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Evaluation Of Overall Marginal Accuracy Of DMLS Copings Fabricated Using 3 Different DMLS Printing Machines

Research Article

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Abstract

Statement of the problem: Laser sintering is commonly used to create metal-ceramic restorations. The layer thickness of the sintering process may have an impact on restoration adaptation. However, little is known about its consequences.
Purpose of the study: This in vitro study compared the marginal and internal adaptation of laser-sintered cobalt-chromium long span bridges and single crown frameworks fabricated using different DMLS machines.
Materials and methods: A typhodont teeth set was used for tooth preparation from 14-22 and 16. 3 Shape software was used to scan the dies and design the samples. Following that, the samples were laser sintered on three different DMLS machines. Each machine received six samples of the long span framework and six samples of the single crown framework. A stereomicroscope was used to perform the microscopic examination. The internal fit values and discrepancy were recorded and tabulated. The statistical analysis was carried out using the Spss version 20 software. The statistical significance was determined using the descriptive ANOVA test followed by the Benferroni test.
Results: The EOS machine (0.0763 ± 0.0602m) had the lowest overall marginal discrepancy values, followed by the Shining 3D machine (0.1148 ± 0.923), while the OR laser (0.1449 ± 0.0687) had the highest marginal discrepancy values. After using the ANOVA test, there was a significant difference in the overall marginal discrepancy values (P value 0.00).
Conclusion: The EOS machine produced the best marginal fit values, indicating that the thickness of the metal deposition layer as well as the type of laser used have a significant impact on the DMLS prosthesis' marginal and internal fit.

Introduction

The long-term clinical success of fixed prostheses is closely linked to restoration adaptation. Increased marginal discrepancy causes cement dissolution, plaque accumulation, and bacterial growth, as well as secondary caries and periodontal disorders [1-3]. As a result, the restoration's marginal and internal adaptation to the prepared tooth structure should be determined [3-5]. Although authors disagree about what constitutes a clinically acceptable marginal discrepancy value, the majority agree that values greater than 120µm are not acceptable [6-8]. Direct microscopic evaluation, sectioning, and the replica method are some of the most common methods for determining marginal discrepancy [9-11].

The popularity and success of metal-ceramic restoration has been attributed to its excellent mechanical properties [12]. For many years, metal-ceramic restorations have been made using the traditional lost-wax method; however, this method has several drawbacks, including multiple technique-sensitive steps and the development of casting imperfections [1]. Computer-aided design and manufacturing (CAD-CAM) systems have grown in popularity in recent years due to their high accuracy and consistent quality [13, 14]. The two types of CAD-CAM systems currently used in dentistry are subtractive manufacturing systems such as milling and additive manufacturing systems such as laser sintering [13-16].

Laser sintering systems are increasingly being used to create metal-based prostheses. To convert CAD data into 3-dimensional (3D) complex structures, these systems use a laser source to consolidate powdered material layer by layer [17]. Metal powders can be sintered using direct metal laser sintering (DMLS), which involves partial melting of metal powders, or direct metal

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laser melting (DMLM), which involves complete melting of metal powders. Metal powders are completely melted, resulting in a high-density structure (approximately 99.8 percent) [16, 18]. Several DMLS and DMLM machines, including the EOSINT M270; EOS GmbH (DMLS), M1; Concept Laser GmbH (DMLM), and MYSINT 100; SismaSpA (DMLM), Shining 3D (DMLS), OR LASER (DMLS), and others, are available for dental applications [19]. The mechanical properties of the metal structures produced during the laser sintering process are determined by the thickness of the sintering layer and the machine's power consumption. Dental laboratories, on the other hand, are in charge of determining this parameter [20, 21].

Reduced layer thickness improves mechanical properties, while increased layer thickness beyond a certain point causes major issues such as poor surface finish, decreased accuracy, and decreased mechanical properties. The thickness of the sintering layer can be varied between 20 and 100 micrometers, but the capacity of laser sintering machines may limit this [22, 23]. This in vitro study compared the marginal and internal adaptation of laser-sintered cobalt-chromium (Co-Cr) frameworks with layer thicknesses of 20 and 100 µm fabricated using three different DMLS machines. According to the study hypothesis, metal frameworks sintered with a layer thickness of 20-50 µm showed improved marginal and internal adaptation.

