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Assessment of tooth positions tooth displacement during the cast-free digital processing of milled dentures

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Abstract

Aim: The purpose of this clinical study was to evaluate the accuracy of tooth position with milled digital dentures processed without physical casts.

Methodology: Ten maxillary and 10 mandibular dentures designed from intraoral scans, milled, and processed without physical casts were investigated. The standard tessellation language (STL) files of the digitally designed dentures were compared with the scan of the dentures after processing (milling the denture base, milling teeth in a complete arch, and then bonding teeth into the base). The STL files were superimposed by using a surface-matching software program. After a preliminary alignment, the STL meshes were trimmed and reoriented; then, the final alignment was carried out by using the cameo surface. Six reference points (th mesiobuccal cusp on the most distal molar, the canine cusp, the middle of the incisal edge of the central incisor on both the left and the right side) were selected to measure tooth displacements along the X-, Y-, and Z-axes, corresponding (from the preliminary reorientation) to anteroposterior, mediolateral, and occlusal displacement, respectively.

Tooth position accuracy was assessed by using median and interquartile range values. Univariate and multivariate statistical analyses were used to investigate the significance of the extent of displacements, as well as differences among displacement directions, reference teeth, side, and denture arch type (α=.05).

Results: Only the median (0.2 mm; interquartile range: 0.27 mm) occlusal displacement was significantly different from zero. A generalized estimated equation model addressing occlusal displacement as a dependent variable showed no significant effect of tooth type, side, or denture arch type, either alone or in combination. **Conclusion;** The tooth position of both maxillary and mandibular milled digital dentures processed without physical casts was accurate in the anteroposterior and mediolateral directions. Occlusal displacement seemed to be within the range of clinical acceptability; its consistency throughout the arch allowed optimization or compensation at the design or manufacturing step.

Keywords: Tooth Position, Milling, Digital Dentures, Occlusal Displacement

Introduction

The manufacturing process for dentures can cause teeth to shift, which can have a big effect on how the prosthesis fits together. The anatomy of the artificial teeth1 or the occlusal vertical dimension may need to be drastically altered due to displacement, requiring clinical and/or laboratory corrections. Both traditional and digital denture processing methods can result in deviations from the intended tooth arrangement.[3] A maximum value of 1 mm for the traditional injection moulding method5 and 0.64 mm for digital dentures6 have been observed. These can occur at various phases of the manufacturing process4. Getting the highest manufacturing accuracy is advantageous, even though an increase of up to 1 mm in the vertical dimension of occlusion after processing complete dentures using standard techniques has been deemed acceptable. Through the management or elimination of a variety of elements involved in processing distortion, the processing of removable dentures utilising computer-aided design and computer-aided manufacturing (CAD-CAM) technology offers the potential to minimise tooth movement.[8] It has been claimed that milled CAD-CAM dentures offer greater accuracy and reproducibility than traditional processing methods.[9] A technique for the digital manufacturing of full dentures that begins with intraoral images and eliminates physical moulds has just been put forth[10] There is a paucity of information about the milled, cast-free denture's tooth movement.

This clinical research's goal was to assess how accurately milled teeth were bonded to the milled denture foundation without the use of physical casts to create digital dentures using a fully digital approach.[10] The underlying assumption was that the teeth's positions in the final denture would be identical to those in the digital file used to create it.

Methodology

The research project has gained permission from the institutional review board. 15 patients' complete dentures, 10 of which were mandibular and 10 of which were maxillary, were examined. Before beginning this investigation, a pilot study was done to validate the methodology. Based on the results of the pilot study and under the assumption of a high effect size, it was determined that a sample size of roughly 10 dentures would have 80% power to detect a significant difference, in line with earlier research.[9] Each and every set of dentures was made in accordance with the process outlined by Lo Russo et al.[10] An intraoral scanner (TRIOS 3; 3Shape A/S) was used to take intraoral scans of the edentulous arches, and the dental system software (Dental System software; 3Shape A/S) was used to design the dentures by selecting the option "designed base and teeth": the teeth connected into a complete arch

