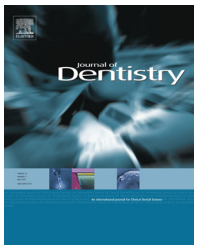
Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.intl.elsevierhealth.com/journals/jden



Fracture analysis of randomized implant-supported fixed dental prostheses

Josephine F. Esquivel-Upshaw [a,*], Alex Mehler [a], Arthur E. Clark [a], Dan Neal [b], Kenneth J. Anusavice [a]

[a] Department of Restorative Dental Sciences, University of Florida, Gainesville, FL, United States
[b] Department of Neurosurgery, University of Florida, Gainesville, FL, United States

ARTICLE INFO

Article history:
Received 30 March 2014
Received in revised form
30 June 2014
Accepted 1 July 2014
Available online xxx

Keywords:
Fractography
Ceramic–ceramic FDP
Metal–ceramic FDP
Occlusion
Occlusal contact
Failure analysis

ABSTRACT

Objective: Fractures of posterior fixed dental all-ceramic prostheses can be caused by one or more factors including prosthesis design, flaw distribution, direction and magnitude of occlusal loading, and nature of supporting infrastructure (tooth root/implant), and presence of adjacent teeth. This clinical study of implant-supported, all-ceramic fixed dental prostheses, determined the effects of (1) presence of a tooth distal to the most distal retainer; (2) prosthesis loading either along the non-load bearing or load bearing areas; (3) presence of excursive contacts or maximum intercuspation contacts in the prosthesis; and (4) magnitude of bite force on the occurrence of veneer ceramic fracture.

Methods: 89 implant-supported FDPs were randomized as either a three-unit posterior metal–ceramic (Au–Pd–Ag alloy and InLine POM, Ivoclar, Vivadent) FDP or a ceramic–ceramic (ZirCAD and ZirPress, Ivoclar, Vivadent) FDP. Two implants (Osseospeed, Dentsply) and custom abutments (Atlantis, Dentsply) supported these FDPs, which were cemented with resin cement (RelyX Universal Cement). Baseline photographs were made with markings of teeth from maximum intercuspation (MI) and excursive function. Patients were recalled at 6 months and 1–3 years. Fractures were observed, their locations recorded, and images compared with baseline photographs of occlusal contacts.

Conclusion: No significant relationship exists between the occurrence of fracture and: (1) the magnitude of bite force; (2) a tooth distal to the most distal retainer; and (3) contacts in load-bearing or non-load-bearing areas. However, there was a significantly higher likelihood of fracture in areas with MI contacts only.

Clinical significance: This clinical study demonstrates that there is a need to evaluate occlusion differently with implant-supported prostheses than with natural tooth supported prostheses because of the absence of a periodontal ligament. Implant supported prostheses should have minimal occlusion and lighter contacts than ones supported by natural dentition.

Clinical Trials.gov No: K23 D2007-46.

* *Corresponding author at*: University of Florida College of Dentistry, P.O. Box 100435, Gainesville, FL32610, United States. Tel.: +1 352 273 6928; fax: +1 352 846 0248.
E-mail address: jesquivel@dental.ufl.edu (J.F. Esquivel-Upshaw).
http://dx.doi.org/10.1016/j.jdent.2014.07.001
0300-5712/

1. Introduction

Ceramic–ceramic prostheses are becoming a preferred option for aesthetic restorative dental procedures. They offer optimal aesthetics compared with metal–ceramic prostheses as well as less tooth reduction, a supragingival finish, and faster turnaround time with computer-aided design and machining (CAD-CAM). However, ceramic–ceramic prostheses are more susceptible to fracture because of the lower fracture resistance of the veneering ceramics.[1] Thus, proper treatment planning is necessary to determine the optimum design and placement location of these ceramic–ceramic prostheses. Yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) ceramics are the strongest and toughest core materials for ceramic FDPs.[1] These materials exhibit the highest flexural strength and fracture toughness of all dental ceramics partially because of a phenomenon known as transformation toughening. The phenomenon known as transformation toughening occurs during a reverse tetragonal to monoclinic transformation. It is considered beneficial in that the material can actually "heal" itself. When tensile stresses are generated at the tip of a crack, the reverse tetragonal to monoclinic transformation occurs. This phase change at the tip of the crack is accompanied by volumetric expansion and subsequent compressive stresses around the crack tip. This volumetric expansion can result in partial closure of the crack and prevent its propagation through the entire structure.[2] However, these core ceramics can undergo adverse localized phase transformations,[3,4] and *in vivo* chipping of their ceramic veneers is a relatively frequent occurrence.[5] Low-temperature degradation (LTD) is a phenomenon in zirconia, which induces tetragonal to monoclinic transformation at the surface of the specimen in the presence of moisture at 250 °C, causing tensile stresses on the surface.

