Time Efficiency of Immediate Loading of Full-arch Implant Reconstructions Using Prefabricated Prostheses Located by an Anchor Pin: a Pilot Study

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Objective: *To investigate the time efficiency of prefabricated prostheses located by an anchor pin stereolithographic attachment system for immediate loading implant reconstruction of completely edentulous jaws and compare it with the conventional protocol.*

Methods: *Edentulous patients were recruited and randomly assigned into two groups: the full digital workflow group (digital group) and the conventional workflow group (conventional group). In the digital group, a provisional prosthesis was fabricated before surgery using a fully digital workflow and delivered immediately after implant placement. The positioning of the provisional prosthesis was guided precisely by the anchor pin attachment system. In the conventional group, the provisional prosthesis was fabricated after implant placement using a conventional procedure. Clinical and laboratory time efficiency were recorded, and clinician and patient satisfaction were evaluated.*

Results: *Six patients were enrolled in this pilot study and 57 implants were placed following the guided surgery protocol. Of these, 54 were immediately loaded. The total clinical chair time in the digital workflow group was significantly less than that in the conventional workflow group (digital 60.0 ± 13.2 minutes; conventional 106.7 ± 24.7 minutes) (P = 0.045). The total post-surgery procedure took significantly less time in the digital group than the conventional group (digital 202.5 ± 22.5 minutes; conventional 403.7 ± 55.4 minutes) (P = 0.004). The patients' and clinicians' satisfaction with the provisional prostheses was similar in both groups.*

Conclusion: *Time efficiency in immediate loading of implant-supported full-arch fixed restorations was improved with prefabricated prostheses located by the anchor-pin-attachment system. Less postoperative chair time was required in the digital group than in the conventional group.*

Key words: *edentulous, guided implant surgery, immediate loading, time efficiency*
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The immediate functional loading of implant-supported, fixed full-arch prostheses has been proven to be predictable for the rehabilitation of edentulous patients[1-3]. Compared to the traditional protocol, immediate loading has many advantages, including immediate function and aesthetics, avoidance of provisional removable prostheses and soft tissue preservation[4]. In addition, the literature has reported a high success rate with immedi-

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ately loaded fixed prosthetic restorations with a long-term follow-up[2,3,5]. A systematic review reported that for the immediate loading protocol with flap surgery, the implant and prosthesis survival rates ranged from 90.10% to 100.00% and 93.75% to 100.00%, respectively, with follow-up times ranging from 1 to 10 years[6]. When immediate loading was combined with guided flapless implant placement, the implant survival rate ranged from 90.0% to 99.4%.

Conventional full-arch prosthetic rehabilitations usually involve multi-unit copings screwed onto the abutments and traditional impression techniques. The multi-unit copings were connected using pattern resin, and the latter needs to be separated and reconnected to reduce the stress produced during resin polymerisation. This is followed by an open-tray impression with vinylpolysiloxane (VPS) material to capture both the implant and soft tissue positions. The technicians then complete the denture conversion, and the prosthesis is secured to the multi-unit abutments[7,8].

With computer-aided implant surgery, implant positions can be planned virtually with the aid of CBCT images and placed in an optimal prosthesis-driven position, which allows fabrication of the provisional restoration prior to surgery. These immediately loaded, fixed, full-arch prefabricated prostheses for edentulous patients have been associated with a high level of patient satisfaction regarding aesthetics, phonetics, comfort and function[9-11]. Most prefabricated prostheses are positioned by the denture base or lateral fixation pins with mucosa-supported flapless surgery; however, local anaesthesia can cause tissue swelling and change the seating of the prosthesis, jeopardising the precision of fit of the prefabricated prosthesis.

Transitional implants or narrow-diameter implants were introduced by some authors to support surgical templates and provisional prostheses during surgery[12,13]. In these studies, three to four transitional implants were placed in edentulous jaws to provide the surgical template with a rigid support and thus reduce the deviation of the formal implant position. The delivery of the provisional prosthesis was also assisted by the transitional implants to provide a precise position. However, in these studies, the templates were connected with the transitional implants by means of screws and parallelisation of transitional implants was required. None of these studies investigated the time efficiency of or patient satisfaction with the transitional implant assisted delivery procedure of the prefabricated prosthesis or compared it with the conventional prosthetic protocol. Thus, the purpose of the present pilot clinical trial was to investigate the time efficiency of and patient satisfaction with a prefabricated prosthesis located by an anchor pin stereolithographic attachment system for complely edentulous jaws and compare it with the conventional prosthetic protocol.

