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EVALUATION OF FLEXURAL STRENGTH OF DIFFERENT RESTORATIVE MATERIALS

FARKLI RESTORASYON MATERYALLERİNİN EĞİLME DAYANIMLARININ KARŞILAŞTIRILMASI

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ABSTRACT

Objective: The aim of this in vitro study was to compare the biaxial flexural strengths of permanent restorative materials produced by additive manufacturing and milling after thermal aging.
Material and methods: For this study, three study groups were formed by producing disc-shaped specimens with a 3D printer (Form3, Formlabs) using permanent crown material (Permanent Crown, Somerville, MA) and two different resin-containing materials (Brilliant Crios,Coltene/Whaledent; Cerasmart, GC Europe) by the milling method (n=10). The entire production process was carried out in accordance with the manufacturer's instructions. All specimens were then polished under water with silicon carbide papers. The specimens were then subjected to thermal aging (5-55°C, 5000 cycles). After aging, biaxial flexural strength values of all specimens were measured with a universal testing machine. The obtained data were evaluated with the one-way ANOVA test and post-hoc TUKEY test (α=0.05).
Results: According to the data obtained, no significant difference was found between the groups produced by the milling method (p=0.878). While no difference was found between the group produced by additive manufacturing and the Cerasmart group (p=0.110), it was observed that the flexural strength was significantly lower than the Brilliant Crios group (p=0.040).
Conclusion: As a result of this in vitro study, the lowest biaxial flexural strength after thermal aging among the groups was observed in the group produced with additive manufacturing.
Key words: Additive manufacturing, biaxial flexural strength, CAD/CAM

ÖZ
Amaç: Bu in vitro çalışmanın amacı termal yaşlandırma sonrası eklemeli üretim ve kazıma yöntemi ile üretilen daimi restoratif materyallerin biaksiyal eğilme dayanımlarını karşılaştırmaktır.
Gereç ve Yöntem: Bu çalışma için 3D yazıcı (Form3, Formlabs) ile daimi kron materyali kullanılarak (Permanent Crown, Somerville, MA) ve kazıma yöntemi ile iki farklı rezin içerikli materyal (Brilliant Crios (Coltene/Whaledent; Cerasmart (GC Europe) ile 10 mm×2 mm boyutlarında disk şeklinde örnekler üretilerek üç çalışma grubu oluşturuldu (n=10). Üretim aşamaları üretici talimatlarına uygun şekilde gerçekleştirildi. Daha sonra tüm örnekler su altında silikon karbid kâğıtlarla zımparalandı. Ardından örnekler termal yaşlandırmaya (5-55°C, 5000 döngü) tabi tutuldu. Yaşlandırma sonrası tüm örneklerin universal test cihazı ile biaksiyal eğilme dayanımı değerleri ölçüldü. Elde edilen veriler Tek yönlü ANOVA testi ve post-hoc TUKEY testi ile değerlendirildi. (α=0,05)
Bulgular: Elde edilen verilere göre kazıma yöntemi ile üretilen gruplar arasında anlamlı fark bulunmamıştır. (p=0,878) Eklemeli üretimle üretilen grubun Cerasmart grubuyla arasında fark bulunmazken (p=0,110) Brillant Crios grubundan anlamlı ölçüde düşük eğilme dayanımı gösterdiği görülmüştür. (p=0,040)
Sonuçlar: Elde edilen sonuçlara göre gruplar arasında termal yaşlandırma sonrası en düşük biaksiyal eğilme dayanımı eklemeli üretimle üretilen grupta görülmüştür.
Anahtar Kelimeler: Eklemeli üretim, biaksiyal eğilme dayanımı, CAD/CAM

INTRODUCTION

As digital dentistry continues to develop day by day, it offers innovations in both additive and subtractive systems. Esthetic concerns and the requirements for rapid and predictable restorations have increased the trend towards chairside procedures (1). While many restorations can be produced by saving time through intraoral scanners and milling methods, patients can also have insights about the final restoration thanks to digital designs (2, 3). Through CAD/CAM systems, a wide variety of restorations have been produced using subtractive methods for many years, using blocks or discs (4). Subtractive or milling

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methods today have a wide range of materials and offer many successful alternatives to expectations (5). After the appropriate material is selected, a previously designed restoration can be produced by means of a milling device (6). However, despite its many advantages, material wastage is inevitable and microreproducibility is questioned on the inner surfaces of the restorations due to factors related to the milling device, and the material geometry affects the success (7, 8).

