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Comparison between fixed orthodontic retainers fabricated through conventional means and those designed virtually and fabricated using cad/cam technology: an in vitro study.

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Abstract:

Introduction: Fixed lingual retainers are commonly used to maintain teeth position after orthodontic treatment. While computer-aided design/computer-aided manufacturing (CAD/CAM) technology has been established in dentistry, its potential use in fixed retainer therapy has not been investigated. The aim of this in vitro study is to compare the mechanical properties of conventionally fixed lingual retainers to those virtually designed and machine-made using digital CAD/CAM technology.

Materials and methods: The study involved producing twenty, three-dimensional, identical printed wax models using the Varseo S 3D printer (BEGO, Bremen, Germany) with VarseoWax Model Material (BEGO, Bremen, Germany). Two groups were categorized, differing in the manufacturing process and material of the lingual retainer. The first group used CAD/CAM technology to produce the retainers, while the second group used conventional stainless-steel wires. The retainers were attached to the lingual surface of the lower front teeth and subjected for a mechanical fracture test using the Zwick/Roell Z010 universal testing machine (Zwick/Roell, Ulm, Germany). The dental arch was then loaded labially to evaluate the fracture strength of the lingual retainer.

Results: Statistical analysis was performed using Sigma Plot 13.0 (Systat, San Jose, USA), and no significant differences were found between the two groups ($p>0.05$).

Conclusion: This study found no significant difference in mechanical properties between the VarseoSmile Crown plus (BEGO, Bremen, Germany) material and conventional stainless-steel wire for lingual retainers.

Keywords: CAD/CAM, Digital Orthodontics, Lingual Retainer, Mechanical Testing, In-vitro Study, VarseoSmile Crown plus

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Introduction

Orthodontics is a specialized field of dentistry that focuses on diagnosing and treating malocclusions, or improper alignment of teeth and jaws. The primary objective is to promote healthy and straight teeth by identifying and correcting any abnormalities in the way teeth come into contact. (1,2). Achieving a harmonious occlusion requires balancing the relationship and intensity between the teeth's biting surfaces. (3)

After orthodontic treatment, it is crucial to maintain the position of teeth, and this is achieved through the retention phase (4). In 1907, E. H. Angle introduced the use of fixed appliances, specifically a lingual retainer with a steel wire attached over the canines, for retention purposes (5). Later, Zachrisson advocated for the use of adhesively bonded metal wires from canine to canine (6). Currently, the 3-3 retainer is the standard retention device used by orthodontists, several studies have shown their effectiveness in the long term (7,8). In the 1970s, Francois Duret introduced the use of computer-aided designs in dental research, exploring various systems (9). Today, computer-aided design/computer-aided manufacturing (CAD/CAM) technology allows he virtual production of retainers. As early as 2014, researchers were already studying the feasibility of using printed removable retention devices (10).

The use of 3D printing technology presents exciting new possibilities for optimal dental care. However, currently there are no published studies on the use of VarseoSmile Crown plus (BEGO, Bremen, Germany) in producing printed retainers. On the other hand, Memotain® technology produces lingual retainers that are CAD/CAM-fabricated from 0.014x0.014 inch nickel-titanium retainers milled from nickel-titanium archwires (CA Digital, Carros, France) Additionally, the retainer's surface is smoother due to electron polishing, which is supposed to reduce microbial colonization (11). The formation of a titanium oxide layer also enhances corrosion resistance (12).

This study combines traditional orthodontics with innovative CAD/CAM technology. While research on standard retention devices and CAD/CAM technologies exists independently, there is a lack of cross-cutting research in this field.

Materials and Methods

In our experimental design, we categorized the retainer into two different groups: Group 1 consisted of CAD/CAM manufactured retainers and Group 2 consisted of conventionally manufactured wire retainers. For this study a total of 20 identical models were printed. Per group 10 models were created with Autodesk Netfabb digital (Autodesk, Frankfurt, Germany) from tooth 33 to tooth 43 on the basis of the Frasaco tooth model (Tetnang, Germany), only the 41 was digitally removed for testing (figure 1) and then produced using the VarseoS 3D printer from BEGO, Bremen, Germany, which uses Digital Light Processing (DLP) technology.

