

Article

Assessing the Predictability of a Digital Workflow for Manufacturing Provisional Maxillary Dentures and Implant-Supported Mandibular Protheses—Observational Case Series

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Abstract

Objective: The aim of this study was to assess the predictability of a digital workflow for manufacturing provisional maxillary removable dentures and immediately loaded implant-supported mandibular protheses. **Materials and Methods:** Eighteen completely edentulous patients were enrolled. Complete dentures, when present, were adapted; when they were absent, records with a denture base and wax rim were fabricated. The adjusted protheses were scanned, generating STL files; photographs with the protheses in occlusion were used to generate a virtual patient; and lateral cephalometric radiographs were obtained. Virtual tooth arrangement was performed, and, after approval, a maxillary denture and a mandibular prosthesis in multifunctional guide format were printed and evaluated intraorally. Four implants (Nuvo, Brazil) were installed using a guide (which was also used as a tray and for registration). In the laboratory, the guide was converted into an interim fixed prosthesis. After installation, the protheses were evaluated independently by three examiners. A new lateral cephalometric radiograph was obtained in occlusion. Descriptive analysis of the data obtained from the professional evaluation was carried out, and the Shapiro–Wilk test was used to test the adherence of the data to a normal distribution for quantitative variables. **Results:** The professional satisfaction rate for the clinical evaluation and installation of the protheses was >9. The different factors were always favorably appraised, with strong agreement between examiners. The cephalometric analysis of OVD showed reproducibility with respect to the initial clinical determination. **Conclusions:** Although the study included a small number of patients, based on the results obtained, it seems reasonable to conclude that this digital workflow exhibits predictability for rehabilitation with 3D-printed provisional maxillary dentures and immediately loaded implant-supported provisional protheses.

Keywords: prosthetic preparation; dental implant; intraoral scanner; implant-supported prosthesis; denture; digital dentistry



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1. Introduction

The global increase in life expectancy has brought about a greater need for tooth replacement in the elderly population [1,2]. Maintaining good long-term oral health depends on the quality of the rehabilitation performed [3,4]. Implant-supported prostheses, including those with immediate loading, are reliable and predictable for edentulous patients, as long as the prosthetic and surgical planning enable the correct positioning of the implants [5–8]. One technique for procedures for the mandible, with careful prosthetic planning that incorporates a multifunctional guide, has been well-documented and scientifically validated [9–12].

Digital technology has significantly altered dental clinical procedures [13–15]. Intraoral scanners offer advantages, including being easy to use, reducing clinical appointments, improving patient comfort, and yielding accurate results for implant-supported prostheses [16–21]. However, the digitalization of completely edentulous arches presents challenges, including achieving correct denture base extension, obtaining a peripheral seal, and ensuring accurate digital alignment in the maxillomandibular relationship. These challenges have led to the proposal of techniques such as additional scans and the use of sectional maxillomandibular relationship recordings [22–25].

Methods involving scanning mucosally supported dentures and alveolar ridges, using Gothic arch tracing for the centric position, have been described for 3D-printed complete dentures [26]. Scanning existing dentures also aids in the fabrication of surgical guides, with subsequent adjustments and rescanning for new 3D-printed dentures [27,28]. However, dentures often present challenges like inadequate vertical occlusion, impacting the predictability of digital workflows [29]. Therefore, in this study, we aimed to assess the predictability of a digital workflow for manufacturing 3D-printed mucosally supported maxillary and immediately loaded implant-supported mandibular interim restorations, specifically in completely edentulous patients without prostheses or those who have undergone previous unsatisfactory prosthetic rehabilitations.

2. Materials and Methods

This study was designed as an observational case series. This study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. The completed STROBE checklist is provided as Table S1. The study protocol was approved by the Research Ethics Committee of the Bauru School of Dentistry, University of São Paulo (CAAE: 46102921.7.0000.5417). All participants were fully informed about the study protocol and provided written informed consent prior to their inclusion. Eighteen completely edentulous individuals aged ≥ 18 years, with or without existing maxillary and mandibular complete dentures, who were in good general health and had sufficient bone volume for implant placement in the anterior mandible were recruited at Brånemark Center Clinic (Bauru, São Paulo, Brazil) in February 2022. Bone availability in the anterior mandible was initially assessed using panoramic radiographs (Figure 1) and confirmed by cone-beam computed tomography (CBCT).

