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Wear behaviour of 3D printed, minimally invasive restorations: Clinical data after 24 months

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Introduction

Computer-aided design and computer-aided manufacturing (CAD-CAM) has been used to manufacture restorations for some time. Three-dimensional (3D) printing, otherwise known as additive manufacturing, has been gaining popularity in conjunction with stereolithography (SLA), digital light processing (DLP) and fused deposition modelling (FDM),being most commonly used to manufacture aesthetic restorations. Interim and definitive single tooth restorations fabricated using 3D printing have reduced material consumption and are time effective.

Inorganic particles (including ceramic particles- up to 60% by volume) have been added to improve the mechanical properties of resin based 3D printable materials. Filler volume, shape, size, hardness values and printing parameters have been reported to influence the mechanical properties of 3D printed restorations. The bond strength between the fillers and the polymer matrix has been reported to affect the mechanical behaviour of restorations and influence wear characteristics. It is not clear if 3D printed single-tooth restorations can withstand masticatory forces under clinical conditions.

Pathological tooth wear prevalence has been reported to range from 26.9-90% in children and adults. It can be due to stress and can manifest as parafunctional habits and bruxism. New and cost-effective treatment options for pathological tooth wear are required. It is beneficial to protect and preserve the remaining tooth structure.

It has been assumed that 3D printed restorations made of ceramic-reinforced composite resin material are suitable for long- term interim restorations. At present, data exist only for CAD-CAM ceramic reinforced composite resin materials. The aim of this clinical study was to assess the clinical performance of 3D printed, non-invasive restorations from a CAD CAM ceramic-reinforced composite resin material as part of a prosthetic plan prior to treatment for pathological tooth wear or occlusal adjustment of single teeth.

Methods

Inclusion criteria were patients who required alteration of the vertical dimension or occlusal adjustment of single teeth. Exclusion criteria were temporomandibular joint disorders. All active periodontal treatment needed to be completed before the study began.

Informed consent was obtained and a thorough dental examination was performed. Any periodontal and/or restorative findings were noted as part of a pretreatment protocol.

An intraoral scanner (IOS Primescan) was used to scan the maxilla, mandible and occlusal registration in the maximum intercuspal position (ICP). Individual jaw movements were recorded with the aid of a digital facebow (Zebris for Ceramill) and a virtual articulator (Artex CR). If required, digital processing of alteration of the vertical dimension was performed.

The design and printing process of the non-invasive restorations were carried out to the manufacturer’s specifications. The design of the restorations was associated with the defect and therefore the restorations in the posterior areas were limited to the defect and occlusal surfaces for increasing the vertical dimension. In the anterior area, the restorations extended to the entire labial surface. Speech was assessed clinically to confirm the available space for alteration of the vertical dimension.

The printing material used was Varseo Smile Crown plus (Ceramic-filled (30–50 wt% inorganic fillers; particle size 0.7 µm)) silanized dental glass, methyl benzoylformate, diphenyl (2,4, 6-trimethylbenzoyl) phosphine oxide hybrid material.

The printing layer thickness was set to 50µm with a build angle of 35 to 45 degrees. After removal from the build platform, the restorations were ultrasonically cleaned in 99% isopropanol first for 3 minutes of rough cleaning followed by 2 minutes of final cleaning and then air dried in an oil-free airflow. After removing the supports, they were air-abraded with glass beads to remove a white layer of unattached filler particles and light polymerised using 1500 flashes twice with two xenon stroboscopic lamps, flash frequency 10Hz, light spectrum 300-700nm. All restorations were glazed.

The restorations were air abraded with aluminium oxide for 10 seconds and conditioned with a universal primer prior to insertion. If enamel was present, the surface was etched with 37% phosphoric acid for 30 seconds. The enamel and dentine were then pretreated with a self-etching universal adhesive (Scotchbond SE) and bonded with a luting composite resin (RelyX Ultimate). Excess resin was removed immediately after insertion. The cement was then light polymerized and static and dynamic occlusion was checked with shimstock foil. The existing dynamic occlusion was not altered when single teeth were restored and anterior guidance was adapted if the vertical dimension was increased by all restored teeth. The restoration was then polished with Sof-Lex discs.

All teeth were scanned after insertion (baseline) and at the 12 month and 24 month follow-ups. The scans were analysed using a metrology software program for 3D quality control. All datasets were obtained in standard tessellation language (STL) file formats. The files were then exported and superimposed. The occlusal surface of each tooth was segmented and compared using the 3D comparison tool in the metrology software. Maximum occlusal height loss and mean profile loss (average surface loss over the occlusal surface) was measured to evaluate the tooth wear.

