Stress distribution difference between Lava Ultimate full crowns and IPS e.max CAD full crowns on a natural tooth and on tooth-shaped implant abutments

KREJCI, Ivo, DAHER, René

Abstract

The goal of this short communication is to present finite element analysis comparison of the stress distribution between CAD/CAM full crowns made of Lava Ultimate and of IPS e.max CAD, adhesively luted to natural teeth and to implant abutments with the shape of natural teeth. Six 3D models were prepared using a 3D content-creating software, based on a micro-CT scan of a human mandibular molar. The geometry of the full crown and of the abutment was the same for all models representing Lava Ultimate full crowns (L) and IPS e.max CAD full crowns (E) on three different abutments: prepared natural tooth (n), titanium abutment (t) and zirconia abutment (z). A static load of 400 N was applied on the vestibular and lingual cusps, and fixtures were applied to the base of the models. After running the static linear analysis, the post-processing data we analyzed. The stress values at the interface between the crown and the abutment of the Lt and Lz groups were significantly higher than the stress values at the same interface of all the other models. The high stress concentration in the adhesive at the interface between the crown [...]
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Keywords Debonding · Implant abutment · Adhesively luted crown

Introduction

On June 12, 2015, 3M ESPE Dental limited the indication of Lava Ultimate CAD/CAM blocks to inlays, onlays and veneers and withdrew the crown indication on teeth and implants due to the existence of a potential for debonding being in the order of around 10 % instead of 2–4 % generally reported in clinical literature. Lava Ultimate CAD/CAM material is a resin nano ceramic composite containing approximately 80 % by weight of nanoceramic particles bound in a resin matrix, with a dentin-like modulus of elasticity of 12.8 GPa. This E-modulus is far from the modulus of elasticity of implant abutments made out of titanium with around 110 GPa or zirconia with around 210 GPa. On the other hand, there are no known reports of a higher debonding rate of ceramic crowns such as IPS e.max CAD, with an E-modulus of 95 GPa.

The aim of this short communication is to study the particular stress distribution in a Lava Ultimate crown adhesively luted to a natural tooth and to titanium and zirconia implant abutments, and to compare it to IPS e.max CAD crowns. For a better comparison, the shape of the implant abutments was identical to the shape of the prepared natural tooth.

Materials and methods

A micro-CT scanner (SkyScan 1076 micro-CT, SkyScan, Aartselaar, Belgium) was used to scan a mandibular first molar. The images were then imported into processing software OsiriX (OsiriX, Geneva, Switzerland) where a segmentation process was performed to separate enamel from dentin. A 3D content-creation program (Blender, Amsterdam, the Netherlands) was then used to simulate a
crown preparation on the natural tooth, and to build up the corresponding crown restoration. To change only one factor (E-modulus), the shape of the implant abutments was identical to the shape of the prepared natural tooth. The models were then opened in a finite element analysis software (FEMAP, Siemens PLM software, Plano, Texas, USA), and a static load of 400 N at a 45° angle was applied on the buccal and lingual cusps, and fixtures in the x-, y- and z- directions were applied at the base of the models (Fig. 1). Different material properties were assigned to each assembly as seen in Table 1. A static analysis was launched and the post-processing file was opened. The maximum principal stress was then studied in all the models after running a static analysis.

Results

The stress distribution at the interface of the natural tooth and the titanium and zirconia abutments were significantly different as seen in Fig. 2. The Lz and Lt models showed the highest stress values of 31 and 28 MPa, respectively. The Ln and En models showed stress values of 8 and 10 MPa, respectively. The Et model showed the lowest stress value of 6 MPa at the same location. The Ez model showed a stress value of 17 MPa, but inside the crown itself.

<table>
<thead>
<tr>
<th>Restoration material</th>
<th>Abutment type</th>
<th>Assembly name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lava Ultimate (12.8 GPa*, 0.30) [1]</td>
<td>Natural tooth (18.6 GPa*, 0.31) [2]</td>
<td>Ln</td>
</tr>
<tr>
<td></td>
<td>Titanium abutment (110 GPa*, 0.35) [3]</td>
<td>Lt</td>
</tr>
<tr>
<td></td>
<td>Zirconia abutment (210 GPa*, 0.25) [4]</td>
<td>Lz</td>
</tr>
<tr>
<td>IPS e.max CAD (95 GPa*, 0.30) [1]</td>
<td>Natural tooth (18.6 GPa*, 0.31)</td>
<td>En</td>
</tr>
<tr>
<td></td>
<td>Titanium abutment (110 GPa*, 0.35)</td>
<td>Et</td>
</tr>
<tr>
<td></td>
<td>Zirconia abutment (210 GPa*, 0.25)</td>
<td>Ez</td>
</tr>
</tbody>
</table>

Fig. 1 Image showing the loads’ locations on the buccal and lingual cusps

Table 1 Description of the six assemblies calculated in this study with the Young modulus* and Poisson ratio of the materials

Fig. 2 Image of a section view showing the maximum principal stress (in MPa) of the six calculated assemblies. The three upper models represent Lava Ultimate crowns, and the lower three models represent IPS e.max CAD crowns
Discussion

The behavior of the Lava Ultimate crown on a natural tooth appeared to be significantly different than on implant and zirconia abutments of the same shape. The elasticity modulus of the Lava Ultimate material is 12.8 GPa which is approximately 11% of the elasticity modulus of titanium (110 GPa) and 6% of the elasticity modulus of zirconia (210 GPa). This high difference in the modulus of elasticity was translated by a stress concentration at the interface between the crown and the abutment. The stress concentration at this interface might deteriorate the adhesive layer and increase the fatigue mechanisms inside it, which, allegedly, together with other cumulative factors, could favor debonding. On the other hand, stress concentration at the interface between the crown and titanium/zirconia abutment was absent for the e.max CAD crowns. Even if being low, some stress was present between the e.max CAD crown and the natural tooth, in contrast to Lava Ultimate where the stress was more uniformly distributed and not concentrated at the interface between the crown and the natural tooth. Therefore, the stress distribution in the Lava Ultimate crown on a natural tooth appears to be more favorable than on titanium and zirconia abutments. In the Ez model, the crown material was able to retain most of the stress, without passing it through to the interface.

The indications for inlays, onlays and veneers are still valid for Lava Ultimate. This means that the quality of the bond to the components of this material is not a problem, since the retention of adhesive inlays, onlays and veneers depends largely if not fully on adhesion. In view of the data presented in this study it seems reasonable to believe that the debonding problems observed with Lava Ultimate crowns may be at least partly attributed to the biomechanical behavior of this material on implants. This assumption is in line with a clinical observation describing thirty CAD/CAM inlays, onlays and crowns made with Lava Ultimate, where the only three debondings that were reported were on implants [5].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References