Multiple unit FDPs have been shown to have more complications than single crowns alone.[6] A systematic analysis[7] showed that the survival probability of FDPs after 10-year was 89.1% while the probability of success was only 71.1%. The 10-year risk for caries was 2.6% and periodontitis leading to FPD loss was 0.7%. The 10-year risk for loss of retention was 6.4%, for abutment fracture 2.1% and for material fractures was 3.2%. This probability analysis was further confirmed by Sailer et al.[8] where they found technical complications such as material fracture, loss of retention and biological complications like caries and loss of pulp vitality were similar to occur over 5 years for FDPs regardless of material used. However, the 5-year survival of metal–ceramic FDPs was significantly higher at 94.4% ($P \leq 0.0001$) than the survival of all-ceramic FDPs, at 88.6%. The frequencies of material fractures (framework and veneering material) were significantly ($P \leq 0.0001$) higher for ceramic–ceramic FDPs (6.5% and 13.6%) compared with those of metal–ceramic FDPs (1.6% and 2.9%). However, when zirconia was used as the framework material, failures were primarily attributed to other reasons such as biological and technical complications.

Dental implants are steadily becoming the treatment of choice for supporting metal–ceramic and ceramic–ceramic partial dentures. Meta-analysis studies show that the cumulative success rates for implant-supported FDPs are 95.2% over a period of 5 years and 86.7% and over a period of 10 years.[9] Conversely, conventional tooth-supported FDPs have survival levels of 93.8% after 5 years and 89.2% after 10 years. Only 61.3% of the implant supported FDP patients did not have any complications after a period of 5 years compared with 84.3% of patients who had tooth supported FDPs. Failures for the tooth supported FDPs were attributed to biological complications such as secondary caries and loss of pulp vitality. Failures for the implant supported FDPs were attributed to technical complications, the most frequent being veneer fractures. Other technical complications include screw or abutment loosening and loosening of prosthesis.[6] Peri-implantitis and soft tissue complications occurred in 8.6% of FPDs after 5 years.[9] However, the studies reviewed in this analysis do not include ceramic–ceramic materials for the FDPs. Thus, there is a dearth of information on the performance and survival of implant-supported ceramic–ceramic prostheses.

A systematic review of clinical studies reveal that the cumulative survival rate over a 5-year observation period for ceramic–ceramic FDPs is 88.6% compared with 94.4% for metal–ceramic FDPs.[10] Several ceramic–ceramic systems have been introduced to improve aesthetics and survivability of all-ceramic restorations. The core ceramics for these prostheses include alumina, glass-infiltrated ceramic, lithium disilicate glass–ceramic, and zirconia.[11–14] Zirconia substructures are the strongest and toughest of the ceramic dental frameworks.[4,15–17] A systematic analysis of zirconia-based tooth supported FDPs revealed a survival rate of 94.3%.[18] However, when technical complications such as chipping of the veneer ceramic are included, their FDP survival decreases to 76.4%.[18] Heinzte and Rousson[1] performed a systematic review to analyze the prosthesis performance and reported three-year survival percentages of 90% for zirconia-supported FDPs and 97% for metal-supported FDPs. They concluded that veneer chipping was a major cause of failure. Long-term survival of zirconia frameworks over a period of 10 years has been reported to be as high as 91.5%,[19] although some prostheses exhibited evidence of marginal deficiencies and veneer chipping. The objective of this research study was to test the following hypotheses:

(1) There is no statistically significant difference in the fracture probability of the veneer ceramic of three-unit, posterior, implant-supported ceramic–ceramic FDPs that either have or do not have a tooth distal to the most distal retainer.
(2) There is no statistically significant difference between the number of fractures located along load-bearing areas and the non-load-bearing areas (lingual cusps for mandibular teeth and buccal cusps for maxillary teeth) or along areas where there are excursive contacts and maximum intercuspation contacts.
(3) There is no significant correlation between magnitude of bite force and the presence or absence of veneer ceramic fractures.

2. Materials and methods

2.1. Study design

This randomized, controlled, clinical trial was conducted to determine the performance and survival of implant-supported,

Please cite this article in press as: Esquivel-Upshaw JF, et al. Fracture analysis of randomized implant-supported fixed dental prostheses. Journal of Dentistry (2014), http://dx.doi.org/10.1016/j.jdent.2014.07.001