Materials and methods

Participants

From May 2018 to July 2019, six participants with a completely edentulous maxilla and/or mandible and who were seeking dental implant treatment at the Department of Prosthodontics, Peking University School and Hospital of Stomatology, were recruited for the study. The participants were randomly divided into two groups: the full digital workflow group (a provisional prosthesis was fabricated prior to surgery with a fully digital workflow and located using an anchor pin stereolithographic attachment system) and the conventional workflow group (a provisional prosthesis was fabricated after surgery using a conventional workflow), with three participants in each group. The research protocol was reviewed and approved by the Institutional Review Board of Peking University School and Hospital of Stomatology (Ethical Approval ChiCTR1800017485).

The inclusion criteria were as follows:

- age ≥ 20 years;
- completely edentulous for > 3 months;
- willing to receive implant-supported fixed prostheses;
- satisfying the anatomical requirements for implant-supported fixed prostheses, ie., alveolar bone width ≥ 6 mm, bone height ≥ 10 mm, and sufficient facial support without a labial denture flange;
- giving full informed consent.

The exclusion criteria were as follows:

- local or systemic contraindications for implant therapy (i.e., uncontrolled diabetes, haemophilia, metabolic bone disorder, history of renal failure, radiation treatment to the head or neck region, current chemotherapy and pregnancy);
- smoking ≥ 10 cigarettes per day;
- patients needing complicated bone augmentation surgery.

Design and fabrication of the radiographic template

In the digital workflow group, at least three anchor pins (Ci Bei 2 × 6 mm, Ningbo Cibei, Ningbo, China) were placed in each edentulous arch (Fig 1a). An attachment system was digitally designed and fabricated

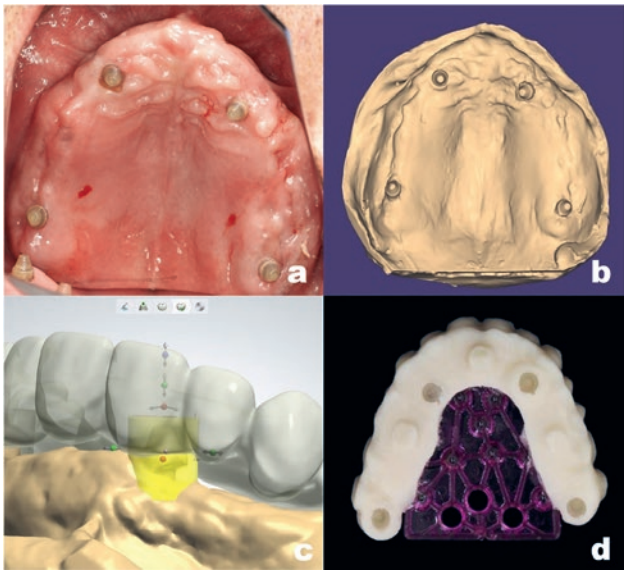

Fig 1 Design and fabrication of the radiographic template for the digital group. **(a)** Three anchor pins were placed in the maxilla. **(b)** The digital model for the maxilla. **(c)** Digital design of the space for the female part. **(d)** The female parts of the SLA precise attachment system were bonded into the tissue surface of the radiopaque dentition to complete the radiographic template.

using stereolithography (SLA) (Projet3600Dental, 3D Systems, Rock Hill, SC, USA). The attachment system consisted of a male and a female part. The female part was able to fit precisely onto the male part, and the male part was bonded onto the head of the anchor pin (Fig 1a). Impressions of the maxilla and mandible were then taken, and stone casts were poured and digitised (Fig 1b). After arch relationship registration and wax-up try-in, the wax-up was digitised using a tabletop scanner (D2000, 3Shape, Copenhagen, Denmark) and radiopaque polymethyl methacrylate (PMMA) dentition (Mei Jing Porcelain Resin Block, 98 mm × 20 mm, Pigeon, Shanghai, China) was milled. The registration template (Diagnostic Template, Organical CAD/CAM, Berlin, Germany) was bonded to the radiopaque dentition. The female part of the SLA attachment system was bonded into the tissue surface of the radiopaque dentition to complete the radiographic template (Figs 1c and d).

