# Precision and accuracy of four current 3D Printers to achieve models for Fixed Dental Prosthesis

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***ABSTRACT***
*The aim of this study was to compare the accuracy and precision of 3D printers used to obtain models of fixed dental prostheses. A fixed dental prosthesis preparation was scanned and reproduced by four 3D printers: RapidShape P40, Asiga MAX, Varseo, and Photon. The impressions were scanned again, and the dataset was compared to the original dataset. Mean discrepancies (µm) were 52.97±20.48 (RapidShape P40), 68.27±43.53 (Asiga MAX), 62.22±56.21 (Varseo), and 80.03±28.67 (Photon). There was no difference (p=0.314) in accuracy; however, the precision differed (p=0.015) among the 3D printers. The printers had distinct precision but did not differ in accuracy.*
*Received: November 2019; Accepted March 2020.*

***Keywords:*** *dental models, dental prosthesis, three-dimensional printing.*

## Precisão de quatro impressoras 3D para obtenção de modelos para prótese fixa

***RESUMO***
*O objetivo desse trabalho foi comparar a acurácia e a precisão de impressoras 3D utilizadas para a obtenção de modelos para prótese fixa. Um preparo para prótese fixa foi escaneado e reproduzido por 4 impressoras 3D: RapidShape 3D, Asiga MAX, Varseo e Photon. As impressões foram novamente escaneadas, e o dataset escaneado foi comparado ao original. Os escaneamentos foram sobrepostos digitalmente e determinada a discrepância entre os modelos original e impresso. A discrepância média (µm) entre os modelos foi de foi 52,97±20,48 (RapidShape 3D), 68,27±43,53 (Asiga MAX), 62,22±56,21 (Varseo) e 80,03±28,67 (Photon). Não houve diferença (p=0,314) entre os valores médios, os quais representam a acurácia; entretanto, o desvio padrão dessas foi diferente (0,015), indicando diferença na precisão das impressoras 3D.*

***Palavras-chave:*** *modelos dentários, prótese dentária, impressão tridimensional.*

## INTRODUCTION

The use of digital workflow in rehabilitation treatments is rapidly increasing. Given the practicality, biological safety, and comfort for the patient and health professional, this technology has gradually been replacing conventional workflow using stone models. Additive manufacturing (3D printing) enables the fabrication of provisional restorations and reliable preparations[1]. The accuracy and precision of these models are related to the final fit of prosthetic parts and, consequently, to the longevity of the restoration. Three-dimensional printers using the Direct Light Processing (DLP) technique have demonstrated good precision in obtaining dental models[2]. The impressions should be identical to the preparations (accuracy) and, if repeatedly printed, they should always have the same dimensions (precision). Recently, a wide variety of 3D printers has been introduced on the dental market, requiring technical assessments[3]. The present study was therefore designed to compare the accuracy and precision of four 3D printers used to obtain models of fixed dental prostheses.

## MATERIAL AND METHODS

An acrylic resin model of a maxillary canine was prepared for a complete crown and then scanned (Trios, 3Shape S/A, Copenhagen, Denmark). Based on the generated dataset file (STL), models of the tooth were obtained from the impressions created using four 3D printers (Table 1). The specimens (n=8 for each printer) were scanned with a high-precision scanner (S600 ARTI, Zirkonzahn GmbH, Gais, Italy). The STLs that generated the impressions were superimposed on the STLs of the printed

models using a specific software system (MeshLab 2016.12, Visual Computing Laboratory, Italy). Based on the overall superimposition prepared tooth, the discrepancies between the measurements were calculated by the Hausdorff method[4] and then qualitatively categorized according to their location. Incisal, mesial, distal, buccal and lingual areas were inspected for presence or absence of misfit (dichotomously, independently of the misfit area) and data were described in terms of misfit prevalence on each surface. The misfit was defined by the presence of red areas on superimposed images of original STL and STL of the printed models. Red areas mean that printed models are larger than original tooth. The mean overall discrepancy values of the 3D printed models were compared by Kruskal-Wallis test. The homogeneity of discrepancy variance was analyzed by the Levene test; differences in this analysis refer to the precision of the printer. The level of significance was set at 5% for all analyses.

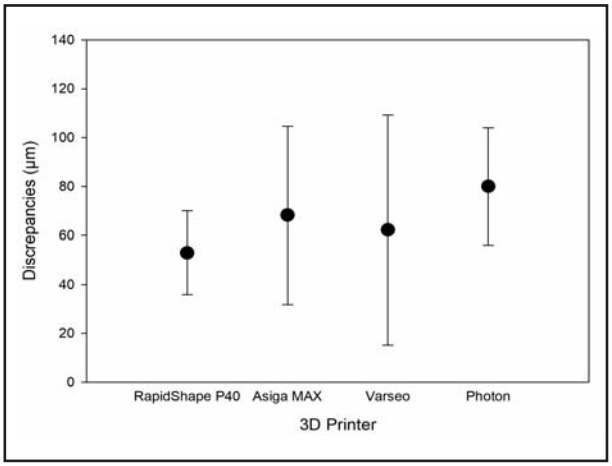


*Fig. 1: Discrepancies (µm) ± standard deviation according to 3D printer. The circle indicates the mean value (accuracy) and the whiskers indicate the 95% confidence interval (precision). There was no difference in accuracy (p=0.587), but precision varied among printers (p=0.015).*