(Fig. 1). Denture bases (Fig. 2) and teeth (Fig. 1) were fabricated using a Roland DWX-51D milling machine (Roland DG Corp) using polymethyl methacrylate blanks that were 25 mm thick (Ruthinium DISC pink; Dental Manufacturing S.P.A.) and multilayer (Ruthinium DISC multilayer; Dental Manufacturing S.P.A.). A fast-polymerizing acrylic resin (Jet Repair; Lang Dental Mfg Co, Inc.) was used to bind the tooth arch to the base as a single unit (Fig. 3). The resin powder and monomer were combined in accordance with the manufacturer's instructions before being used to fill the denture base's tooth sockets, place the tooth arch, and apply manual compression. A tiny brush was used to remove the extra resin. Without any polishing or additional processing following bonding, each denture was scanned using the same intraoral scanner (TRIOS 3; 3Shape A/S) by using the "scan only" capturing workflow. The scan of the denture was exported as a standard tessellation language (STL) file and used for 3-dimensional (3D) analysis.

Figure 1: Milled teeth connected into single arch

Figure 2: Milled denture base.

Figure 3: A- Milled denture base, tooth arch before bonding. B - Example of definitive maxillary denture.

The methodology used for comparisons and measurements for 3D analysis was as follows: for each denture, the STL files of the designed denture and the corresponding STL files of the scanned denture were imported into a piece of software (Geomagic Wrap 2021; 3D Systems Inc.) to carry out a 2-phase best-fit preliminary alignment. To increase the precision of the superimposition and measurements after alignment, the intaglio surface of the created and scanned dentures was trimmed.11 To enable any tooth displacement to be measured along the occlusal displacement along the Z-axis, displacement on the sagittal plane along the X-axis, and displacement on the frontal plane of the global coordinates system, the position of the trimmed dentures (both designed and scanned) was altered along the Y-axis (Fig. 4). In order to do this, the first molar line was chosen as the origin of the axes, which were then centred left and right, and the XY plane was chosen to be parallel to the occlusal plane. Then, using only the cameo surface of the denture base as a consideration, a fresh alignment method had to be carried out using a best-fit. A colour difference map was created to visualise the deviation patterns, and the mean distance between the surfaces utilised for the final alignment was taken into account as an indicator of alignment correctness (Fig. 5).

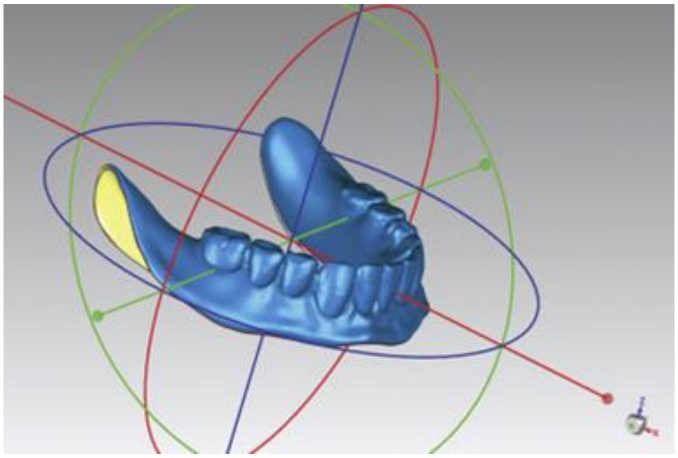

Figure 4: Setting of axes origin to direct potential tooth displacement along coordinates system; Z-axis: occlusal displacement; X-axis: anteroposterior displacement; Y-axis: mediolateral displacement