In the conventional workflow group, impressions were taken for both the maxilla and mandible, and stone casts were poured and digitised. After arch relationship registration and wax-up try-in, the wax-up was digitised and radiopaque PMMA dentition was milled. The registration template was bonded to the radiopaque dentition, and a transparent composite resin base was built up on the model (Fig 2).

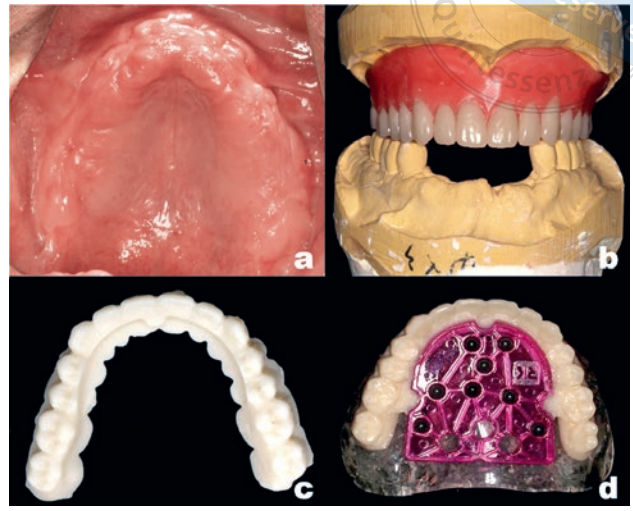

Fig 2 Design and fabrication of the radiographic template for the conventional group. **(a)** Edentulous maxilla. **(b)** Wax-up. **(c)** Radiopaque PMMA dentition. **(d)** A transparent composite resin base was built for the radiographic template, and the pink registration template was attached.

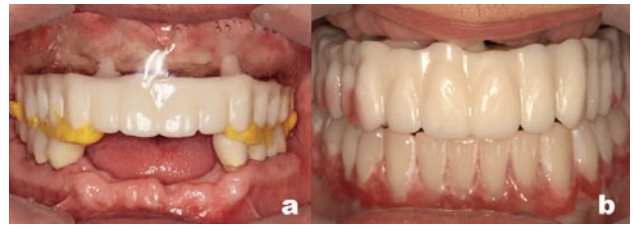

Fig 3 Radiographic template fitting in patients' mouths. **(a)** Conventional radiographic template in position. **(b)** Anchor pin–supported radiographic template in position.

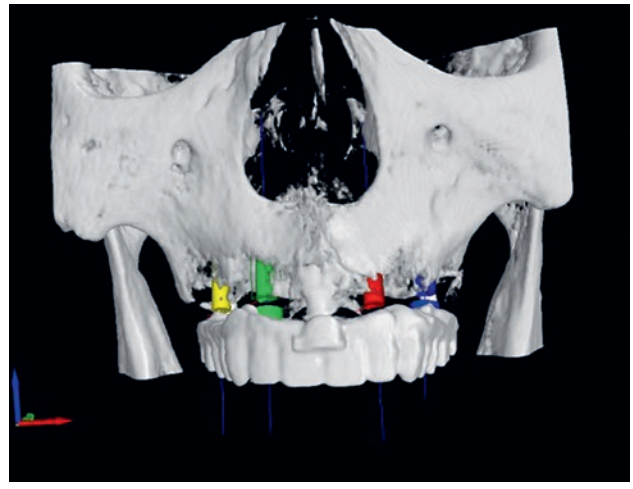

Fig 4 DICOM data were imported into Organical Dental Implant virtual planning software.

