96	0.16	0.66	-1.78	1.31	0.10	0.99	-2.75	1.09	0.45	0.41	-0.59	1.43

ACIT; altered cast impression technique; CDI, conventional definitive impression; L, left; P, participant; R, right; SD, standard deviation. Descriptive statistics applied.

values in areas 2, 3, and 4. In these areas, the ACIT resulted in less displacement in area 2 (buccal slope of the residual ridge), area 3 (crest of the residual ridge and retromolar pad area), and area 4 (lingual slope of the residual ridge), with overall results of 0.16 ± 0.66 mm, 0.10 ± 0.99 mm, and 0.45 ± 0.41 mm, respectively. Figure 4 shows the boxplots of the deviation values from the 4 different areas of investigation of the 3 different participants. The deviation values of the superimposed surface of the measured data (ACIT) to the reference data (CDI) were in the range of 2 mm to -3 mm. Area 1 showed more deviations below zero value compared with other areas, as shown in Figure 4.

After running the Wilcoxon test to assess the differences between the CDI and ACIT superimposed virtual casts between the right and left sides of the same participant, statistical significance was observed in area 1 ($P < .009$) of participant 1 and area 2 ($P < .047$), area 3 ($P < .016$), and area 4 ($P < .016$) of participant 3. However, the comparison was not significant in all areas of investigation for participant 2 (Table 2).

A comparison among participants between the right and left sides was carried out using the Mann-Whitney test. Most of the comparisons showed nonsignificant differences ($P > .05$), except for comparisons of the right side of area 1 ($P < .047$) and area 2 ($P < .028$) of participants 1 and 3. For the left side comparisons, areas 1 and 2 ($P < .009$) of participants 1 and 2, area 2 ($P < .009$) of participants 1 and 3, areas 2, 3, and 4 ($P < .009$) of participants 2 and 3 all showed statistical differences.

DISCUSSION

The authors are unaware of a previous digital study that compared the CDI with the ACIT using a 3D analysis software program. In a systematic review on the ACIT, most studies identified were conducted on completed partial dentures or at the occlusion rim stage, and, according to these studies, the removable denture produced by the ACIT demonstrated reduced vertical movement of the denture base as compared with those fabricated using standard single-step impression procedures and 1-piece casts.¹² The ACIT has been reported to provide properly regulated tissue support in addition to less denture vertical displacement, with a difference of 0.19 to 0.06 mm.^{19–21} In the present investigation, and after 3D analysis, the ACIT resulted in overall higher tissue displacement over area 1, the buccal shelf area (BSA), of approximately 0.05-mm displacement, consistent with previous studies.^{12,19–21} The higher tissue displacement indicated that the ACIT was successful in recording the functional form of the mucosa, which can result in increased stress being placed on the denture-bearing region by the RPD, which is the intended

