Comparative evaluation of marginal and internal fit of anatomic and nonanatomic metal frameworks fabricated by selective laser sintering

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Abstract: For teeth restoring single metal-ceramic crowns were the gold-standard for many years. Selective laser sintering is a new technology which can provide accurate complex-shaped frameworks for dental restorations, layer-by-layer, according to a three-dimensional computer model, using metal powder. An important factor for long term success of fixed prostheses is the marginal and internal adaptation. The aim of the study was to evaluate the effect of framework design and design of tooth preparation on marginal and internal fit of laser-sintered frameworks. Two maxillary first molars where prepared with two different kind of marginal limits. Two different framework designs were constructed for each: model 1 – a coping with a constant framework thickness of 0.6 mm and model 2 - an anatomically modified shaped cusp supporting framework with a constant veneering thickness. The mean marginal gap values were between 37 and 95 µm, the means for the axial region were between 47 and 70 µm and for the occlusal region between 67 and 147 µm. Copings produced by selective laser sintering using CAD/CAM technologies demonstrate acceptable marginal and internal fit in the range of 47 to 120 µm, with better results in case of anatomically-reduced frameworks.

Key-Words: rapid prototyping, selective laser sintering, marginal and internal fit, CAD/CAM system, cobalt-chromium alloy, metal-ceramic crowns

1 Introduction

Even though integral ceramic restorations gained more and more popularity among clinicians and patients, metal-ceramic crowns are still widely used and considered the standard treatment in dentistry, due to their cost, long term results, biocompatibility and ease to produce [1].

Conventional technologies (lost-wax technique) are wide used to obtain metal substructures for dental restorations using different metal alloys for casting. This procedure has many steps were errors can occur, and which are technique sensitive. This is why CAD/CAM technologies arouse more and more interest among practitioners.

Most benefits associated with computer generated dental prosthetic restorations include the use of industrial prefabricated and controlled materials, without defects, increased quality and reproducibility, storage emerging data in a standardized chain of production, improved precision and planning, increased efficiency [2,3,4].

The beginning of the 1970s started a new era in dentistry by introducing automated manufacturing processes. Until the early 1980s, most fabrication techniques of dental restorations were based on subtractive manufacturing. Recently, the introduction of additive manufacturing provided a completely new concept [5].

Different additive techniques were developed to meet the requirements of rapid manufacturing (RM) and rapid prototyping (RP), such as stereolithography (SLA), fused deposition modeling (FDM), selective electron beam melting (SEBM) or selective laser sintering (SLS). The most used in prosthetic dentistry for fabricating dental restaurations is SLS, which seems to be ideal for producing dental prosthetic restorations. Current studies indicate that Co-Cr alloys restoration can be obtained with similar or better properties than those obtained by the classic casting technique or computerized milling, faster and at a lower cost [6,7,8]. SLS is a process of 3D parts manufacturing, consisting in consolidation of layers of powders of various materials (such as polymers, ceramics, and metals), under the heat of a focused laser beam, directed by the data provided by a CAD file [9].

A key factor for long term success of fixed prosthesis is the precise fitting of restaurations [10].
Restorations adaptability is determined by the marginal and internal gap. Large marginal discrepancies expose the cement to the oral conditions leading to dissolution of luting material and microleakage. This percolation allows occurrence of decays and inflammations of the vital pulp. Studies shown that increased marginal gaps are correlated with higher plaque index and reduced periodontal conditions. On the other hand, minimal marginal discrepancies results in less gingival inflammation, cement dissolution, decay and marginal discoloration. The internal gap was defined as the perpendicular distance between the framework and the abutment teeth and it is the misfit of the coping at the occlusal/incisal and axial surfaces. The internal fit should be uniform to provide an ideal space for cement without compromising the retention or the resistance of the crown. If this space is too large the cement will be washed away [11].

2 Problem Formulation

Although fabrication of metal-ceramic crowns has a long history and these are still widely used in daily practice, experts have not reached a consensus yet, regarding the optimal tooth preparation and framework design for porcelain fused to metal restorations produced by CAD/CAM technologies.

3 Purpose

The aim of the study was to evaluate the effect of preparation and core design on marginal and internal fit of metal frameworks fabricated by selective laser sintering.

4 Materials and method

Two resin first upper molars were prepared: one of them with chamfer finish line, and 6 taper angle of the axial walls, the other one was prepared with right angle shoulder and also 6 taper angle. The preparations were duplicated with silicone. Than twenty stone-casts of each preparation were poured using Type 4 Dental Stone GC Fujirock Gc, Leuven, Belgia). These abutments were scanned with D700 3D Scanner (3Shape, Copenhagen Denmark). Ten anatomic and ten non-anatomic metal copings (using Cobalt-Chromium ST2724G powder) of 0.5 mm thickness were designed with PHENIX Dental (Phenix Systems, Riom, France) (Fig. 1) for each tooth preparation and fabricated by selectiv laser sintering with PXS Dental (Phenix Systems, Riom, France), for each, with 0.05 mm space for cement.