Results

Three hundred and fifty two non-invasive restorations in 28 patients (17 men and 11 women) were evaluated. The mean value of maximum occlusal height loss was 0.76mm while the mean profile loss was 0.22mm at 24 months. The maximum occlusal height loss and mean profile loss showed lower wear in anterior restorations than in premolar and molar restorations, with molars having highest wear rates. Only anterior restorations had a mean profile loss of less than 0.1mm after 12 months.

Restorations with 0.5mm or more of wear were classed as fractured; 24% were fractured at 12 months and 35% fractured at 24 months. At 12 months, 17 anterior, 28 premolars and 39 molar restorations were fractured. At 24 months, 33 anterior, 37 premolar and 53 molar restorations were considered fractured. Excluding the fractured restorations, comparable values of profile loss were found for anterior, premolar and molar restorations. 3D printed non-invasive restorations could be recommended for long-term use up to six months as survival rates were limited after 12 months.

In the non-fractured restorations, comparable values of profile loss were found for anterior, premolar and molar restorations. Material wear was higher in the molar and premolar restorations.

The maximum occlusal height loss of non-fractured restorations was between 0.01-0.5mm, the median value of maximum occlusal height loss was 0.17mm at 12 months and 0.24mm at 24 months. At 24 months, the median maximum occlusal height loss for non-fractured restorations was 0.27mm for premolars and 0.25mm for molars. Most of the restorations had a mean profile loss between 0.05mm and 0.1mm. The mean profile loss of non-fractured restorations after 12 and 24 months was less than 0.1mm.