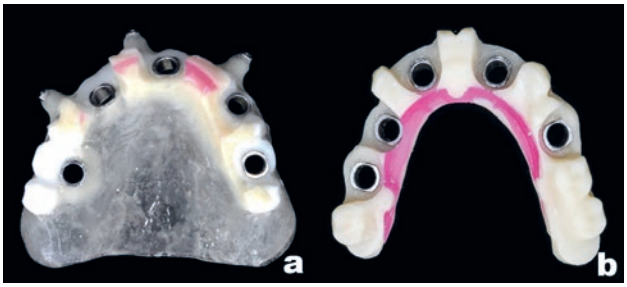

Fig 5 Radiographic template transferred into the surgical guide. **(a)** The final mucosa-supported surgical guide in the conventional group. **(b)** The final anchor pin–supported surgical guide in the digital group.

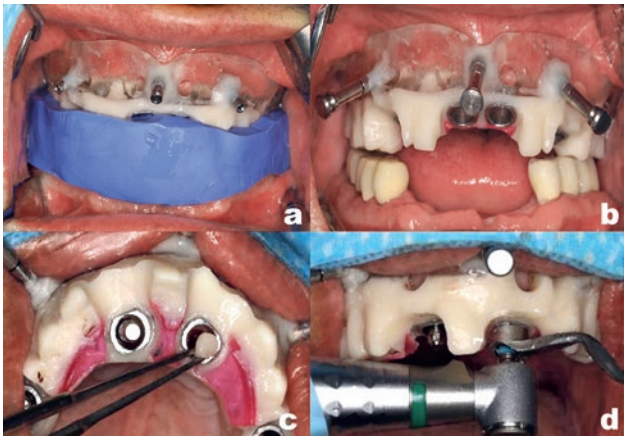

Fig 7 Guided surgery using a mucosa-supported guide. **(a)** The surgical guide was positioned with the interocclusal silicon index. **(b)** The surgical guide was fixed in place by three lateral fixation pins. **(c)** A punch drill was used to remove the mucosa on top of the alveolar crest. **(d)** An osteotomy was performed using drill handles and guided instruments.

CBCT scan

A CBCT scan (VGi, NewTom, Imola, Italy) was taken for each patient wearing the radiographic template (Fig 3), and DICOM data were exported.

Virtual planning

The DICOM data were imported into virtual planning software (Organical Dental Implant, ODI 1.1.0.5, R+K) (Fig 4), then the implant position was designed virtually.

Milling of surgical guide

The implant planning data were transferred into the milling software (Organical Mill2, R+K). Bore holes for surgical guide sleeves were milled directly in the radiographic template; in this way, the template was transferred into a surgical guide (Fig 5).

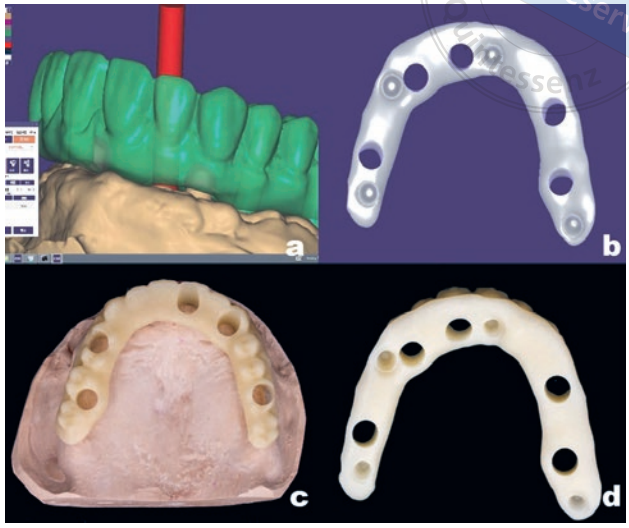

Fig 6 Fabrication of the digital provisional prosthesis **(a)** Abutment positions were virtually designed in the software. **(b)** Virtual female parts for the attachment system were designed in the tissue surface of the provisional prosthesis. **(c)** The provisional prosthesis was fabricated using the CAD/CAM milling process. **(d)** Intaglio female parts in the tissue surface of the provisional prosthesis.

Fabrication of the digital temporary prosthesis

After virtual planning of the implant position, the digitised wax-up dentition for the digital group and the virtually planned implant position data were fused by matching radiopaque dentitions that were present on the wax-up scan and CBCT images. The virtual abutment position and digitised wax-up dentition were then exported to the designing software (exocad, exocad, Darmstadt, Germany) to design the digital provision prosthesis. Virtual female parts of the SLA attachment system were designed in the tissue surface of the provisional prosthesis, then the composite resin provisional prosthesis was milled using the CAD/CAM milling process (Organical Multi S, R+K) (Fig 6).