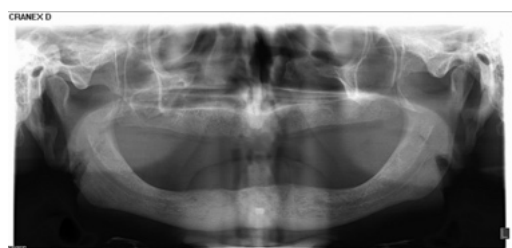


Figure 1. Initial panoramic radiograph.

The exclusion criteria included acute infectious or inflammatory processes, systemic diseases, or complications that could compromise bone metabolism or wound healing; incomplete mandibular growth; pregnancy; alcohol abuse; psychiatric disorders that could interfere with compliance; and a lack of cooperation or motivation to participate in the study.

2.1. Preoperative Prosthetic Workflow

The tooth/lip relationships of pre-existing prostheses and overall rehabilitation conditions were evaluated, including the vertical dimension of occlusion (OVD), the horizontal maxillomandibular relationship, tooth color and size, facial proportions, and amount of tooth exposure (at rest, during speech, and when smiling). When necessary, modifications were made and reference points were transferred to the existing prosthesis using Pattern Resin (GC America Inc., Alsip, IL, USA) and pen markings. The reference for new tooth length, OVD, and registration position was first created by constructing a device in the anterior sector by bonding Pattern-type resin to the maxillary central incisors. After confirmation, two additional bilateral occlusal records were obtained with the same material. The occlusal plane orientation was guided using a Fox plane (JON, São Paulo, Brazil). Conventional aesthetic analysis methods were applied.

The peripheral seals of the prostheses were established using low-fusing Godiva (Kerr, Orange, CA, USA). A functional impression was subsequently obtained using light-body VPS silicone (Neodent, Curitiba, Brazil). The material was applied to the intaglio surface of both the upper and lower bases, which had been previously coated with a Universal adhesive (Zhermack, Rome, Italy) to enhance material retention. The patients were instructed to keep their mouths closed such that occlusion was achieved without applying excessive pressure, while cheek and tongue movements were performed to capture functional extensions. Finally, excess material was cut off. A lateral cephalometric radiograph was obtained with the patient in a position achieving occlusion (Figure 2).

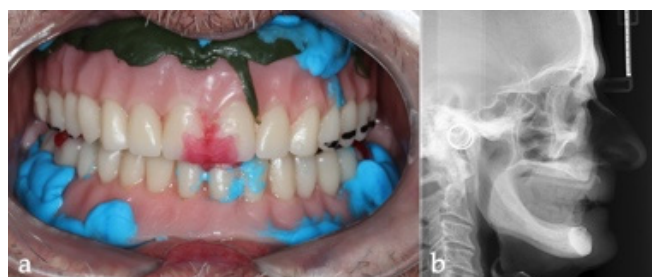


Figure 2. (a) Frontal photograph of the prostheses in position after registration and functional impression of the internal surface. (b) Profile cephalometry with the patient in occlusion after adaptation of the prosthesis.

After all adjustments had been made, frontal and profile photographs were obtained with the prostheses in position and the patient adopting a posed smile (Figure 3). The cameo and intaglio surfaces of the adjusted prostheses were scanned, and an extraoral scan was conducted to register the spatial relationship (Virtuo Vivo, Straumann, Basel, Switzerland) (Figure 4). The STL files and photographs were aligned using CAD software (Ceramill Mind, Amann Girrbach, Koblach, Austria) and sent to the dental laboratory (DLab, Curitiba, Paraná, Brazil) along with detailed instructions for the required modifications. A virtual tooth setup was established based on the previously established reference markings, and adjustments were made until the definitive prosthetic design was finalized (Figure 5).

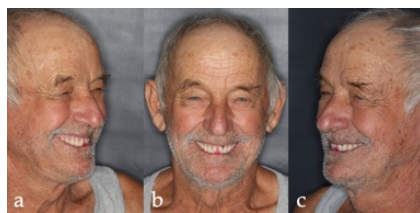


Figure 3. Photographs, with the modified prostheses in place, to be sent to the laboratory: (a) right profile, (b) front photograph, and (c) left profile.