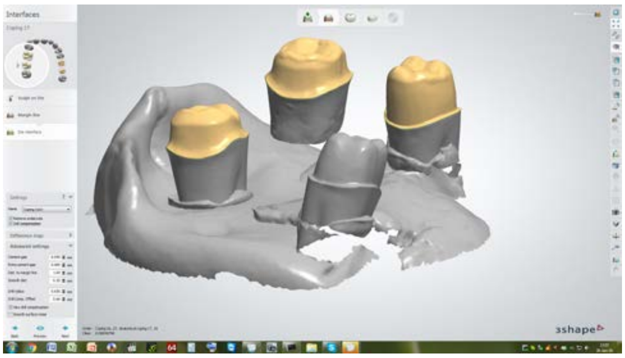

Fig.1. Design of the frameworks.

For fit evaluations a very light silicone (Oranwash VL, Zhermack, Badia Polesine, Italy) was placed between sintered copings and stone-cast abutments, and then this thin layer of flowable silicone was embedded in putty silicone (Zetaplus, Zhermack, Badia Polesine, Italy) and covered with light silicone (Oranwash L, Zhermack¸ Badia Polesine, Italy) - silicone replica technique [12].
One millimeter diameter holes were drilled into the occlusal surface of the frameworks to overcome the hydraulic-effect when placing it on stone-cast (Fig. 2).

Fig. 2 Framewor prepared for fit tests.

They were made by two random sections for each sample and were analyzed with Leica DM500 microscope (Leica, Wetzlar, Germania) at 4x magnifications with a hundred microns scale (Fig. 3).

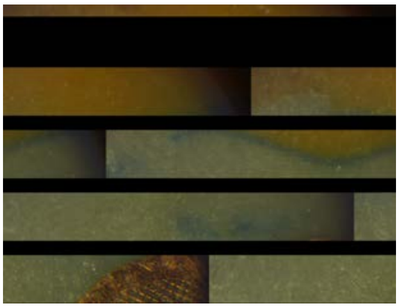

Fig. 3. Specimen with 100 µm scale.

Seven mesiodistal and vestibulolingual positions were measured, and each of these were divided into the following categories: marginal gap (MG), cervical gap (CG), axial wall at internal gap (AG), and oclusal wall at internal gap (OG), using this silicone key for measuring the gap between coping and abutment. Measurements were made with ImageJ software (Fig. 4).

Fig. 4. Measurements made with ImageJ software.

5 Results and discussions

Descriptive data for mean marginal gap was significantly smaller for the fourth group-anatomical coping on s houlder preparations. The highest values for marginal discrepancy were found in first group - uniform thickness on chamfer preparation. The mean occlusal gap width of anatomically reduced framework on chamfer preparation was sensible smaller than in case of anatomically reduced framework on s houlder finishing line. Best adaptability results were found in anatomic copings both on chamfer and shoulder marginal preparations, the best being found in the group with the shoulder preparation, except occlusal level, where this group recorded the biggest discrepancies (Table 1).

Table 1. The mean values measured (in µm) for all four groups. Group 1: chamfer preparation, uniform thickness framework; Group 2: chamfer preparation, anatomic coping; Group 3: shoulder preparation, uniform thickness framework; Group 4: shoulder preparation, anatomic coping.

Group	MG	CG	AG	OG
1	95.01	91.623	70.709	98.68
2	55.34	55.12	50.059	67.28
3	78.87	83.33	67.078	85.89
4	37.787	47.37	47.457	146.5

The mean marginal and internal discrepancy measured on the sintered Co-Cr copings were within the range considered clinically acceptable by most studies. The results for better adaptability are not longer expected with specific preparations margins. The better results from literature for chamfer margin design compared with shoulder finishing line can be explained as a consequence of scanning, software and milling difficulties for accessing strong angles, using subtractive CAD/CAM technologies. With performing scanners and additive techniques, these limitations exist no longer [12].

A study like this one can be limited by sources of variability such as manual pressure applied to restorations for four minutes while the very light silicon had to set.

Most studies conducted in this field are directed to marginal and internal fit comparing laser sintered crowns with conventionally fabricated crowns and with ones obtained by alternative technologies (different casting methods, milling, etc), without considering the framework design [13]. Therefore further studies will be necessary.

6 Conclusion

Within the limitations of this in vitro study, the sintered Co-Cr copings produced with PHENIX Dental Systems show clinically acceptable marginal fit within 15-120 µm, before ceramic veneering, except occlusal gap in case of anatomical copings on shoulder preparations, which goes up to 304 µm. It can be concluded that the preparations and framework design can have a major influence on adaptability of restorations obtained by selective laser sintering.

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