Guided surgery

All surgical procedures were performed by two experienced general dental practitioners. Prior to surgery, the surgical guides were disinfected in 0.12% chlorhexidine for 30 minutes. For the digital workflow group, after local anaesthesia was administered, the surgical template was supported by the anchor pin SLA attachment system. Precise fitting of the anchor pin–supported surgical template was verified, and an osteotomy was performed (Fig 7).

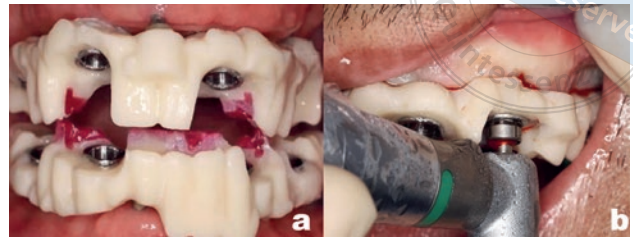

Fig 8 Guided surgery using an anchor pin–supported guide. **(a)** The surgical template was rigidly supported by the anchor pins with the male and female parts of the SLA attachment system fitting into each other precisely. **(b)** An osteotomy was performed using drill handles and guided instruments.

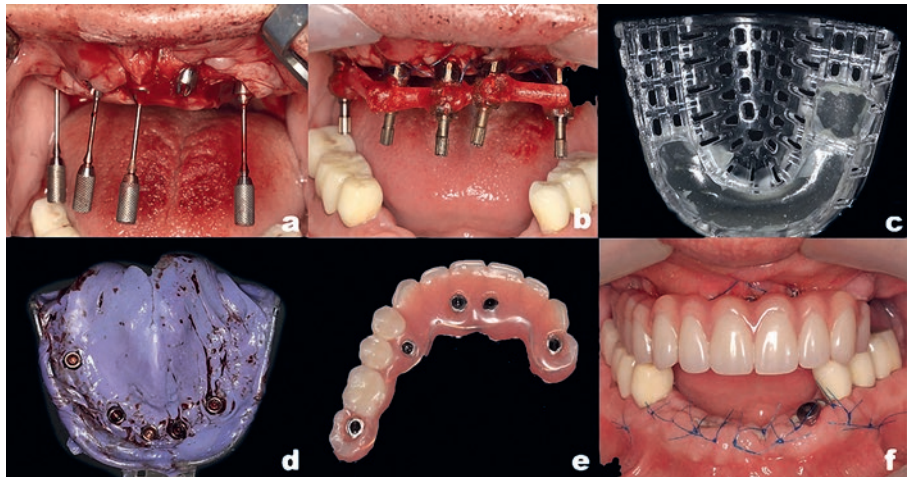

Fig 9 Prosthetic protocol for the conventional group. **(a)** The screw-retained abutments were connected to the implants. **(b)** The pickup copings were mounted. **(c)** Windows were opened in the tray for the pickup of the transfer pins. **(d)** Abutment level open-tray impression. **(e)** Provisional prosthesis. **(f)** Provisional prosthesis in position 1 day after surgery.

For the conventional group, after local anaesthesia was administered, the surgical guide was mucosa-supported and fixed using three lateral fixation pins. A flapless surgery protocol was followed (Fig 8). If a guided bone regeneration (GBR) procedure was necessary, localised flap surgery was performed after implant insertion.

During guided surgery in both groups, implant osteotomy was performed according to a drill handles and guided instruments sequence. The implants with guided carriers were placed through sleeves to the designed depth.

Provisional prosthetic procedure

Immediately after implant placement, the screw-retained abutments (SRA abutments, Straumann, Basel, Switzerland) were connected to the implants. For the conventional workflow group, the pickup copings were mounted and connected, followed by impression with an individual tray and polyether material (Impregum, 3M, St Paul, MN, USA) and stone models were poured. After arch relationship registration, the models were sent to the laboratory for wax-up and fabrication of the provisional prosthesis. The latter was delivered the day after surgery (Fig 9).