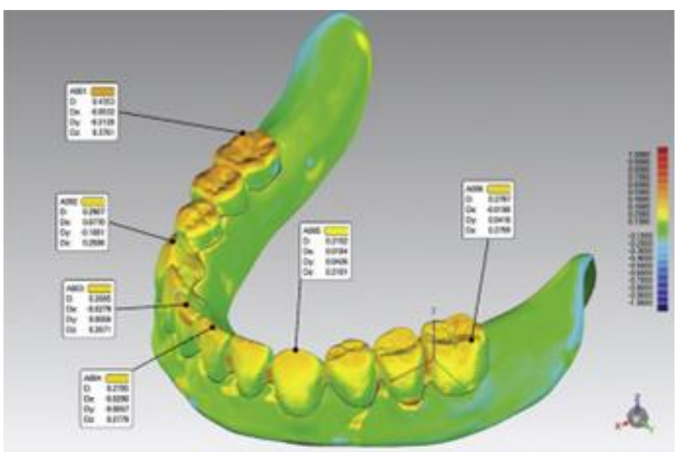

Figure 5: Color difference map of scanned denture aligned to designed denture. Measurements of tooth displacement performed at reference points.

The canine cusp, the midpoint of the incisal edge of the central incisor, and the mesiobuccal cusp of the most distal molar (M), on both the left and right sides, were used as the six reference points for measuring tooth displacement (Fig. 5). At these reference sites, the separation between the intended and scanned dentures indicated the tooth displacement. According to the preliminary reorientation, this distance was measured along the X, Y, and Z axes (Fig. 6), which correspond to anteroposterior, mediolateral, and occlusal displacement, respectively. The 6 reference points (M, C, I: 3 per side) were thus labelled for each denture with information on the X, Y, and Z axes displacement, the kind of denture arch (maxillary or mandibular), and the side (right or left).

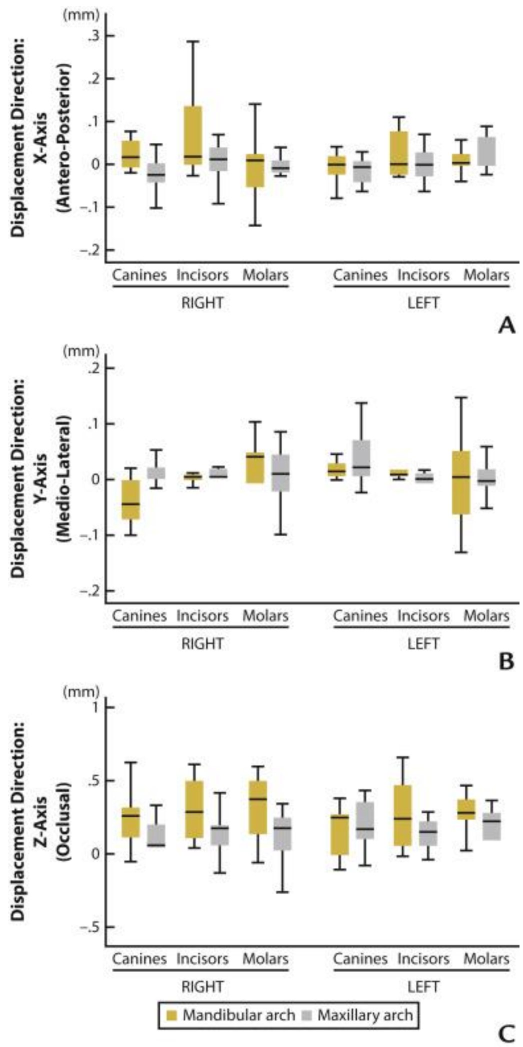

Figure 6: Measured tooth displacement stratified for denture arch type, reference teeth, and side. A, Anteroposterior direction. B, Mediolateral direction. C, Occlusal direction.