The tooth models we used were specifically designed to match an optimized aligned dental arch and were based on the Frasaco tooth model. We ensured that the anatomy of the occlusal surface matched that of a young, wear-free type. The custom models were made using VarseoWax Model from BEGO, Bremen, Germany, a special resin suitable for 3D printing dental models. This material consists of a monomer based on acrylic acid ester, which, according to the manufacturer, is suitable for printing different types of dental models.

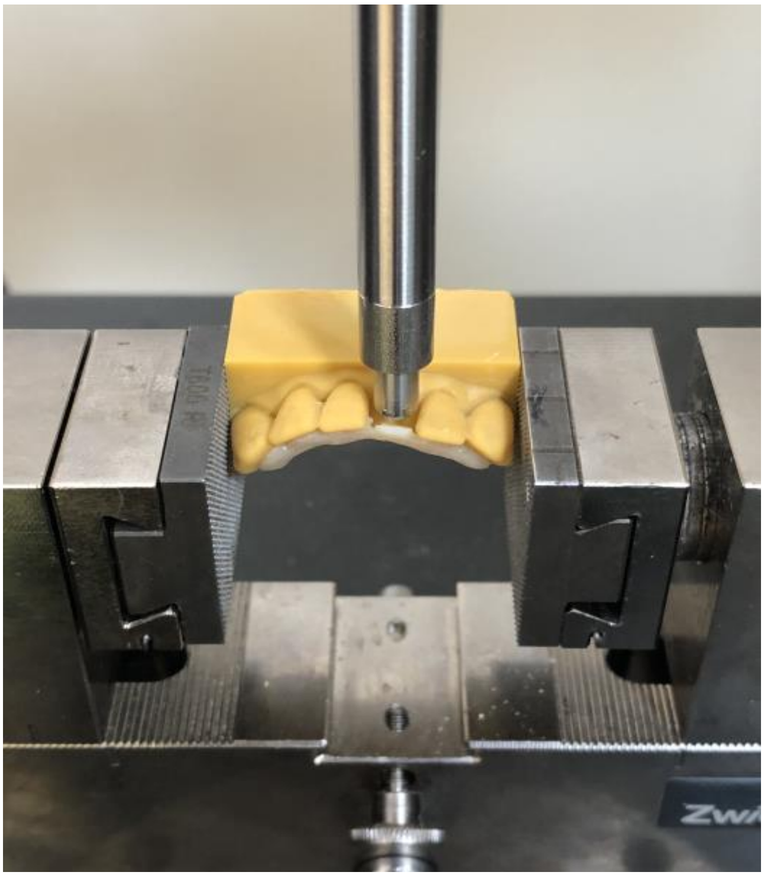
The Frasaco dental model was digitalized using the 3Shape D800 scanner, a 3D scanner that can produce 3D scans of different model situations such as stumps, implants, bites, etc. The data was processed using 3Shape Dental System 2021 program from Copenhagen, Denmark. To fabricate the CAD/CAM printed retainer, a novel, ceramic-filled hybrid material called VarseoSmile Crown plus (BEGO, Bremen, Germany) which is a light-curing, flowable plastic based on methacrylic acid ester was used. The material was cured layer by layer in the VarseoS 3D printer using the DLP 3D-printing exposure process.

Finally, the models were sandblasted using the Basic quattro IS fine sandblasting unit from Renfert, Hitzingen, Germany, and bonded the brackets to the models using G-Bond Bonding and the Gaenial-Universal Flo GC CORPORATION in Tokyo, Japan. For this experiment, the Zwick/Roell Z010 (Zwick/Roell, Ulm, Germany) was used. This is a universal testing machine for static applications.

The electronics used for measurement, control, and regulation were be utilized to configure the testing process in the machine. This type of testing involved performing a compression test without specifying the shape of the specimen. The distance between the test bar and the lingual retainer was set to 1 mm for the models being tested, while the preload was set at 5N. The test speed was controlled by position, and the upper force limit was set at 3000N.

Figure 1: Comparsion of conventionally manufactured retainers (right) vs. CAD/CAM-manufactured retainer (left) on two wax models

Figure 2: model clamped in Zwick/Roell machine



Studies have shown that the technology of lingual braces has changed very little over the last 40 years, especially in terms of wire strength (14,15, 16,17). For ease of comparison, we have converted the measurements to inches. The highest success rates have been reported for strengths ranging from 0.016x0.022 inches to 0.20x0.70 inches, and the average wire strength used in conventional orthodontics is typically 0.022 inches.