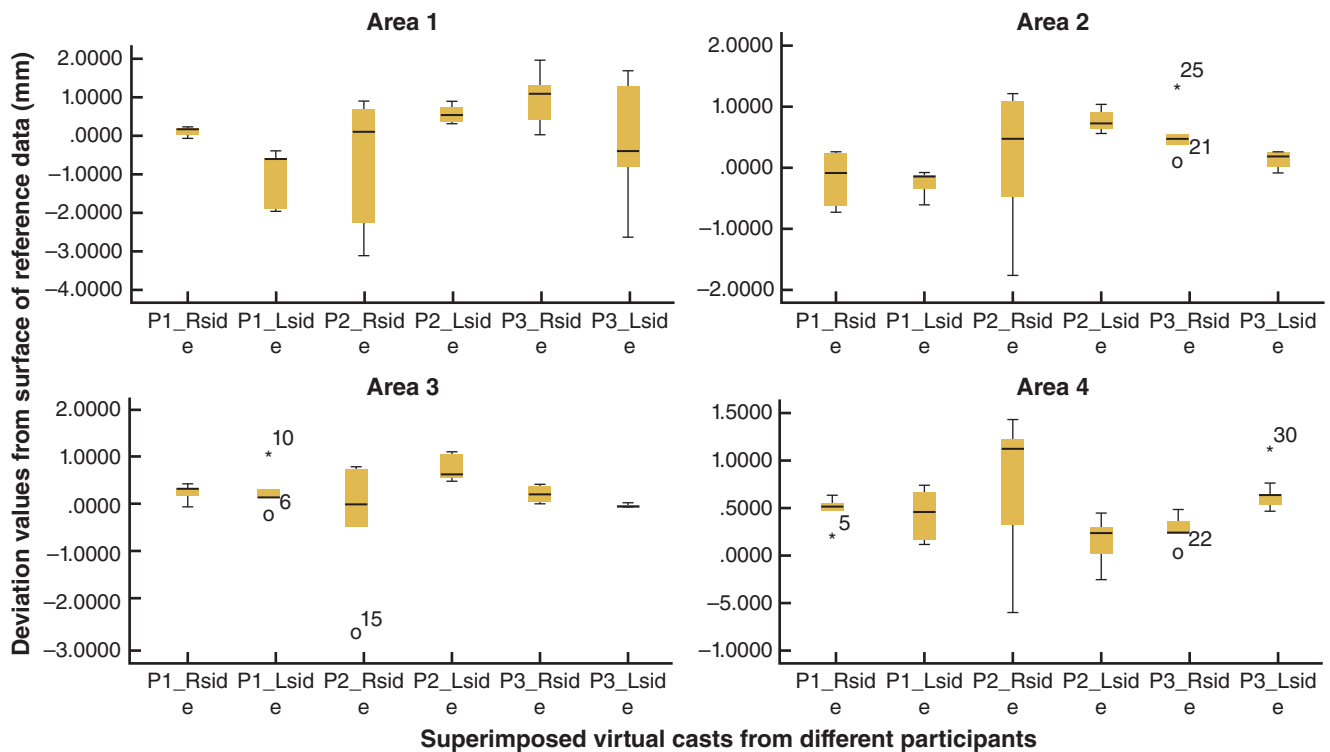


Figure 4. Boxplots of deviation values of four different areas from three participants.

outcome of the ACIT. However, the results of comparisons in area 1 among the 3 participants, as shown in Table 3, were statistically similar except in 2 comparisons ($P < .047$) and ($P < .028$), respectively, and this difference is unlikely to be clinically important, as reported previously.^{19–21} However, in other studies^{1,2,4,7,22} a statistically significant difference in vertical movement was found; however, the authors did not determine whether this difference was clinically relevant.

In the present study, the ACIT resulted in higher displacement over the BSA. The BSA has a cortical bone and buccinator muscle connection, which makes it resistant to resorption, and it may withstand greater occlusal forces than the surrounding tissues.²³ For tooth-tissue supported RPDs with a distal extension, a denture flange should completely cover this area to maximize the denture retention, stability, and support.²⁵

In the present study, areas 2, 3, and 4 were subjected to less tissue displacement with the ACIT than the values of area 1; however, the differences were small and some were not statistically significant. The null hypothesis that no difference would be found between the 2 impression techniques when comparing both sides of

the edentulous ridge within the same participant and among the 3 participants was rejected as there were differences between the 2 impression techniques in the same participant and among the 3 participants on both sides; however, most of the differences were minor and not statistically significant.

Abt et al⁵ stated in their Cochrane review that the information available for evaluating whether conventional cast RPDs are better or worse than RPDs produced using ACIT was inadequate. A systematic review indicated that the straightforward 1-step definitive impression approach is equal to, or even better than, the ACIT, which requires greater technical skill, higher costs, and more time. In clinical practice, many dentists prefer more straightforward impression processes for the provision of distal extension RPDs.¹²

In the present study, a novel 3D analysis was used to compare the 2 impression procedures. However, limitations of the study included the sample size of only 3 participants. Furthermore, the optimal alignment methodology for obtaining the most accurate comparisons is unclear. Further research with a larger sample size is required. A comparison with digital scanning technology is also needed.