Materials And Methods

Study setting

This research was conducted at Saveeta Dental College in Chennai in a university setting. The research department of the Saveetha Institute of Medical and Technical Sciences in Chennai granted ethical approval (SIMATS). G power software was used to calculate the sample size.

Sample size calculation

The sample size was calculated using g power software using the studies conducted by Papadiochou et al, James et al, and Park et al as parent studies [24-26]. According to the software readings, a total of 126 samples were estimated, with 18 six unit bridges (6 per machine) and 18 single crowns (6 per machine). The EOS M 100, Shining 3D EP-M 100T, and OR laser Creator machines were used in the comparison study.

Die preparation

The dies were prepared with a typodont teeth set. A straight flat end diamond bur was used to prepare the teeth. The teeth that were prepared were 14-22 and 16. During the tooth preparation, precautions were taken to avoid the formation of any undercuts. All of the prepared teeth received a smooth shoulder finish line.

Scanning Procedure

Scanning of the dies separately

The typodont's prepared acrylic teeth were then removed and scanned separately from the model. This was done to accurately scan and record the teeth's finish margins as well as all of the unreachable surfaces.

Scanning of the model

Without the acrylic teeth, the typodont model was scanned. This step was completed in order to align the prepared teeth with the model.

Superimposition of dies to the model

Finally, the prepared acrylic teeth were superimposed on top of the model, and both were scanned separately. Marking aligning points on the MEDIT software aligned the two scans. After that, the final scan was exported in order to design the copings.

STL file generation

The design that was made digitally was converted into an STL format and was exported for printing using the three different machines.

DMLS machines used and their features

The three machines used for the comparison study were EOS M 100, Shining 3D EP-M 100T and OR laser Creator machine.

Material deposition layer Thickness

The EOS machine had a layer thickness of 20 to 40 m, while the Shining 3D machine had a layer thickness of 50 to 80 m and the OR laser machine had a layer thickness of 50-100 m. The EOS machine's layer thickness was the smallest, indicating that the metal micro-particles were arranged in a more compact manner.

Type of laser used

The sintering process was carried out on all three machines using a Ytterbium laser.

Printing Procedure

The STL format had to be loaded into the DMLS machine software first. Nesting the prosthesis was then done, followed by providing support sprews. After that, the printing platform was cleaned and prepared for the procedure. To avoid failures, precautions were taken to ensure that the printing platform was free of any old material or scratches. Finally, the printing procedure began, with the recoater arm layering the material until the final prosthesis was completed. There were precautions taken to avoid pausing the procedure, which could have resulted in inaccuracies. After the prosthesis had been printed, it was heat treated before the sprews were carefully cut with a metal cutting bur. To avoid touching the metal cutting bur on the prosthesis' surface, precautions were taken.

Evaluation of marginal fit

Apparatus

A Lawrence and Mayo stereo microscope with an optical zooming of 80x was used to assess the marginal fit. To avoid any reflections, the samples were examined against a matte black background.

Procedure

The mesiobuccal, buccal, disto buccal, mesiolingual, lingual, and dentilingual points on the prepared tooth were all evaluated for marginal discrepancies. Each point was examined with a stereo microscope, and the difference in micrometers was calculated. Magvision was used to perform the calculations. For each sample, the distance between the prosthesis's margin and the finish line was calculated. A total of 756 points were assessed, with the results tabulated.

Statistical analysis

The tabulation was done based on the type of surface being examined as well as the tooth being assessed. The software SPSS version 20 was used for tabulation and descriptive statistics. For each tooth, the mean of each surface discrepancy was calculated. To compare means and find statistical differences between the samples, an ANOVA statistical test was used.

Independent variables included; Laser used by the machine, Gas inlet for the machine, Metal used for printing , Software used to evaluate the marginal and internal discrepancy, Magnification used to focus on the surface is being examined, Typodont model Dependent variables included; Marginal discrepancy, Internal fit, Surface roughness.

Results

The overall mean and standard deviation values for OR laser were 0.1449 ± 0.0687. For Shining 3d 0.1148 ± 0.0923, for EOS machine 0.0763 ± 0.0602 (Table 1).

There was a significant difference in the overall marginal discrepancy values after applying ANOVA test P value 0.00 (Table 2). Based on the Post Hoc analysis using Bonferroni test, there was a statistical difference between the marginal discrepancy values of the coping fabricated using Shining 3d, OR laser and EOS machine (Table 3).