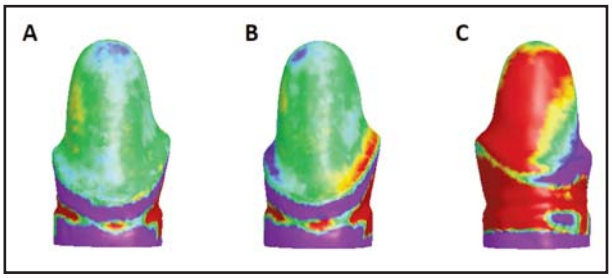


*Fig. 2: Example of misfit (red areas) of models. A. no misfit; B. discrete misfit on the proximal surface; C. severe misfit on the buccal and proximal surfaces.*

## RESULTS

The mean discrepancy (µm) and standard deviations among the models were 52.97±20.48 (RapidShape P40), 68.27±43.53 (Asiga MAX), 62.22±56.21 (Varseo), and 80.03±28.67 (Photon), as shown in Fig. 1. Discrepancy values present a non-Gaussian distribution, and are shown in Table 1. There was no difference (p=0.314) in mean values, which

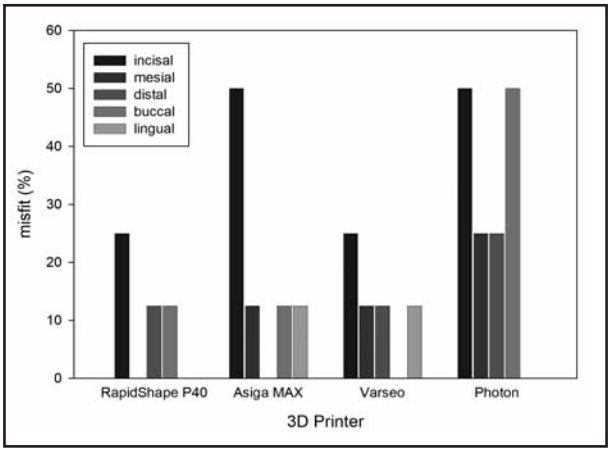


*Fig. 3: Misfit (%) of models according to 3D printer and tooth surface.*

**Table 1: Detailed discrepancy values measured according printer evaluated.**

| Printer | Mean* ± sd# | Minimum discrepancy measured (µm) | Maximum discrepancy measured (µm) |
|---|---|---|---|
| RapidShape P40 | 52.97±20.48 | 31.86 | 84.65 |
| Asiga MAX | 68.27±43.53 | 29.59 | 126.57 |
| Varseo | 62.22±56.21 | 19.42 | 156.83 |
| Photon | 80.03±28.67 | 43.75 | 115.06 |

*arithmetic mean; #standard deviation of mean

represent accuracy; however, the standard deviation distribution was distinct (0.015), which means that precision was different among the 3D printers. Fig. 2 shows images of superimposed original STL files on 3D printed models. Colors close to green indicate minimal discrepancy, while red areas indicate regions of greater superimposition. Fig. 3 shows the prevalence of discrepancies according to tooth surface.

## DISCUSSION

Accuracy did not differ among the tested 3D printers, ranging from 52.97±20.48 to 80.03±28.67 µm. These values are consistent with the resolutions indicated by the manufacturers. Considering the distribution of these values, we can infer that is possible that all 3D printers can reproduce details in accordance with the ISO 6873 requirements for dental gypsum products, which establish a minimum detail reproduction of 75±8 µm for types 1 and 2 dental materials and of 50±8 µm for gypsum types 3, 4, and 5. The variability, given by the standard deviation, refers to the precision of the 3D printers, indicating that the most precise printer (the one with the lowest standard deviation for the mean value of discrepancy among models revealed by Levene test) was the one manufactured by Straumann.

The differences in precision could be related to the distinct resolutions, especially in the Z plane[4]. Larger deviations associated with the 3D printed model may be due to the thickness and shrinkage between the layers of the material that occur in the Z plane and to contraction of the material caused by post-curing[4]. The shrinkage in the Z plane may also be the cause of the higher prevalence of discrepancies on the incisal surface of the preparation. Positive discrepancies in this region, even without causing marginal misfit of prosthetic parts, may compromise the longevity of the restoration as a result of greater thickness of the cement line.

The large standard deviations of discrepancy values should be considered upon evaluation of the data presented. They are related to the precision of the printer, but random errors of methods used could also be present. Thus, the data presented in this study should be considered cautiously. Future clinical studies are welcome to evaluate the efficacy of oral rehabilitations where digital workflow is part of treatment.

Overall, all tested 3D printers appear to have sufficient accuracy and precision to be used in the digital workflow for patient rehabilitation. However, it should be noted that 3D printers with lower precision are more likely to lead to the misfit of prosthetic parts and consequently, to rework.

## CONCLUSION

The printers had distinct precision but did not differ in accuracy.

**FUNDING**
None

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