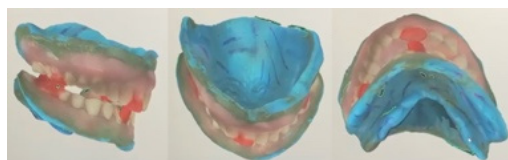


Figure 4. Scanning images of the prostheses with occlusal records.



Figure 5. Virtual patient assessment. (a) Teeth considered large. (b) Final approval with alterations suggested.

In cases without a pre-existing prosthesis, we obtained impressions of the edentulous arch using addition silicone (VPS impression material (Neodent, Curitiba, Paraná, Brazil)), following a two-step technique to fabricate record bases and wax rims, which were subsequently adjusted intraorally according to the principles described above. After the adjustments were made, border molding was performed, and functional impressions were made using the closed-mouth technique. For scanning procedures as well as photographic and radiographic records, we followed the same methodology described for patients with existing prostheses.

Once the digital tooth arrangement was approved, the CAD design files were sent for 3D printing of the maxillary and mandibular complete dentures using a 3D-printable denture resin (Cosmos Denture; Yller, Pelotas, Rio Grande do Sul, Brazil) via a P40 printer (Straumann, Basel, Switzerland). The maxillary prosthesis was printed in two parts (teeth and base), whereas the mandibular prosthesis was printed as a single-piece design with a lingual window, allowing its use as a multifunctional surgical guide.

During the pre-surgical clinical try-in, the prostheses were evaluated intraorally, and any necessary adjustments were made. Subsequently, three interocclusal registration points (incisal and posterior molar regions) were established using Pattern resin to stabilize the prostheses during the surgical procedure. The patients were then released for the implant surgery.

2.2. Surgical and Immediate Prosthetic Workflow

A full-thickness mucoperiosteal flap was elevated, and the multifunctional guide was positioned and used as a reference for osteotomy preparation (Figure 6). All the patients received four implants (Nuvo, Curitiba, Paraná, Brazil), with a minimum insertion torque of 40 Ncm. After implant placement, mini conical abutments were selected and installed with a final torque of 32 Ncm. Suturing was performed, and impression copings were

subsequently connected and splinted to each other and to the guide using Pattern resin (Figure 7). After the guide was rigidly splinted, the interocclusal registration was verified, and addition-based silicone VPS (Neodent, Curitiba, Brasil) was injected onto the intaglio surface of the guide to obtain the definitive impression. The definitive impression was removed and disinfected according to standard clinical protocol (Figure 8). Mini conical abutment analogs were connected to the impression copings for laboratory procedures (Figure 9).



Figure 6. Printed multifunctional guide and positioners installed in the milled areas to check milling.



Figure 7. MUA impression coping attached to the multifunctional guide.



Figure 8. Bottom and top view of the multifunctional guide printed after the impression procedure.

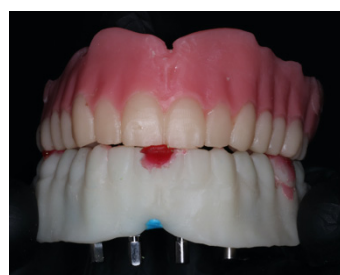


Figure 9. Upper prosthesis and lower guide with screwed analogs.

2.3. Prosthetic Laboratory Workflow

A gypsum cast was fabricated from the definitive impression. Prosthetic cylinders (Nuvo) were connected to the mini-abutment analogs, and a distal bar framework was

constructed, with grooves prepared on the two anterior cylinders and bar extensions on the two posterior cylinders. The framework was then bonded to the guide using self-polymerizing acrylic resin (VIPI, Pirassununga, São Paulo, Brazil). After polymerization, the gingival portion was characterized using gingival pigment (Cosmos Creation (Yllar, Pelotas, Brazil)).

2.4. Prosthetic Assessment and Adjustment Protocol

The prostheses were inserted (Figures 10 and 11), and any necessary occlusal and fit adjustments were made. Prosthesis adaptation was assessed clinically and via periapical radiographs. For evaluation, the prostheses were temporarily secured using two fixation screws to allow evaluation of passive fit and occlusal stability (Figure 12).



Figure 10. Frontal view of the prostheses inserted one day after implant installation.



Figure 11. Frontal view of the patient with the 3D-printed interim prostheses installed: (a) profile and (b) smiling.

