Laboratory Evaluation of Production Efficiency for Removable Partial Denture Frameworks Using In-House Casting vs Outsourced Additive Manufacturing Techniques

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**Purpose:** To compare the production efficiency of selective laser sintering (SLS) to traditional casting for the fabrication of metal prosthodontic frameworks in a prospective pilot evaluation in a hospital prosthodontic laboratory setting. **Materials and Methods:** The time taken to complete each of the identified stages in the production of 50 removable partial denture frameworks made using either SLS (n = 25) or casting (n = 25) workflows was measured. The mean time for production was calculated for each workflow, and the difference was tested for statistical significance. **Results/Conclusion:** The results indicate that an SLS workflow may be more time-efficient, and further cost-effectiveness research is indicated. Int J Prosthodont 2023;36:338–342. doi: 10.11607/ijp.7132

Production of cast metal denture frameworks requires a great deal of technical skill and precision to avoid the introduction of inaccuracies at each stage of the fabrication process in order to achieve an accurate, well-fitting framework. Concerns over the potential for occupational exposure to materials involved in this process have also been considered. Strict adherence to health and safety protocols are therefore required by production laboratories to reduce the risk of staff exposure to these materials.

Selective laser sintering (SLS) is a development in computer-aided additive manufacturing that avoids the need for wax pattern laying, investment, and casting in the fabrication of metal frameworks (such as cobalt-chromium [Co-Cr]) for removable partial dentures (RPDs). A further advantage over other computer-aided alternatives such as milling is that the SLS process is additive, which reduces waste.

The accuracy of SLS frameworks has been evaluated against that of casting in laboratory and clinical studies, and parameters such as mechanical properties, bio-compatibility, and fitting accuracy have been reported in the literature. However, one pertinent question relates to the efficiency of fabrication. The aim of the service evaluation was therefore to compare the production efficiency of the manufacturing process of SLS vs traditional wax pattern casting for Co-Cr RPD frameworks in an National Health Service production laboratory.
MATERIALS AND METHODS

A convenience sample of 50 patients requiring fabrication of RPDs for the replacement of missing teeth were selected. Treatment was provided in both service and teaching clinics at the Charles Clifford Dental Hospital (CCDH), Sheffield, United Kingdom. Patients were provided with frameworks made with either a traditional wax pattern and casting or a digital design and SLS fabrication workflow. Allocation was provided in an unrandomized manner, with the patients allocated to a workflow on the basis of the time that their dentures were made and the availability of technicians. The steps in each production workflow were identified, as seen in Table 1. Each of these steps was timed by the same technician (P.K.) who produced all of the frameworks. Examples of the different production workflows are shown in Figs 1 and 2.

Outsourced stages of manufacture for the SLS framework occurred at step 6. These were not included in the evaluation time, as they occurred outside of the dental laboratory and are included in the cost of SLS framework production. These steps include:

- Data download
- Development of “build file”
- Selective laser melting production process
- Postfabrication processing, including removal of framework from the build plate; removal of excess metal support required for manufacture (eg, sprues and support struts); and packaging and delivery to the dental laboratory

To allow any improvement in efficiency of the workflow to be considered against the potential cost, a standard nonpay cost was calculated for each workstream. Pay costs were not included, as laboratory staff costs will vary between sites and because production time was considered a more appropriate measure of production efficiency.

Mean and SD for production time was calculated for each group. The difference between groups was assessed using an independent samples t test. The number of frameworks made in the production laboratory per year was calculated using historic activity data. These data were used to calculate the time saved per year for the most efficient workflow. The increase in capacity was calculated using the time saved per year divided by the time taken to make a framework using the most time-efficient workflow.

RESULTS

A total of 25 traditional cast frameworks were evaluated. Fabrication for cast frameworks took a mean time of 273.3 minutes (SD: 107.9 minutes, range: 130 to 569 minutes).

Twenty-five SLS workflow frameworks were evaluated. The mean time for fabrication of SLS frameworks was 154.4 minutes (SD: 37.9 minutes, range: 100 to 225 minutes).

The SLS workflow therefore resulted in a mean time saved of 118.9 minutes (t = 5.2, P < .001, 95% CI: 72.9–164.9) per framework.

Activity data identified that the number of frameworks made per year in the CCDH Prosthetic Dental Laboratory was 241. Therefore, the time saved per year for this production laboratory would be 28,438 minutes. Given the mean production time for the most time-efficient workflow (SLS), this would mean an increase in capacity of 184 frameworks per year for this production laboratory.
Fig 1  Key steps in the traditional casting production workflow.
Fig 2  Key steps in the selective laser sintering production workflow.
DISCUSSION/CONCLUSIONS

This evaluation identified significant savings in technician time when a partly digital workflow for the fabrication of Co-Cr RPD frameworks was adopted. Digital workflows may be totally digital, requiring the use of intraoral scanning to produce an STL file for digital denture design, or partly digital, whereby the dentist acquires a traditional impression of the denture-bearing surfaces and a model is cast. This model is then scanned to create an STL file or digital denture design. In this evaluation, the clinical steps for the SLS framework were exactly the same as those for the cast frameworks. This evaluation therefore did not evaluate any clinical time saved, but was focused on changes within the dental laboratory.

Clearly many issues will influence decisions by production laboratories in regard to the introduction of digital design and SLS workflows to their practice, including the digital expertise of staff, the cost of scanning equipment, IT hardware and digital design software, costs of outsourcing the SLS fabrication, and acceptability of the finished product for clinicians. In this evaluation, all frameworks made using the SLS workflow were eventually fitted for patients, though some modifications were required for 3 out of the 25 frameworks provided. In a clinical evaluation of SLS vs cast frameworks, SLS had fewer inaccuracies, though this study only evaluated 9 frameworks. A full cost-effectiveness analysis would be a useful addition to the research literature, taking into account both laboratory and clinical costs, including the cost of return visits by patients for further adjustments after the fit of the prosthesis and the effectiveness in the context of accuracy of fit and patient-centered outcomes of effectiveness.

REFERENCES