Discussion

The EOS machine (0.0763 ± 0.0602m) had the lowest overall marginal discrepancy values, followed by the Shining 3D machine (0.1148 ± 0.923), while the OR laser (0.1449 ± 0.0687) had the highest marginal discrepancy values. After using the ANOVA test, there was a significant difference in the overall marginal discrepancy values (P value 0.00).

Laser sintering machines could previously handle layer thicknesses of 50 to 80 mm. Laser sintering systems with a layer thickness of about 20 µm have been introduced for dental applications. In determining marginal discrepancy, the depth of laser penetration is crucial [27, 28]. When evaluating marginal, the depth of laser penetration is crucial. A thicker layer of powder is more difficult to fully melt, and unconsolidated sections between the layers can

Tabel 1. Table showing the mean and standard deviation values of marginal discrepancy of dmls copings fabricated using 3 different machines.

	N	Mean	Std. Deviation	Std. Error
OR LASER	252	0.145	0.069	0.004
SHINING 3D	252	0.115	0.092	0.006
EOS	252	0.076	0.060	0.004
Total	756	0.112	0.080	0.003

Table 2. Table showing the p values obtained after applying the ANOVA test to the marginal discrepancy values of all the 3 dmls machines.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.597	2	0.298	53.021	0.000
Within Groups	4.238	753	0.006		
Total	4.835	755			

Table 3. Table showing individual comparisons between the discrepancy values of dmls copings fabricated using 3 different machines.

MACHINES	MACHINES	Mean Difference (I-J)	Std. Error	Sig.
OR LASER	SHINING 3D	.03012*	0.007	.000
	EOS	.06865*	0.007	.000
SHINING 3D	OR LASER	-.03012*	0.007	.000
	EOS	.03853*	0.007	.000
EOS	OR LASER	-.06865*	0.007	.000
	SHINING 3D	-.03853*	0.007	.000

Figure 1. Pictorial representation of the three machines used to fabricated the dmls prosthesis (EOS M 100, Shining 3D EP-M 100T and OR laser Creator machine).

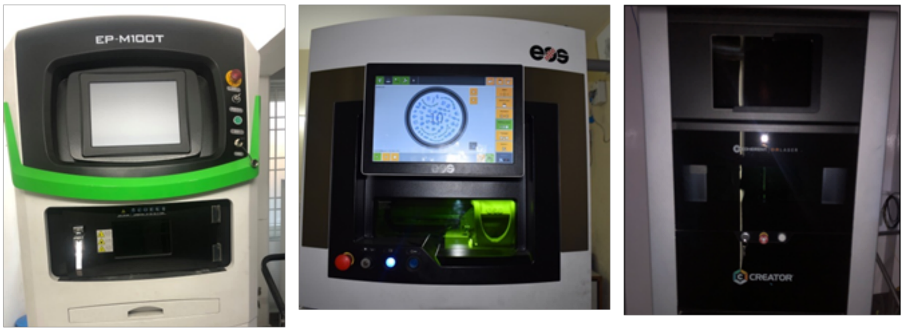
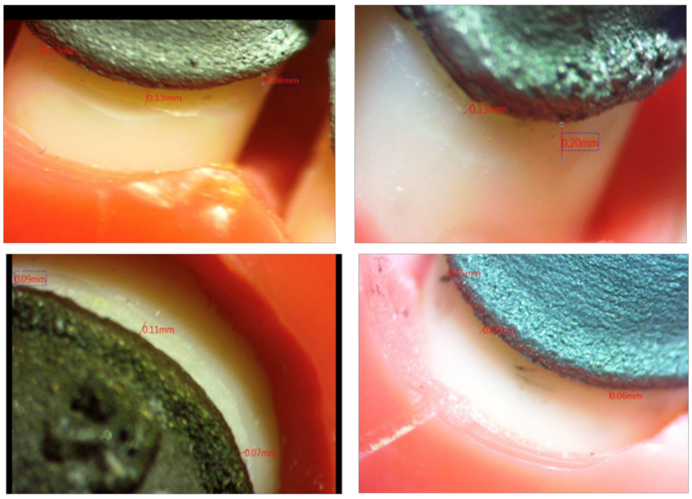


Figure 2. Pictorial representation of the anterior and posterior prosthesis fabricated after the DMLS printing.

Figure 3. Pictorial representation of the process of steriomicroscopic evaluation of the dmls copings.