Table 2. Nonparametric Wilcoxon signed-rank test (matched-pairs) analysis of differences between right and left sides of same participant

Comparison	Area 1			Area 2			Area 3			Area 4		
	Wilcoxon W ^Δ	Z-Value	P*	Wilcoxon W	Z-Value	P	Wilcoxon W	Z-Value	P	Wilcoxon W	Z-Value	P
P1 R side and P1 L side	15,000	-2.611	.009	27,000	-.104	.917	24,000	-.731	.465	26,000	-.313	.754
P2 R side and P2 L side	23,000	-.940	.347	25,000	-.522	.602	21,000	-1.358	.175	21,000	-1.358	.175
P3 R side and P3 L side	22,000	-1.149	.251	18,000	-1.984	.047	16,000	-2.402	.016	16,000	-2.402	.016

ACIT; altered cast impression technique; CDI, conventional definitive impression; L, left; P, participant; R, right.

^Δ Wilcoxon test applied to assess differences between right and left sides of same participant.

*Statistical significance $P < .05$.

Table 3. Nonparametric analysis of differences between right and left sides among three participants

Comparison	Area 1			Area 2			Area 3			Area 4		
	Mann-Whitney U ^Δ	Z-Value	P*	Mann-Whitney U	Z-Value	P	Mann-Whitney U	Z-Value	P	Mann-Whitney U	Z-Value	P
P1 R side and P2 R side	12	-.104	.917	8	-.940	.347	11	-.313	.754	9	-.731	.465
P1 R side and P3 R side	3	-1.984	.047	2	-2.193	.028	12	-.104	.917	5	-1.567	.117
P2 R side and P3 R side	5	-1.567	.117	10	-.522	.602	10	-.522	.602	7	-1.149	.251
P1 L side and P2 L side	0	-2.611	.009	0	-2.611	.009	4	-1.776	.076	6	-1.358	.175
P1 L side and P3 L side	9	-.731	.465	0	-2.611	.009	5	-1.567	.117	8	-.940	.347
P2 L side and P3 L side	10	-.522	.602	0	-2.611	.009	0	-2.611	.009	0	-2.611	.009

ACIT; altered cast impression technique; CDI, conventional definitive impression; L, left; P, participant; R, right.

^ΔMann Whitney test applied to assess differences between right and left sides among participants.

*Statistical significance $P < .05$.

CONCLUSIONS

Based on the findings of this pilot study, the following conclusions were drawn:

1. A digital comparative analysis of the CDI and ACIT methods for bilateral distal extension of partially edentulous mandibular arches showed that the ACIT method exhibited controlled tissue displacement and applied more displacement on area 1 compared with areas 2, 3, and 4, which experienced less displacement.
2. However, the differences between the 2 techniques in the tissue displacement of the examined areas were minimal.
3. Overall, the outcomes of the ACIT were close to those of the CDI technique, and differences may lack clinical significance.

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Corresponding author:

Dr Matheel AL-Rawas
Prosthodontics Unit
School of Dental Sciences
Health Campus
Universiti Sains Malaysia
Kubang Kerian, Kota Bharu, Kelantan 16150
MALAYSIA.
Email: matheel@usm.my

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PATIENT CONSENT

Informed patient consent has been obtained.

CRedit authorship contribution statement

Matheel AL-Rawas: Conceptualization, Data curation, Investigation, Methodology, Software, Validation, Writing- original draft preparation. **Johari Yap Abdullah:** Software, Validation, Writing- reviewing and editing. **Belal Elmarhoumy:** Data curation, Investigation and **Yanti Johari:** Visualization, Supervision. **Azirrawani Ariffin:** Supervision, Writing- reviewing and editing. **Adam Husein:** Validation, Writing- reviewing and editing.

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