Results

The analysis was conducted by utilizing SigmaPlot 13.0 (Systat, San Jose, USA) and the Mann-Whitney rank-sum test. For Group 1, which involved CAD/CAM-fabricated retainers, the median value for the ten tested models was found to be 116.9N. In contrast, the median value for Group 2, which involved conventionally fabricated retainers, was 30.4N. The difference between the median values of the two groups did not demonstrate a statistically significant difference, as the p-value was found to be 0.241.

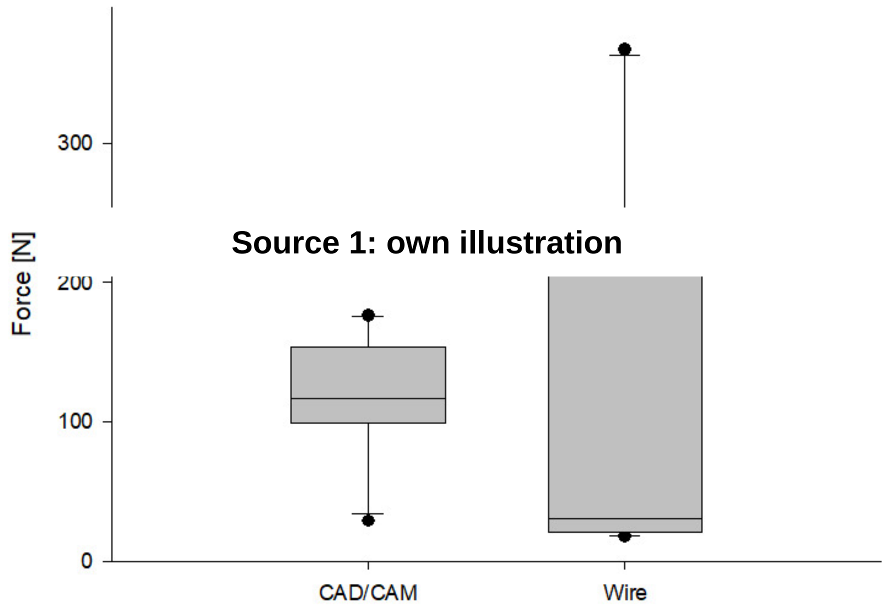


Figure 3: Boxplot comparison CAD/CAM (blue) vs. wire (orange)

Source: own Illustration

Discussion

The objective of this study was to compare the strength of the retainers made through CAD/CAM printing with conventionally made retainers in the field of dentistry. A static Zwick/Roell testing machine was used to conduct the tests, where 20 models were made based on a Frasaco model, bonded with two types of retainers and then clamped in the testing machine. The sample size was chosen based on the average value from four previous studies (13,14,15,16).

Orthodontics is crucial in maintaining long-term results after treatment, and the use of retainers is recommended (17). Tooth movement and bone remodeling during orthodontic treatment can cause the teeth roots to loosen within the alveolus, leading to relapse, where the teeth shift back in their position before the orthodontic treatment. To prevent this, lingual retainers made of orthodontic wires are bonded to the inside of the teeth.

This study aims to explore if CAD/CAM printed retainers offer an advantage over orthodontic wires. With a special focus on the use of VarseoSmile Crown plus (BEGO, Bremen, Germany), this study closely examines the accurate application, processing and attachment of the retainers.

The study reviewed previous research on the use of orthodontic wires, including studies by Zinelis S. et al (2018), Kocher K. et al (2020), Ferreira L. et al (2019), and M. Aycan et al (2018). An average layer thickness of 0.016x0.022 inch was mentioned in the studies, and based on this, preformed wires of Ormco (California, USA) with a layer thickness of 0.016x0.022 inch were chosen for this study.

Each retainer was tested in the Zwick/Roell Z010 testing machine using a test pin pressed vertically onto the retainer. However, the study suggests that additional experiments from different angles or perspectives are necessary to gain further insights. The study also mentions that the fractures occurred perpendicular to the applied force and not parallel to the layer structure.

An extension of the experiment could be an evaluation of the fracture surfaces of the retainers using a microscope to obtain further information on the fracture behavior. The study concludes that this is a pilot project, and further clinical studies are necessary to make concrete statements.

Conflict of interest

This study was conducted independently and out of personal interest, and therefore, there is no conflict of interest.

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