To determine if the alignment accuracy was significantly different from zero or not, the 1-sample t test was performed. The same procedure was used to determine whether the median X-, Y-, and Z-axis tooth displacements were significant. The distance between the intended denture and the scanned denture would be 0 if they exactly coincided and no displacement happened at all, assuming that an accurate superimposition was produced. Therefore, the 1-sample t test was applied to the data for each axis in order to determine the following: Is the median distance that was recorded significantly different from 0? A statistical software programme was used to conduct tests of hypotheses (=.05). A generalised estimated equation (GEE) model was used to examine the impact of measurement positions on discrepancies along the X-, Y-, and Z-axes both between and within dentures. The within-unit measurements from the six locations were modelled and managed using the GEE approach. The denture was utilised as the subject variable, and the variations of the other 2 axes were included as covariates. The tooth type (molar/canine/incisor), arch type (maxillary/mandibular), and side (right/left) were included as factors to study differences measured along each axis. The model also took into account the nested measurement of teeth on the same side and arch. A statistical programme (IBM SPSS Statistics, v25.0; IBM Corp) was used to conduct the analysis (p .05).

Results

The final alignment of the intended and scanned dentures' surfaces' median distance was not statistically different from zero (Wilcoxon test: P=.266), indicating that the alignment procedure was reasonably accurate. Only the median (0.2 mm) Z-axis displacement, which corresponds to the displacement in the occlusal direction (Table 1), was significantly different from zero (Wilcoxon test: P.001); the medians (0 mm) X-axis (anteroposterior) displacement and (0 mm) Y-axis (mediolateral) displacement were not (Wilcoxon test: P=.272 and P=.559, respectively). Therefore, the occlusal direction (Z-axis) represented the sole significant displacement. the tooth type, side, and denture arch type as independent variables, and occlusal displacement as a dependent variable. The GEE model addressing occlusal displacement as a dependent variable, with tooth type, side, and denture arch type as factors and X- and Y-axis displacements as covariates showed no significant effect of tooth type, side, or denture arch type, either alone or in combination (Table 2).

Table 1: Results for investigated tooth displacements.

Reference Group	X-axis Displacement (Anteroposterior) (mm)		Y-axis Displacement (Mediolateral) (mm)		Z-axis Displacement (Occlusal) (mm)	
	Median	IQR	Median	IQR	Median	IQR
Total data set statistics (all 120 reference points)	0	0.05	0	0.03	0.2	0.27
Maxillary dentures (60 reference points on maxillary dentures)	0	0.12	0	0.08	0.17	0.3
Molars	-0.01	0.03	0	0.04	0.19	0.24
Canines	-0.01	0.05	0	0.05	0.15	0.18

Incisors	0.01	0.05	0	0.02	0.16	0.16
Mandibular dentures (60 reference points on mandibular dentures)	0.01	0.05	0	0.04	0.26	0.31
Molars	0.01	0.04	0.02	0.1	0.28	0.31
Canines	0.01	0.04	0	0.08	0.25	0.27
Incisors	0.01	0.11	0	0.01	0.25	0.54

IQR, interquartile range.

Table 2: Results from generalized estimated equation model addressing effects of investigated factors on occlusal (Z-axis) displacement.

Parameter	B	*P*	Lower 95% C.I.	Upper 95% C.I.
Y-axis	-0.294	.120	- 0.664	0.077
X-axis	0.184	.366	- 0.215	0.583
Tooth	—	—	—	—
Incisor (ref.)	1.	—	—	—
Canine	0.006	.783	-0.038	0.051
Molar	0.022	. 823	-0.172	0.216
Arch	—	—	—	—
Maxillary (ref.)	1.	—	—	—
Mandibular	0.166	.103	-0.034	0.365
Side	—	—	—	—
Left (ref.)	1.	—	—	—
Right	-0.015	.783	-0.044	0.14
[Tooth=Molar]([Arch=Lower)]	0.021	.836	-0.178	0.219
[Tooth=Canine]([Arch=Lower)]	-0.047	.203	-0.118	0.025
[Tooth=Molar]([Side=Right)]	0.003	.965	-0.110	0.115
[Tooth=Canine]([Side=Right)]	-0.017	.658	-0.093	0.059
Intercepts	0.104	.192	-0.052	0.260