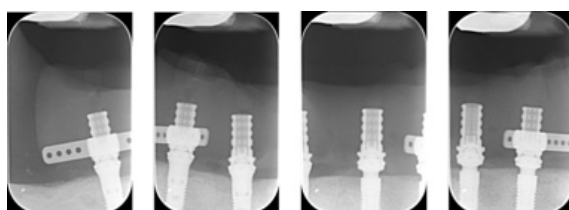


Figure 12. Periapical radiographs taken during prosthesis installation.

After the prostheses were installed, all patients underwent a lateral cephalometric radiograph with the prostheses in occlusion (Figure 13). A cephalometric analysis (the Seraidarian–Tavano method) was performed based on angular measurements. It is recommended for assessing OVD even in edentulous individuals [30]. This approach allowed accurate evaluation of the reproducibility of the OVD established during interim prosthesis planning. A prosthodontist, blinded to the planning records, compared the initial registration with the provisional rehabilitation.

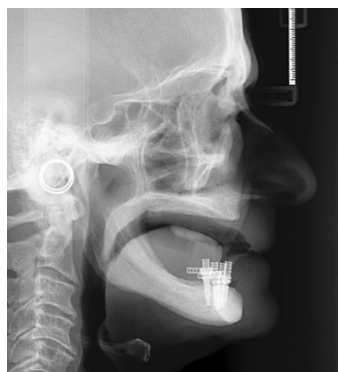


Figure 13. Profile cephalometry photo taken during the installation of temporary prostheses.

The clinician responsible for the impression procedure and prosthesis insertion determined satisfaction using a structured questionnaire (Figure 14). To assess specific rehabilitation-related variables, three independent clinicians with experience in oral rehabilitation (three implantology specialists, including one prosthodontist) evaluated the cases using a standardized assessment form containing predefined criteria. All evaluations were performed independently. The evaluators were trained on the criteria to be applied: “optimal” (when the evaluated item could be considered perfect) or “acceptable” (in cases where the item could have been slightly better but without compromising the result). If any item were deemed “not ideal,” the prosthesis would be remade. This did not occur in any case; therefore, the “not ideal” category does not appear in the table.

Clinician Satisfaction (T0)

1. Are you satisfied with the impression procedure for prosthesis confection?

0 ————— 10
Completely unsatisfied Completely satisfied

Enter the measurement cm

2. Are you satisfied with the general outcomes of the maxillary rehabilitation?

0 ————— 10
Completely unsatisfied Completely satisfied

Enter the measurement cm

3. Are you satisfied with the general outcomes of the mandibular rehabilitation?

0 ————— 10
Completely unsatisfied Completely satisfied

Enter the measurement cm

3. Are you satisfied with the aesthetic results of the rehabilitation?

0 ————— 10
Completely unsatisfied Completely satisfied

Enter the measurement cm

Role	Signature	Date
Principal Investigator or Designee		

Formulário / FORM: FORM-CL5.078.007 - Relatório do Caso / Case Report Form- Revisão / Revision: 01 - Publicado em / Published in: 04/10/2018
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Figure 14. Professional satisfaction questionnaire, VAS.

Statistical analysis was performed to evaluate professional satisfaction at the two stages of prosthetic treatment (pre-surgical clinical try-in and prosthesis delivery). Descriptive analysis included the mean, median, standard deviation, and the 25th and 75th percentiles for quantitative variables, as well as the absolute and relative frequencies for qualitative variables. The Shapiro–Wilk test was performed to test the adherence of the data to a normal distribution for the quantitative variables. To better visualize these analyses, bar

graphs were produced. All tests were considered significant when $p < 0.05$. Statistical analyses were carried out in the R 4.2.0 environment [31].

3. Results

The sample consisted of 18 individuals—11 females (61.1%) and 7 males (38.9%)—with a mean age of 65.8 years (± 1.9). Six participants had no mandibular prosthesis, and two participants had no prosthesis at all.

Table 1 shows the statistical analysis of the data collected in the presurgical clinical test.

Table 1. Characterization of the data collected in the presurgical test.