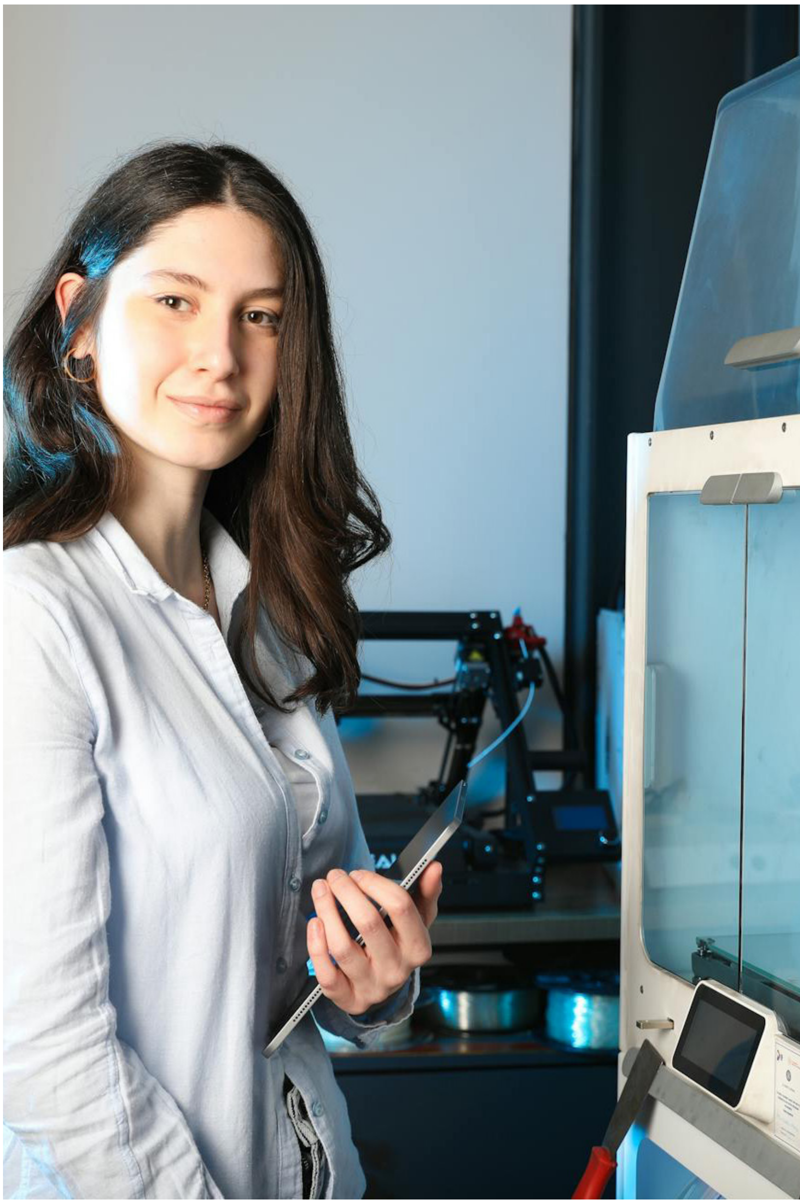
Discussion

The results of this study showed that the mean maximum occlusal height loss was highest for molar restorations (1.25mm) and the mean profile loss was higher for the molars (0.33mm) at 24 months. This is similar to other clinical studies that analysed material wear of CAD-CAM ceramic- reinforced composite resin material for milling which showed higher wear in the areas of the occlusal contacts.

Prior to this, only in vitro data existed for the 3D printable material. The VarseoSmile Crown plus showed higher wear rates than other tested materials. All tested additively manufactured materials were recommended for interim use only. In this study, the non-invasive design was a proof of concept and the 3D printable material has not been approved for a non-invasive design and therefore the results should be considered with caution.

Different methods regarding clinical wear analysis have been tested but there is no standard method. The current best clinical method for wear analysis is intraoral scanning using digital profilometry with a matching software program. There have been advances in trueness and precision of intraoral scanning, meaning that quantitative analysis of superimposed dental structures at different time points is now possible. Previous studies used best fit alignment but this may be prone to errors. The occlusal surface of each treated tooth was individually segmented in the baseline scan and compared with the follow-up. The values are susceptible to errors because of the many fractures and areas of material wear.

Limitations of this study included that this was a single centre with a single printer and resin. A second test group with a CAD-CAM millable ceramic reinforced composite resin may have helped with direct comparison between additive and subtractively manufactured materials. A control group with analogue restorations would have helped with the findings. The use of the material to print non-invasive restorations has not been approved by the manufacturer and that the restorations were glazed may be limitations. Future studies should consider mechanical polishing. In the current study, the material was printed at an angulation of 35-45 degrees as this is the reported optimal angle for ceramic reinforced composite resin materials. Other build angles may influence the wear behaviour.



Conclusion.

The following conclusions were drawn.

- Non-invasive 3D printed restorations made from a ceramic reinforced composite resin material had wear of up to 1.5mm after 24 months in the oral environment and therefore can only be recommended for short term temporary use of six to 12 months
- Molar restorations had the highest wear of material
- Approximately 35% of the restorations had occlusal height loss of more than 0.5mm and were classed as fractures
- The results should be interpreted with caution as this 3D printable material was not authorised for a non-invasive approach.

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1. A B C D
2. A B C D
3. TRUE or FALSE
4. A B C D
5. A B C D
6. A B C D
7. TRUE or FALSE
8. A B C D
9. A B C D
10. A B C D

November 2025 QUIZ answers

1. B
2. B
3. B
4. B
5. B
6. C
7. C
8. B
9. B
10. C

Questions

1. The 3D printing material used in this study contained what proportion of ceramic filler?
   a. 10-30%
   b. 30-50%
   c. 50-60%
   d. 70-90%

2. How many anterior restorations were fractured (0.5mm of wear) at 24 months?
   a. 17
   b. 28
   c. 33
   d. 53

3. Universal adhesive (Scotchbond SE) was used alone on enamel.
   - TRUE
   - FALSE

4. Limitations of this study included:
   a. There were two groups for comparison for this study
   b. The study was conducted for a period of 24 months
   c. Multiple printers and resins were used
   d. Use of the material to print restorations had not been manufacturer approved

5. Reasons for pathological toothwear may be due to:
   a. Genetics
   b. Developmental enamel thickness
   c. Parafunctional habits
   d. Temporomandibular dysfunction

6. The mean maximum occlusal height loss for molars was:
   a. 0.10mm
   b. 0.25mm
   c. 0.33mm
   d. 1.25mm

7. Only anterior restorations had a mean profile loss of less than 0.1mm after 12 months
   - TRUE
   - FALSE

8. Advantages of using 3D printed materials include:
   a. Less material consumption
   b. Less inorganic particles
   c. Ability to withstand masticatory forces
   d. Preservation of remaining tooth structure

9. In the posterior area, the design of the restoration included:
   a. The labial surface
   b. The palatal surface
   c. The defect and occlusal surfaces
   d. The interproximal surfaces

10. The best clinical method currently for wear analysis is:
    a. Intraoral scanning using digital profilometry
    b. Best fit alignment
    c. CAD- CAM manufacturing
    d. Alginate impressions