Discussion

Monolithic dentures made with CAD-CAM technology may have little tooth displacement[9], but there may be downsides in terms of their aesthetics or accessibility to their particular technologies. As a result, methods for processing digital dentures that involve bonding teeth to denture bases are frequently employed.[3,12] A process where teeth are bonded into the base before finishing milling is done[3] has the potential to reduce variations in tooth position from the intended tooth arrangement, but it necessitates moving the disc to exactly the same location in the milling machine, which is not possible for all milling machines. Therefore, understanding the probable tooth displacement brought on by denture production has clinical and useful applications. In the current research, tooth position accuracy was examined using milled digital dentures that were created without using physical moulds.[10] This method involves bonding the tooth arch into a "socket" created in the CAD workflow and milling it into the denture foundation. Therefore, tooth displacements that are united into a single arch, either anteriorly or posteriorly, are rare; this could be due to manufacturing error. On the other hand, occlusal displacement is conceivable given that acrylic resin is used to attach the teeth to the denture base. As a result of the teeth being joined into a single arch, the chosen 6 reference points, which are dispersed across the arch, may be able to detect tooth displacement in all directions.

The outcomes demonstrated that the alignment method produced a superimposition that was pretty accurate. The mediolateral or anteroposterior displacements did not differ substantially from zero. Therefore, the processed dentures were essentially consistent with the digital files produced by the design process for displacements in these directions (X- and Y-axes); as a result, the researched processing technique may produce high precision for tooth position on the X- and Y-axes (Table 1). The X- and Y-displacements were quite similar to those reported by Goodacre et al[9] for buccal movement (-0.01 mm to 0.103 mm) or mesiodistal movement (-0.09 mm to 0.112), with median values (0 mm) and interquartile range (0.05 mm to 0.03 mm). The stated accuracy of the measured X and Y deviations' interquartile ranges is within the reported accuracy of the intraoral scanner used in the present study, as reported both by clinical11 and in vitro13 studies.

The results of the current investigation demonstrate that there is no considerable posterior shift, which is important for maintaining the intended occlusion.[14] But it was discovered that there was a significant median (0.2 mm) displacement in the occlusal direction. The process to attach the teeth onto the base may have contributed to the observed displacement because milling has been shown to give good trueness of the socketed surface of the denture base15. The measured occlusal displacement was more than that reported by Goodacre et al[9] (-0.044 mm) and less than that reported by Kanazawa et al8 (0.50 mm), despite the fact that only maxillary dentures were examined in the later study and just one denture was examined in the former. Mandibular dentures were also explored in the current study, and the findings showed no significant differences when compared with maxillary dentures. The interquartile range measured in the occlusal direction (0.27 mm) was higher than that in the previous study[9] (0.12 mm). Tooth displacement in the occlusal direction associated with the maxillary dentures included in the present study (0.17 mm) was similar to that reported[9] for conventional “pack and press” (0.16 mm) or “injection” (0.18 mm) techniques.

Although it appeared to be within the range of clinically acceptable displacement, the clinical implications of such an occlusal displacement has to be further examined. It has been determined that a 1-mm increase in vertical dimension due to a 0.25-mm occlusal displacement is acceptable.[7] Additionally, the occlusal displacement recorded in the present study was constant throughout the arch, in both anterior and posterior teeth, as well as on the right and left side, with no significant effect identified for any of the analysed factors, as evidenced by results from the GEE model. Because it enables optimisation or correction for such an occlusal displacement at the design or manufacturing process, this finding has valuable and practical ramifications. Depending on the specific technology or system, this potential might exist. Future research should address such potential limitations in the context of developing adequate approaches for minimal tooth displacement.

Conclusion

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

- The tooth position of both maxillary and mandibular milled digital dentures processed without physical casts was stable in the anteroposterior and mediolateral direction.
- Care should be taken to minimize occlusal displacement.

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