Variable		N	%
Does the centric relation coincide?	No	4	22.22
	Yes	14	77.77
Bilateral contact	No	7	38.88
	Yes	11	61.11
Occlusal adjustment	Not required	8	44.44
	Required	10	55.55
Good vertical dimension of occlusion	No	3	16.67
	Yes	15	83.33
Lip frenulum adjustments	Not required	10	55.55
	Required	8	44.44
Lower surgical guide stability	Yes	18	100.0
	No	4	22.22
Good visual aspect of peripheral sealing	Yes	14	77.78
	No	7	38.89
Retention of peripheral sealing	Yes	11	61.11
	No	1	5.56
Coincident midline	No	1	5.56
	Yes	17	94.44

N = absolute frequency; % = relative frequency.

Table 2 shows the results of the satisfaction index obtained by the professional who performed the rehabilitation (scores were assigned to the items using a Visual Analog Scale).

Table 2. Operator scores assessed using a Visual Analog Scale (VAS).

	Mean ($\pm$ SD)
Are you satisfied with the impression procedure used to make the prosthesis?	9.6 $\pm$ 0.7
Are you satisfied with the overall results of your maxillary rehabilitation?	9.3 $\pm$ 1.5
Are you satisfied with the overall results of mandible rehabilitation?	9.7 $\pm$ 0.5
Are you satisfied with the aesthetic results of the rehabilitation?	9.5 $\pm$ 1.2

SD = standard deviation.

The data collected in the analysis carried out by the three independent examiners after the rehabilitations were performed are presented in Table 3 (maxillary prosthesis), Table 4 (mandibular prosthesis), Table 5 (quantitative variables pertaining to the mandibular prosthesis), and Table 6 (general aspect of rehabilitation).

Table 3. Maxillary prosthesis assessment data for each examiner.

Variable		Examiner 1		Examiner 2		Examiner 3		Examiners Agreement		Examiners Disagreement	
		N	%	N	%	N	%	N	%	N	%
Left lateral test	Acceptable	4	22.22	3	16.67	4	22.22	2	11.11	3	16.67
	Optimal	14	77.78	15	83.33	14	77.78	13	72.22		
Right lateral test	Acceptable	4	22.22	4	22.22	4	22.22	3	16.67	2	11.11
	Optimal	14	77.78	14	77.78	14	77.78	13	72.22		
Anteroposterior sealing	Acceptable	3	16.66	3	16.67	5	27.78	2	11.11	5	27.77
	Optimal	15	83.33	15	83.33	13	72.22	11	61.11		
Posteroanterior sealing	Acceptable	5	27.77	6	33.33	5	27.78	4	22.22	2	11.11
	Optimal	13	72.22	12	66.67	14	72.22	12	66.67		
Incisal/bipupillary line parallelism	Acceptable	2	11.11	1	5.56	1	5.56	1	5.56	1	5.56
	Optimal	16	88.89	17	94.44	17	94.44	16	88.89		
Incisor/lip length	Acceptable	1	5.56	1	5.56	1	5.56	1	5.56	0	0.00
	Optimal	17	94.44	17	94.44	17	94.44	17	94.44		
Tooth exposure when smiling	Acceptable	0	0.0	0	0.0	1	5.56	0	0.00	1	5.56
	Optimal	18	100.0	18	100.0	17	94.44	17	94.44		
Incisal line/lower	Acceptable	1	5.56	2	11.11	2	11.11	0	0.00	1	5.56
	Optimal	17	94.44	16	88.89	16	88.89	17	94.44		
Lip support	Acceptable	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00
	Optimal	18	100.0	18	100.0	18	100.0	18	100.00		

N = absolute frequency; % = relative frequency.

Table 4. Mandibular prosthesis evaluation scores for each examiner.

Variable		Examiner 1		Examiner 2		Examiner 3		Examiner Agreement		Examiner Disagreement	
		N	%	N	%	N	%	N	%	N	%
Teeth/lip ratio	Acceptable	1	5.56	1	5.56	0	0.0	0	0.00	2	11.11
	Optimal	17	94.44	17	94.44	18	100.0	16	88.89		
Lip support/chin design	Acceptable	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00
	Optimal	18	100.0	18	100.0	18	100.0	18	100.00		

N = absolute frequency; % = relative frequency.

Table 5. Quantitative variables pertaining to the mandibular prosthesis (per examiner).