For the digital workflow group, the provisional prosthesis was adapted and positioned precisely by the anchor pins with the male parts of the attachment fitting into the female parts milled in the tissue surface of the prosthesis. Provisional abutments were then installed and bonded to the prosthesis with double-cured acrylic resin (LuxaCore Z, DMG, Hamburg, Germany), and then the prosthesis was removed and finished in the laboratory and delivered the day after surgery (Fig 10).

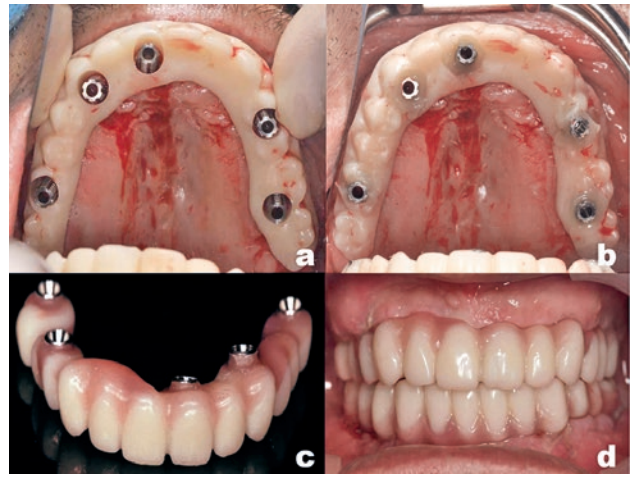

Fig 10 Provisional prosthesis fabrication in the digital workflow group. **(a)** The provisional abutments were installed and the provisional prosthesis was fitted precisely with the fitting of the male and female parts of the attachments. **(b)** Provisional abutments were bonded to the prosthesis with acrylic resin. **(c)** The completed provisional prosthesis. **(d)** Provisional prosthesis delivered 1 day after surgery.

Table 1 Details of workflows in the digital and conventional groups for time recording.

Time point	Digital workflow group	Conventional workflow group
T1	Laboratory workflow: Design and milling of provisional prosthesis	NA
T2	Clinical workflow: Provisional prosthesis fitting in patients' mouth and abutment connection with the provisional prosthesis	Clinical workflow: Transfer coping connection, open-tray pick-up impression, arch relationship registration
T3	Laboratory workflow: Provisional prosthesis finishing	Laboratory workflow: Model fabrication; provisional prosthesis fabrication
T4	Clinical workflow: Provisional prosthesis delivery	Clinical workflow: Provisional prosthesis delivery

NA, not applicable.

After the provisional restorations were delivered, the marginal adaptation and fit were examined clinically and the occlusion was evaluated carefully using articulating papers (Bausch, Nashua, NH, USA).

Time measurements

A stopwatch (LOEASE, Leyi Electronic Technology Company, Zhongshan City, China) was used to record the clinical and laboratory time required for fabrication and placement of the provisional prosthesis (Table 1). Time was recorded by an independent investigator who was informed about the study protocol before study initiation. In the digital workflow group, the laboratory working time for the provisional prosthesis consisted of two parts: laboratory working time before surgery (T1) and laboratory working time after surgery (T3). In the conventional workflow group, the laboratory working time only included T3. For both groups, the clinical chair time included the time for clinical work immediately after implant placement (T2) and that for prosthesis delivery (T4). The total time consisted of the laboratory working time and the clinical chairside time (T1 + T2 + T3 + T4). The total postoperative time included postoperative laboratory working time and total clinical chair time (T2 + T3 + T4).

Patient satisfaction

After delivery of the prosthesis, each patient was asked to complete a satisfaction questionnaire. This consisted of three questions evaluated on a 100-mm visual analogue scale (VAS) to evaluate satisfaction, ranging from 0 (not satisfied at all) to 100 (completely satisfied):

- Overall, are you satisfied with your provisional restorations?
- Are you satisfied with the function of your provisional restorations?
- Are you satisfied with the aesthetics of your provisional restorations?