Figure 4. Pictorial representation of the microscopic images captured to evaluate the marginal accuracy of the copings using a stereo microscope.



weaken the structure. As a result, the thickness of the sintering layer can affect the final product's consistency and dimension [27-29]. Increasing the sintering layer thickness beyond a certain point reduces process accuracy and degrades surface finish, whereas decreasing the layer thickness by up to 20 μm improves process accuracy and improves surface finish. Reducing the layer thickness to less than 20 μm , on the other hand, can make the structure more porous, and reducing the layer thickness typically increases manufacturing time [21, 16]. The marginal accuracy and internal fit of dmls copings have been evaluated in only a few studies [30-32]. Furthermore, no studies comparing the efficiency of different DMLS machines based on marginal and internal fit have been conducted. In this study, the overall marginal discrepancy for the three DMLS machines was favored by the EOS machine, which had the lowest discrepancy values. The Shining 3D machine came in second, followed by the OR Laser machine, which had the greatest marginal discrepancy. It's possible that the EOS machine's minimal metal layer thickness is the key to this finding.

Furthermore, it is possible that the EOS machine had better accuracy than the other two machines because the laser quality and power consumption were superior. In terms of layer thickness and power consumption, the EOS met all of the requirements for a perfect dmlsmachine. Only a few studies have looked at the effect of layer thickness on the overall accuracy of laser sintered prostheses. Previous research has shown that the marginal accuracy of metal frameworks fabricated using different layer thicknesses (25microns, 50microns) during the printing process is not significantly different [27]. Previous studies on commercial metal fabrication using Selective laser melting and Stereolithigraphy have shown that the thinner the layer thickness of the material, the higher the accuracy and the lower the dimensional instability of the final product [32-35]. Direct microscopy and sectioning are commonly used to determine marginal discrepancy [36, 8]. Direct microscopy is a straightforward, quick, and repeatable procedure, but it is less precise. Sectioning, on the other hand, is a time-consuming procedure that produces delicate results. The use of only stereo microscopy for evaluating the marginal discrepancy was a flaw in the current study, which could be a bias because it is not perfectly accurate.

There haven't been any studies that look at the impact of prosthesis span length on the accuracy and marginal fit of DMLS-fabricated prostheses. In studies on zirconia prostheses, changes in span length were found to have a significant impact on marginal and internal fit [37]. In the single and four-unit fixed partial denture groups, the mean value of marginal fit was within clinically reasonable limits. In the 6-unit sample, however, some margins had values that were outside of the clinically acceptable range. Curved anterior frameworks, particularly those that cross the midline, have also been shown to have a significant impact on the prosthodontics' marginal and internal fit [38]. This suggested that increasing the span length could make the prosthesis less comfortable to wear. The current study's findings were consistent with previous research, with the long span framework and, in particular, the bilaterally distal abutments, showing higher discrepancy values. In comparison to the long span prosthesis, the single molar crown had lower marginal discrepancy values. Another cause of the discrepancy in long span frameworks, particularly those that cross the midline, could be scan inaccuracies introduced by the stitching algorithm. These inaccuracies would manifest themselves in the prosthesis as marginal discrepancies [38-40]. These findings were reflected in the current study, which included a scan of the prepared cast using a lab scanner. It can also be hypothesized that the inaccuracies and discrepancies incorporated in the prosthesis could be due to the inaccuracy of the scanner or the CAD designing software.

All of the samples, were examined using a stereomicroscope, which isn't the gold standard.

Because only three machines were evaluated, a generalized conclusive statement for all DMLS machines cannot be made. Because only three machines were evaluated, a generalized conclusive statement for all DMLS machines cannot be made.

More research into the mechanical bond strength of dmls copings with ceramic, flexural strength, and long-term survival of copings fabricated with different DMLS machines should be encouraged. On the other hand, the microstructural and mechanical properties of metal structures were not evaluated in this study. As a result, more research is needed into the effects of various DMLS printing machines on laser-sintered restorations.

Conclusion

The marginal fit of the dmls copings was significantly influenced by different DMLS machines. The EOS machine produced the best marginal fit values, indicating that the thickness of the metal deposition layer as well as the type of laser used have a significant impact on the prosthesis' marginal fit. The length of the span of had an effect on the overall fit of the prosthesis, implying that there were errors introduced during scanning or metal printing.

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