Variable	Examiner 1					Examiner 2				Examiner 3			
	N	M	MD	SD	IQR	M	MD	SD	IQR	M	MD	SD	IQR
Occlusal right cantilever	18	9.94	10.0	1.27	2.0	9.94	10.0	1.27	2.0	9.89	10.0	1.33	2.0
Occlusal left cantilever	18	9.92	10.0	1.59	1.38	9.92	10.0	1.59	1.38	9.97	10.0	1.54	1.38
Internal right cantilever	18	9.98	10.0	1.48	0.88	9.83	10.0	1.53	0.88	9.83	10.0	1.53	0.88
Internal left cantilever	18	10.0	10.0	1.07	0.0	10.0	10.0	1.07	0.0	10.0	10.0	1.07	0.0

Shapiro–Wilk test; *N* = absolute frequency; %; *M* = mean; *MD* = median; *SD* = standard deviation; *IQR* = interquartile range.

Table 7 shows the results regarding the upper and mean angles in the cephalometric tracings.

Table 6. General aspects of the rehabilitation (per examiner).

Variable			Examiner 1		Examiner 2		Examiner 3		Examiners Agreement		Examiners Disagreement	
			N	%	N	%	N	%	N	%	N	%
Vertical dimension of occlusion	Acceptable		0	0.0	0	0.0	0	0.0	0	0.00	0	0.0
	Optimal		18	100.0	18	100.0	18	100.0	18	100.00		
Free functional space	Acceptable		0	0.0	0	0.0	0	0.0	0	0.00	0	0.0
	Optimal		18	100.0	18	100.0	18	100.0	18	100.00		
Teeth color	Acceptable		1	5.56	1	5.56	1	5.56	1	5.56	0	0.0
	Optimal		17	94.44	17	94.44	17	94.44	17	94.44		
“S” phoneme	Acceptable		3	16.67	3	16.67	4	22.22	3	16	1	5.56
	Optimal		15	83.33	15	83.33	14	77.78	14	77.78		
Tooth/lip relationship during pronunciation of “F” and “V” phonemes	Acceptable		1	5.56	0	0.0	0	0.0	0	0.00	1	5.56
	Optimal		17	94.4	18	100.0	18	100.0	17	94.4		
Occlusal adjustment (articulating film becomes caught in posterior teeth and is free at anterior teeth)	Acceptable		0	0.0	1	5.56	1	5.56	0	0.00	2	11.11
	Optimal		18	100.0	17	94.4	17	94.4	16	88.8		
Lateral guide	Acceptable		2	11.11	3	16.67	2	11.11	2	11.11	1	5.56
	Optimal		16	88.89	15	83.33	16	88.89	15	83.33		
Protrusive guide	Acceptable		2	11.11	4	22.22	2	11.11	2	11.11	2	11.11
	Optimal		16	88.89	14	77.78	16	88.89	14	77.78		

N = absolute frequency; % = relative frequency.

Table 7. Upper and medium angles measured in cephalograms obtained with the initial prostheses adjusted (T1) and after the rehabilitations were performed (T2).

Age	Sex	Upper Angle		Medium Angle		Radiograph Dates	
		T1	T2	T1	T2	T1	T2
57 yr 1m	F	50	50	48	49	5 March 2022	10 May 2022
61 yr 8 m	F	50	52	49	51	16 March 2022	19 May 2022
53 yr 8 m	M	56	51	56	50	7 March 2022	11 May 2022
75 yr 1 m	M	60	54	60	54	7 March 2022	13 May 2022
77 yr 9 m	M	59	59	59	60	4 March 2022	9 May 2022
61 yr 3 m	F	53	50	53	49	4 March 2022	9 May 2022
71 yr 7 m	F	52	55	53	53	5 March 2022	14 May 2022
56 yr 11 m	M	47	46	47	46	7 March 2022	6 May 2022
71 yr 8 m	M	52	52	52	52	4 March 2022	9 May 2022
74 yr 6 m	F	55	49	55	49	5 March 2022	9 May 2022
58 yr 9 m	M	52	52	52	53	7 March 2022	9 May 2022
73 yr 9 m	F	59	59	60	60	16 March 2022	17 May 2022
55 yr 9 m	F	54	54	55	54	7 March 2022	4 May 2022
66 yr 5 m	F	54	52	53	53	5 March 2022	6 May 2022
68 yr 10 m	F	50	45	50	45	5 March 2022	11 May 2022
54 yr 1 m	M	54	56	54	57	7 March 2022	12 May 2022
72 yr 10 m	M	56	56	55	56	5 March 2022	17 May 2022
72 to 10 m	F	60	60	61	62	25 July 2022	7 December 2022
Mean		54.3	52.9	54.4	52.9		
Upper–Medium Angle Difference		0	0				

4. Discussion

The digital workflow used in this study to fabricate provisional dentures/prostheses for fully edentulous patients was found to be efficient in transferring occlusion, aesthetics, and functional planning parameters.