Clinician satisfaction

After delivery of the prosthesis, clinicians were asked to fill in a satisfaction questionnaire consisting of four questions also evaluated on a 100-mm VAS to evaluate satisfaction:

- Are you satisfied with the simplicity of operation? (0, not satisfied at all; 100, completely satisfied)
- Did the provisional restoration need to be modified at delivery? (0, required a lot of adjustments; 100, required no change at all)
- Are you satisfied with the passive fit of the provisional restorations? (0, not satisfied at all; 100, completely satisfied)
- Are you satisfied with the occlusion of the provisional restoration? (0, not satisfied at all; 100, completely satisfied)

Statistical analysis

The data were coded in Excel (Microsoft, Redmond, WA, USA), and all statistical analyses were performed using SPSS software (SPSS Statistics v22; IBM, Armonk, NY, USA). Differences in time and satisfaction between the digital group and conventional group were calculated using a *t* test and the level of statistical significance was set at $P < 0.05$.

Results

A total of six patients were enrolled in the present pilot clinical trial. Of the 57 implants placed, 54 were immediately loaded using a provisional fixed full-arch prosthesis. The details of patient groupings and distribution of implants are shown in Table 2.

The time required for the clinical and laboratory procedures of immediate prosthesis fabrication and delivery are shown in Table 3. The total clinical chair time (T2 + T4) for the digital group was significantly lower than that for the conventional group (digital 60.0 ± 13.2 minutes; conventional 106.7 ± 24.7 min-

Table 2 Information of patient groupings and implant distribution.

Group	Patient	Arch	Implant number	Immediately loaded implants
Digital	1	Maxilla and mandible	12	10
	2	Maxilla and mandible	10	10
	3	Maxilla and mandible	11	11
Conventional	1	Maxilla and mandible	12	12
	2	Mandible	6	6
	3	Maxilla	6	5

Table 3 Clinical chair time and laboratory working time per arch in the two groups (minutes).

Group	Patient	Laboratory working time			Chair time			Time for full workflow	Total postsurgical time
		T1	T3	Total	T2	T4	Total		
Digital	1	111.5	135.0	246.5	22.5	22.5	45.0	291.5	180.0
	2	120.0	137.5	257.5	35.0	30.0	65.0	322.5	202.5
	3	105.0	155.0	260.0	40.0	30.0	70.0	330.0	225.0
Conventional	1	0.0	225.0	225.0	60.0	75.0	135.0	360.0	360.0
	2	0.0	371.0	371.0	50.0	45.0	95.0	466.0	466.0
	3	0.0	295.0	295.0	60.0	30.0	90.0	385.0	385.0

Table 4 Patient satisfaction in the two groups.

Group	Patient	Patient satisfaction VAS score		
		Aesthetics	Function	Total
Digital	1	98	98	99
	2	85	91	91
	3	92	85	90
Conventional	1	92	89	91
	2	83	85	86
	3	91	91	92

utes) (P = 0.045). The chair time for clinical work immediately after surgery (T2) was significantly lower for the digital group than the conventional group (digital 32.5 ± 9.0 minutes; conventional 56.7 ± 5.8 minutes) (P = 0.017); however, no significant difference was found in prosthesis delivery time between the two workflows (T4, digital 27.5 ± 4.3 minutes; conventional, 50.0 ± 22.9 minutes) (P = 0.17).

The complete postsurgical procedure took significantly less time in the digital group than the conventional group (T2 + T3 + T4, digital 202.5 ± 22.5 minutes; conventional 403.7 ± 55.4 minutes) (P = 0.004), but the total workflow time was similar for both groups (T1 + T2 + T3 +T4, digital 314.7 ± 20.4 minutes; conventional 403.7 ± 55.4 minutes) (P = 0.059). No significant difference was found in the total laboratory working time between the two workflows (T1 + T3, digital 142.5 ± 10.9 minutes; conventional 297.0 ± 73.0 minutes) (P = 0.37).

The results of the patient satisfaction questionnaire are summarised in Table 4. The patients were satisfied with the treatment received and there was no significant difference in the mean patient satisfaction score awarded by the digital and conventional groups.

The results of the clinician satisfaction questionnaire are presented in Table 5. No significant difference was found in clinician satisfaction between the digital and conventional groups; however, in one case in the conventional group, a clinician complained of the complexity of the operation and thus awarded a score of 45 for simplicity.