Additive manufacturing methods are now known by different names such as 3D manufacturing and rapid prototyping (9). This method, which has been used in metal-supported restorations under the name of selective laser sintering for years in dentistry, allows the production of almost all types of restorations with the production of tooth-like colored materials and the development of devices using different Technologies (10). These developments in additive systems contribute to the adaptation to the full digital workflow of prosthetic applications (11). In the literature, different layering systems have been introduced for this technology. SLA and DLP systems, which often use the vat polymerization method, are widely used in dentistry (12). In this system, a powder or liquid material is polymerized and solidified to create 3-dimensional objects (13). Multiple simultaneous productions are possible, and material wastage is greatly reduced as the remaining material can be used repeatedly (14). Production speed, type of material, and restoration properties may vary depending on the capacity of the 3D printer (15). Using these technologies, surgical guides, dental models, maxillofacial prostheses, occlusal splints, and prosthetic infrastructures can be produced (11).

While only temporary crown materials were available for 3D printers until recent years, permanent crown materials are now also available in dental markets (16). However, the variety in these relatively new materials is limited. In addition, information about the mechanical properties of these materials is quite insufficient. Therefore, the aim of this in vitro study is to compare the flexural strength of permanent restorative materials produced by additive manufacturing and milling after thermal aging. The hypothesis of the study is that there would be no difference between the flexural strengths of the materials after thermal aging.

MATERIAL and METHOD

In the study, three study groups were used for different materials, 1 printed and 2 milled (n=10). An STL file was created for the disc-shaped specimens designed with a diameter of 10 mm and a thickness of 2 mm in accordance with ISO standards. The STL data prepared for the Printed group were transferred to the nesting software compatible with the 3D printer. The printing direction was determined as horizontal and after the supports were placed, the data was transferred to the 3D printer (Form 3; Formlabs) with SLA technology. The printed specimens were first immersed in the bath tank (Form Wash; Formlabs) for 3 minutes with 99% isopropyl alcohol (IPA). Then, it was cured at 60°C for 20 minutes in the curing device (Formcure; Formlabs) in accordance with the manufacturer's instructions, and the curing process was repeated after the supports were removed.

Two different resin-based restorative materials (Brilliant Crios [Coltene/Whaledent]; Cerasmart [GC Europe]) were used for the Milled groups. The discs were produced with the same STL data by using CAD/CAM blocks through the milling device. All produced specimens were polished under water with silicon carbide papers. Then, the specimens were subjected to 5000 cycles of thermal aging with a 30-second dwell time (5-55ºC). After aging, the biaxial flexural strength test of the specimens was performed on a Universal test device.

$$\frac{\sigma = -0{,}25\ N\ (X - Y)}{b^2}$$

$$X = (1 + v)\ In \left(\frac{r_2}{r_3}\right)^2 + [(1 - v)/2] \left(\frac{r_2}{r_3}\right)^2$$

$$Y = (1 + v)\left[1 + In \left(\frac{r_1}{r_3}\right)^2\right] + (1 - v)\left(\frac{r_1}{r_3}\right)^2;$$

σ flexural strength (MPa), N fracture load (N), v value Poisson ratio (=0.3), r1 radius of support circle (mm), r2 radius of loaded area (mm), r3 specimen radius (mm), b the thickness of the specimen (mm).

The distribution of the obtained data was evaluated with the Saphiro-Wilk normality test. Then, one-way ANOVA and the Tukey Posthoc test were applied. All analyses were performed using statistical software.

RESULTS

According to the results of one-way analysis of variance, there was a significant difference between the groups (df:2, F:3.758, p=0.036). According to the data obtained, there was no significant difference between the groups produced by the milling method (p=0.878). While there was no difference between the additive manufacturing group and the Cerasmart group (p=0.110) it was observed that the flexural strength was significantly lower than the Brillant Crios group (p=0.040). Table 1 presents the descriptive statistics of flexural strength values. The highest flexural strength was seen in the BC group (313.49 MPa), followed by Cerasmart (305.92 MPa). The lowest flexural strength belongs to the printed specimens (273.41 MPa).

