Chipping on zirconia: a comparison of FEA and in-vitro simulation

V. Preis[1], H. Gietl[2], C. Schliekmann[2], D. Behrend[3], M. Steiger[1], M. Rosentritt[1]
([1]University Medical Center Regensburg , Department of Prosthetic Dentistry;
[2]Department of Mechanical Engeneering, University of Applied Science, Regensburg;
[3]Department of Material Science and Medical Engineering, University of Rostock)

Universitätsklinikum Regensburg

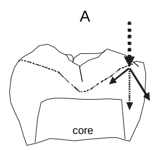
151597

Introduction:

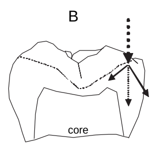
The aim of this study was to test whether chipping of ceramic veneering is influenced by the design of a zirconia core. Finite Element Analysis (FEA) data were compared with in-vitro chewing simulation results.

Materials and methods:

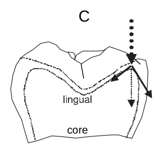
Resin molars (Morita, 46, G) were digitalised with µ-CT (SkyScan 1172, Micro Photonics, USA), transformed to CATIA (Dessault Systemes, F) and analysed (Solid187, 0.45mm, ANSYS 12.1 USA). Studies of the in-vitro simulation and FEA analysis were designed accordingly. Human periodontium was simulated with a 1mm thick layer of a polyether material (Impregum, 3M Espe, G). Preparation was a 1mm deep circular shoulder. Load was applied via four point contacts.
Three series of molar copings (n=8) of the yttria-stabilized zirconia (Cercon Base; DeguDent, G) were simulated.
The cores differed in design and thickness:
A: simple core 0.5mm,
B: core with minimal occlusal support (max. 0.8mm) and
C: core with optimized occlusal support and cusp-design (max. 1.3mm).
The thickness of core plus veneering (Cercon Ceram Kiss) was 2.5 ± 0.1 mm. For FEA verification, one crown was used without core. All crowns were cemented (ZnO-Ph-cement Harvard, Hoffman&Richter, G). Identical antagonists were used (CoCr-alloy; Wirobond LFC, Bego, G/ veneered with Duceram Kiss, Degudent, G).
Thermal cycling and mechanical loading (TCML) was performed for aging simulation (1,200,000 mechanical loadings [ML] x 50N sinusoidal loading and 6000 thermal cycles [TC] -2min between 5℃ and 55℃). Crown failures were analy zed by means of a SEM.
Statistics: One-way ANOVA (α=0.05).



simple core 0.5mm



core with minimal occlusal support (max. 0.8mm)



core with optimized occlusal support and cusp-design (max. 1.3mm)

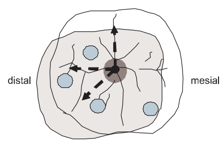
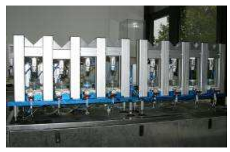


Diagram: contact situation

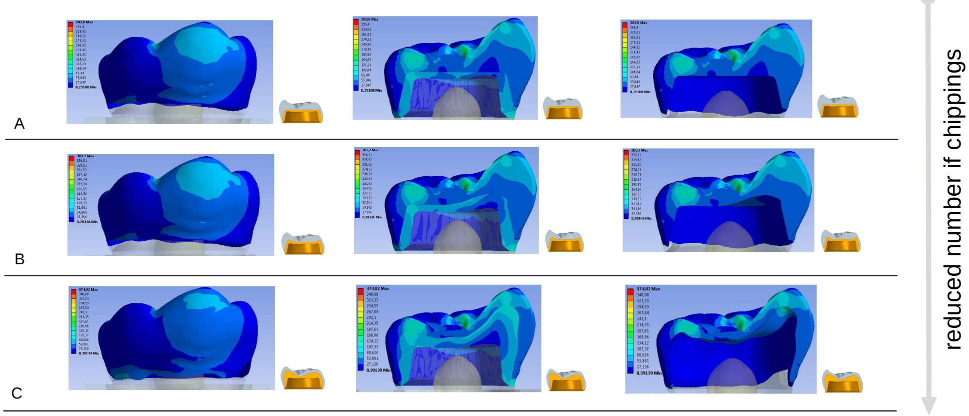


Regensburg chewing simulator

Results:

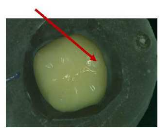
FEA and in-vitro data confirm that number and size of chippings was dependent on the design of the core. Simple cores showed a survival rate during in-vitro simualtion of only 25%, whereas an optimized design increased survival rates up to 75%. Chipping area was reduced from about 8 mm² to 2 mm². FEA figures underline the strong influence of the core design on the force distribution.

FEA

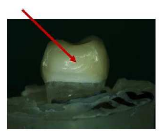


View: crown | View: cross section core/veneer | View: cross section veneer

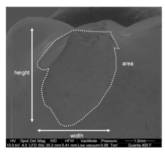
In-vitro simulation



Chipping location



Chipping location



Overview scanning electron micrograph: marked surface (width, height) of chipping area

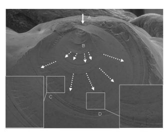


Figure 4: Detail scanning electron micrograph:
A = point of origin;
B = crack propagation;
C = wake hackles;
D = arrest lines

Discussion:

Both, FEA and in-vitro chewing simulation showed that chipping was dependent on the design of the core: the better the support of the veneering ceramic, the lower the chipping rates.