Discussion

The present study showed that time efficiency was improved in a digital workflow with prefabricated prostheses compared to a conventional workflow with prostheses fabricated after implant placement, especially with regard to postoperative time. Patients' and clinicians' levels of satisfaction with the provisional prostheses were similar for both workflows.

The present study investigated the efficiency of prefabricated prostheses located by an anchor pin SLA attachment system for completely edentulous arches to compare it with the conventional prosthetic protocol. Patients waited less time for provisional restorations, and function and aesthetics were restored at an earlier stage when using prefabricated prostheses.

Table 5 Clinician satisfaction in the digital workflow group and the conventional workflow group

Group	Patient	Clinician satisfaction VAS score			
		Simplicity	Modification	Passive fit	Occlusion
Digital	1	81	93	85	93
	2	87	63	63	96
	3	92	84	82	85
Conventional	1	85	87	77	73
	2	93	91	93	91
	3	45	91	57	87

Several studies have reported that full-arch prefabricated prostheses could achieve a high level of patient satisfaction regarding aesthetics, phonetics, comfort and function[9-11]. Lerner et al[9] investigated the success of full-arch fixed reconstructions without artificial gum and found that 66.6% of prostheses did not undergo any failure or complications during the entire follow-up period. At the 1-year follow-up control, soft tissue was stable in all patients and showed satisfactory aesthetic results[9]. In the present study, provisional restorations showed a clinically passive fit and satisfactory occlusion and aesthetics in both groups. For the digital group, clinicians only needed to bond provisional abutments to the prosthesis, avoiding complicated procedures such as multi-unit pick-up impression and arch relationship registration.

Most of the prefabricated prostheses reported in previous studies were located by the denture base or lateral fixation pins with mucosa-supported flapless surgery[3,4,9]. Compared with the provisional restoration located in the edentulous ridge for edentulous arches, the anchor pin–located prefabrication prosthesis had many advantages. The anchor pins provided stable and reproducible seating of the provisional restoration and the seating of the anchor pin–located prefabricated prosthesis was not affected by tissue swelling at the time of surgery, even if the flap had been raised and sutured. In some cases where bone reduction or augmentation was needed, this prosthesis provided increased convenience and precision.

Transitional implant supported provisional restorations were also reported. Gallucci et al[12] conducted studies in which four transitional implants were placed vertically in the alveolar crest to support the screw-retained surgical templates and provisional restoration. At 4 months after loading, the transitional implants successfully served as abutments for a provisional prosthesis, resulting in a 95.7% success rate for the mini-implants. Tahmaseb et al[13,14] conducted two clinical studies in which three transitional implants were placed to support a surgical template and serve as a digital reference for the titanium frameworks of the definitive restoration. After implant placement, the mini-implants were removed by reverse torque and the definitive restorations were screwed directly at the implant level[13,14]. At the 1-year follow-up, 97.5% of the definitive restorations showed satisfactory occlusion and no major adjustments were needed; however, in these clinical studies, time efficiency and patient satisfaction with the prefabricated prosthesis were not reported or compared with the conventional prosthetic protocol[13,14].

Finally, the present study has several limitations, such as the limited number of patients enrolled and the short follow-up time. Moreover, the study was performed following a mixed, digital-analogue workflow and this could be considered as another limitation since the use of intraoral scanners has been adopted in prosthodontics[15,16] and could potentially reduce the number of steps and procedures using analogue models; however, the accuracy of intraoral scanning for edentulous arches needs to be investigated. Thus, further studies should be conducted with a prospective design and possibly randomised controlled trials to draw more specific conclusions about the validity and effectiveness of this technique.

Conclusion

Time efficiency in immediate loading of implant-supported full-arch fixed restorations was improved with prefabricated prostheses located using the anchor pin attachment system. Less postoperative chair time was required in the digital workflow group than in the conventional workflow group.

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Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Drs Xiao Qian LIU, Jian Zhang LIU, Hai Lan FENG and Shao Xia PAN conceived the ideas; Drs Xiao Qian LIU collected the data; Drs Xiao Qian LIU, Mo Di HENG and Bing WANG and Shao Xia PAN analysed the data; Drs Xiao Qian LIU, Jian Zhang LIU and Shao Xia Pan wrote and revised the manuscript.

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