DISCUSSION

Nowadays, resin-containing materials are preferred for permanent restorations as well as popular materials such as glass ceramics and zirconia (17). Subtractive and additive manufacturing technologies are developing rapidly and allow the long-term use of resin-containing materials. Resin materials produced for 3D printers using additive manufacturing technologies have been introduced mostly for interim restorations. However, there have been resin materials introduced by some companies to the dental market for permanent restorations in

Table 1: Mean ± standard deviation biaxial flexural strength (BFS in MPa) values

Material	BFS
BC	313.49 (287.49-339.49)[a]
CE	305.92 (277.60-334.24)[a]
Printed	273.41 (254.06-292.76)[b]

*Different superscript letters indicate significant differences ($p<0.05$)

recent years. Knowledge of permanent 3D printed resins, which are relatively new compared to interim ones, is rather limited. Therefore, in our study, the flexural strength of the 3D printed material, which is defined as permanent resin, was compared with the milled resin material with two different contents. As a result of the experiments, there was a significant difference between the BFS values after thermal aging of the permanent crown materials produced with different production techniques, thus the hypothesis of the study was rejected.

In the present study, while the highest fracture strength belonged to the BC group, no significant difference was observed between CE, another milled material. The nonsignificant difference in flexural strength of the materials can be attributed to the relatively similar contents of the materials. The filler content and particle sizes of both materials are similar (18). In a previous study, the fracture strength of permanent crowns, including Cerasmart and Brillant Crios materials, was evaluated (19). The researchers reported that although the BC group had the highest fracture strength, it was not statistically different from the CE group, which is consistent with the results of the presented study. However, the 3D group used in the same study showed similar fracture strength to BC, in contrast to this study (19). This difference may be due to different specimen thicknesses and shapes, the content of the 3D resin materials used and the test conditions. In another study testing the fracture strength of 3D permanent crown material, the researchers also evaluated 3 different millable materials, including BC and CE blocks. As a result of the study in which all specimens were produced in the form of implant supported crowns, no difference was found between the experimental groups in terms of fracture strength (16). In another study in which permanent 3D printed material was produced as implant-supported screw-retained crowns, researchers tested the fracture strength of anterior and premolar crowns (20). Researchers have reported that crowns produced by subtractive manufacturing have higher fracture strength than those produced by additive manufacturing. However, in the aforementioned study, unlike this study, a 3D printer with DLP technology was used instead of SLA.

The composition of resin materials affects water absorption rates, and mechanical and physical properties. Details of the chemical composition of the materials used are required for more accurate comparisons (21). The content of the Permanent Crown (Formlabs) material used in present study has not yet been disclosed by the manufacturer. Although there are a few studies using 3D printed permanent resins in the literature, a different brand of restoration material was used in this study. Therefore, it is not possible to make a comparison in terms of material content.

There are many parameters that affect the mechanical properties of materials in production with 3D printers (22). Factors such as printing direction, layer thickness, and the postpolymerization process have been evaluated in many studies and it has been reported that 3D printed interim materials have effects on flexural resistance (22-27). However, the results presented in previous studies belong to interim materials. In the present study, only the manufacturer's instructions were followed and no changes were made to the parameters. Evaluation of different parameters in further studies will provide more detailed information. Moreover, this study has some limitations. It has been reported that glaze application improves the mechanical and optical properties of the materials before the clinical use of resin-containing materials (18, 28). However, the glaze process was not applied to the specimens in this study. In addition, because only a group of printed materials was used and the content of this material has not been disclosed by the producer yet, the inability to interpret the results in terms of content can be shown as another limitation. In future studies, evaluating 3D printed resins from different companies together, applying thermomechanical aging procedures, and examining the effects of different parameters will contribute to the addition of more detailed information in the literature. Within the limitations of this current study, it was concluded that permanent resin materials produced by additive manufacturing offered lower biaxial flexural strength after thermal aging than those produced by the milling method.

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