EFFECT OF SPECIAL LAYERS SHAPING ON STRESS DISTRIBUTION IN DENTAL RESTORATIONS

P.Kowalczyk
Division of Applied Mechanics, Warsaw University of Technology, Warsaw, Poland

1. Introduction

One of the most popular materials used for restorations in dentistry are the resin-based composites reinforced by ceramic particles. In contrary to amalgam, the composites are mercury-free, do not require special cavity shaping and are esthetical. Photo-cured composites are one of the types of the resin-based composites. Typical features of the photo-polymerization process are: high speed of the polymerization, room temperature process, and limitation of the polymerization depth due to light absorption. Typical polymerization time of the photo-cured composite is 20 seconds for 2 mm thick layer. Fillings are made layer by layer. One of the main disadvantages of these materials is volumetric shrinkage that occurs during polymerization. It results in high residual stress in tooth and restoration, which can cause gaps between the tooth tissue and the filling. It may leads to microleakage and tooth decay. To ensure strong bonding between the tooth tissue and the composite restoration, bonding agents are used. The bonding agent is a photo-cured polymer with small viscosity. This material creates thin, approximately 0.01 mm layer on the tooth tissue and penetrates into it, and this creates kind of mechanical bonding. Adhesives bond with composite restoration chemically. For modern systems the bonding strength is 15 – 35 MPa [1]. Experiments reveal that the bonding strength of adhesives depends of cavity preparation before coating it with bonding agent. Existing of thin layer of bonding agent causes stresses reduction between composite filling and tooth tissue [2]. Most recently the effect of bonding agent is assumed to be negligible. Ausiello and coauthors had modeled the tooth under load with adhesive layer modeled with springs [3]. The tooth filling was assumed to be strain free, without polymerization shrinkage and residual stress.

Clinical practice reveals that shape of layers and method of layering are important [4]. In this study restoration of Class I is modeled with existing adhesive layer. Different shapes of composite layers and its influence on stress distribution in dental filling are taken into account.

2. Materials and methods

Premolar tooth was modeled with ABAQUS - the finite element method software. Mechanical properties of the tooth tissues (Young modulus E, and Poisson's ratio ν) are as follows: enamel E = 80000 MPa, $\nu = 0.33$; dentin E = 18000 MPa, $\nu = 0.31$; pulp E = 2.07 MPa, $\nu = 0.45$ [5]. The tooth tissues are assumed to be linearly elastic materials. Properties of the adhesive layer (UniFill) are: Young's modulus – 39100 MPa, assumed Poisson's ratio – 0.25 [6]. A 0.01 mm thick adhesive layer was modeled with cohesive elements. Properties of the resin-based composite (P50) are: Young's modulus – 20000 MPa, Poisson's ratio – 0.24 [4]. Polymerization shrinkage was modeled as analogical to thermal deformation. Total linear shrinkage of composite is $s_{max} = 0.008$. According to Versulis [4] shrinkage stress is developed after the gel point. Before this point all stresses are fully relaxed by the flowing of the material. Shrinkage value after the gel point is about $s_{post\text{-}gel} = 0.0022$. The filling material was modeled as linearly elastic with maximal linear shrinkage of 0.0022. The tooth and its restoration were modeled in assumption of axisymmetric model. Influence of adhesive layer is presented in Fig 1.

In these work, two shapes of horizontal layer are presented: a flat layers and a rounded layers. Moreover, a modification of the layering with additional vertical layer (called a pre-layer) is presented (Fig.2).

3. Results

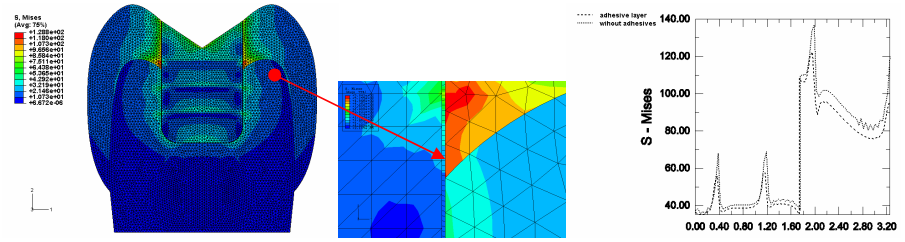

Fig. 1 Modeled adhesive layer with cohesive elements and plot of Huber-Mises stress in tooth tissue (adhesive layer reduces stresses of about 20%)

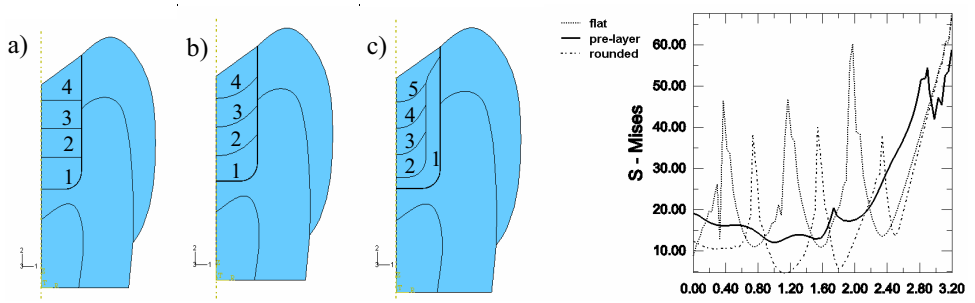

Fig. 2 Three types of layering techniques - a) flat, b) rounded, c) pre-layer, and plot of Huber-Mises stress along the right vertical wall of the cavity.

The horizontal rounded layers give smaller values of stresses along the cavity than flat layers. The lowest stress is achieved when an additional vertical layer is added. The pre-layer reduces significantly influence of the layers corners, and in consequence, stress accumulations near the adhesive layer. Unfortunately the pre-layer can increase stress at the top of restoration due to accumulation of the shear stresses at the top of the layer. To avoid this problem, the vertical layer should not reach the top of the cavity. The last horizontal layer should be extended on whole area of the cavity.

6. References

[1] A. Takahashi, Y. Sato, S. Uno, P.N.R. Pereira, H. Sano (2002). Effect of mechanical properties of adhesive resins on bond strength to dentin, *Dental Materials* **18** 263-268

[2] B.S. Dauvillier, P.F. Hubsh, M.P. Aarnts, A.J. Feilzer (2001). Modeling of viscoelastic behavior of dental chemically activated composites during curing, *Inc. J. Biomed Master Res (Appl Biomater)* **58**: 16-26,

[3] P. Ausiello, A. Apicella, C.L. Davidson (2002). Effect of adhesive layer properties on stress distribution in composite restorations – a 3D finite element analysis, *Dental Materials* **18** 295-303.

[4] A. Versluis, W.H. Douglas, M. Cross, R.L. Sakaguchi (1996). Does an incremental filling technique reduce polymerization shrinkage stress?, *J. Dent. Res*. **75** 871-87

[5] G. Couegnat, S.L. Fok, J.E. Cooper, A.J.E. Qualtrough (2006). Structural optimisation of dental restorations using the principle of adaptive growth, *Dental Materials* **22** 3-12.

[6] A. Takahashi, Y. Sato, S. Uno, P.N.R. Pereira, H. Sano (2002). Effect of mechanical properties of adhesive resins on bond strength to dentin, *Dental Materials* **18** 263-268