The results of the professional assessment of the prostheses regarding the aesthetic and functional items in the presurgical test were considered very favorable. The centric

intermaxillary relationship was considered coincident in most patients, and 100% of the mandibular prostheses were stable. When simultaneous bilateral contact was absent, adjustments could be made. The guided unforced method was used to obtain a recording of the centric position by using an acrylic resin jig made in the mouth. Other methods have been described [26,32,33]; however, they are considered more difficult. Scanning prostheses in occlusion has also been described, but this approach would only be recommended for patients whose prostheses have acceptable vertical dimensions and occlusion [28,34]. Therefore, this study demonstrates an innovative technique regarding the possibility of improving the aesthetics and function of existing prostheses.

The midline was considered correct in 94.4% of individuals, indicating that the registration method associated with photography greatly facilitated the clinical procedure. The analog method entails more difficult communication between clinic and laboratory and sometimes requires several clinical evaluation appointments [35]. In this study, no clinical evaluations were carried out on patients before the prostheses were completed. Tooth arrangement was only assessed virtually.

After adjustments, the patients received the implants, and the mandibular prosthesis was used as a surgical guide, tray, and reference, as per a previously validated method [9–12]. The adequate extension of the denture base and its stability resulted in high professional satisfaction during the border-molding procedure (9.6 ± 0.7). This was probably due to the digital workflow applied in this study, that is, scanning the intaglio part of the bases but not the borders. Scanning the edentulous ridges was contraindicated, which led to the development of the new techniques [28,33,36].

The degree of professional satisfaction in relation to other variables (the appearance of the maxillary prosthesis, the aspect of the mandibular prosthesis, and the general aspect of rehabilitation) was also very favorable, supporting the routine use of this technique. Similar results have been described previously [37].

After the insertion of the prostheses, independent examinations carried out by three oral rehabilitation professionals revealed professional satisfaction and strong agreement among the examiners regarding most variables. Initial prosthetic preparation was carried out by professionals with knowledge of the parameters necessary to obtain satisfactory complete denture arrangement [35]. Since existing prostheses or trial bases were adapted to the molded ridges, the bases were correctly adapted. The posterior seal was also determined in the mouth. Posterior seals planned using software to obtain printed complete dentures have been reported in the literature [38]. However, obtaining base extensions using a clinically obtained peripheral seal and subsequent molding may have had a positive influence, as reported in another study [33].

The reproducibility of the OVD established during the prosthetic preparation in the interim prosthesis was confirmed via Seradairan–Tavano analysis [30]. The measurements obtained in the first cephalometry analysis were clinically comparable to the measurements obtained in the second stage (with the interim prostheses installed). Overall, the cephalometric measurements remained quite stable between the two evaluations, although small individual angular variations were observed. This corroborates the fact that the digital flow led to the manufacture of interim prostheses printed with the characteristics that had been designed in the prosthetic treatment plan, confirming the predictability of the technique. In this method, the correlation between the upper and middle angle indicated that the size of the lower third was well determined, corroborating findings obtained from dentate patients [30]. The rules that determined the records were clinical references used in the registry of completely edentulous individuals that had been recently revised [35]. No OVD errors were found, as previously reported, in the digital flow for obtaining complete

dentures; however, the technique used to measure the OVD was not mentioned in the corresponding report [39].

The efficiency of the adopted digital flow corroborates data described in case reports about this methodology [28,29,40]. However, this study makes an important contribution to this method, as it was applied to several patients. The speed of the process was also confirmed [26,32,37,41,42]. All prior preparation of the patients using prostheses was carried out in a single clinical session, an even more favorable result than others previously reported [37]. When a patient did not have prostheses, two sessions were necessary: one to obtain a model for the denture base and another for recording and scanning [29,32]. There are reports of a need for five sessions when analog flow is adopted [9]. This can be a very important factor, especially when treating elderly patients.

Another advantage of this method is the ease with which aesthetic data can be transferred to the laboratory. Marks can be made on pre-existing prostheses or in photographs—an advantage that has been previously mentioned [32]. With the virtual tooth arrangement method, it is much easier to follow the defined parameters. These facts have already been noted as advantages of digital flow, a straightforward process that does not make the procedure more expensive [35,41]. Studies that created a four-dimensional (4D) virtual patient, also simulating mandibular movements so that rehabilitation could be carried out, were considered viable in a systematic review [43]. However, they warned of the need for financial investment by the professional. One study showed the applicability of the method for the diagnosis of temporomandibular disorders, and another showed the applicability of joining files to optimize planning [44,45].

We used digital prostheses in this study to serve as a prototype for the manufacture of future definitive prostheses. Other researchers have used printing to test the aesthetics and machining of bases [35,46]. In another study, researchers manufactured several prostheses to test various occlusal schemes [41]. The methodology used, with photographic files and STL obtained from scans, can be considered satisfactory. This is an important clinical finding as it does not require the purchase of many devices. Despite the importance of studies that include facial scans and seek to create a 4D patient, the expensive—often even unaffordable—nature of this process for most clinicians must be considered [14,44,45]. Therefore, it is necessary to consider that professional knowledge is crucial to obtain adequate registration using the currently widely available, and more cost-effective, camera and intraoral scanner technologies.

The results regarding the clinical performance, satisfaction, workflow, and cost-effectiveness of complete dentures obtained by printing were considered promising in a narrative review; however, further studies, as well as the development of new materials, were considered necessary [4,42]. The superiority of complete dentures obtained via milling has been mentioned, but the printing method enables testing and the confirmation of aesthetic and functional factors [42,46,47].

Aesthetic disadvantages have been mentioned when printed digital prostheses are compared with conventional prostheses [48]. In this study, no such comparison was made, but since this was an interim rehabilitation, the professional satisfaction index was very positive.

Factors such as reduced flexural strength, fracture toughness, color stability and adaptation of bases, and increased roughness have also been mentioned when printed complete dentures are compared with milled complete dentures [42]. However, these disadvantages do not negate the use of this method. One study considers it a promising approach for the manufacture of complete dentures in the coming years as knowledge increases and materials and techniques advance [42].

Although the workflow demonstrated high professional satisfaction and reproducible OVD determination, potential sources of error must be considered. Inaccuracies during clinical recording and laboratory procedures may have influenced the outcome. All procedures were performed by clinicians with expertise in oral rehabilitation, and successful implementation of this protocol requires adequate technical training in both phases to ensure there are predictable outcomes. Future studies should incorporate an assessment of the number of clinical appointments and patient-reported outcome measures related to treatment satisfaction.

5. Conclusions

Although the study included a small number of patients, based on the results obtained, it seems reasonable to conclude that this digital workflow exhibits predictability for rehabilitation with 3D-printed provisional maxillary dentures and immediately loaded implant-supported provisional prostheses.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/prosthesis8080080/s1>, Table S1: STROBE Statement—Checklist of items that should be included in reports of case-control studies.

Author Contributions: Study conception, design, and resource collection were performed by I.A.d.M.S. and E.M.S. Material preparation, data collection, and data analysis were performed by F.J.S.d.A., E.M.S., M.N.T., E.R.M., and I.A.d.M.S. Formal analysis, interpretation, and the writing of the original draft of the manuscript were performed by F.J.S.d.A., E.M.S., I.d.S.R., and I.A.d.M.S. The final review and editing were performed by I.A.d.M.S. and E.M.S. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent authorizing full-face disclosure in a scientific publication was specifically obtained from the patient whose images are displayed.

Data Availability Statement: The experimental data and the results that support the findings of this study are available as open data via the Ilapeo College online data repository: <https://www.ilapeo.com.br/tdm/previsibilidade-do-preparo-digital-de-pacientes-edentulos-totais-para-carga-imediata-implantossuportadas-em-mandibula-e-protese-mucossuportada-de-maxila-estudo-coorte/> (accessed on 23 July 2026).

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Abbreviations

The following abbreviations are used in this manuscript:

CBCT	Cone-beam computed tomography
OVD	Occlusion vertical dimension
CAD	Computer-aided design
VAS	Visual analog scale

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