



Analysis of Clinically Failed Implant-Supported Complete Arch Zirconia Prostheses

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Abstract

Zirconia restorations provide high mechanical strength, biocompatibility, and esthetics in dentistry, yet failures still occur. This study investigated the failure modes and fracture characteristics of two complete arch zirconia restorations using Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD). Sample 1, fractured lingually after five years, exhibited a vertical fracture around the titanium abutment with a predominantly tetragonal phase and mixed transgranular-intergranular fracture. Sample 2, failed by a complete fracture after five months at a non-abutment site and showed both tetragonal and monoclinic phases with intergranular fracture, grain pull-out, and interconnected cracks. Findings highlight the influence of zirconia phase transformation, prosthesis cross-sectional thickness, and functional loading on failure patterns. Further research is needed to assess phase transformation beneath glazing layers and optimize prosthesis design for longevity.

Materials and Methods

Two implant-supported complete arch restorations with different failure times were retrieved and examined:

Sample 1 exhibited a visible crack line on the lingual side and a fractured temporary cylinder, with unclear fracture initiation after 5 years in function.

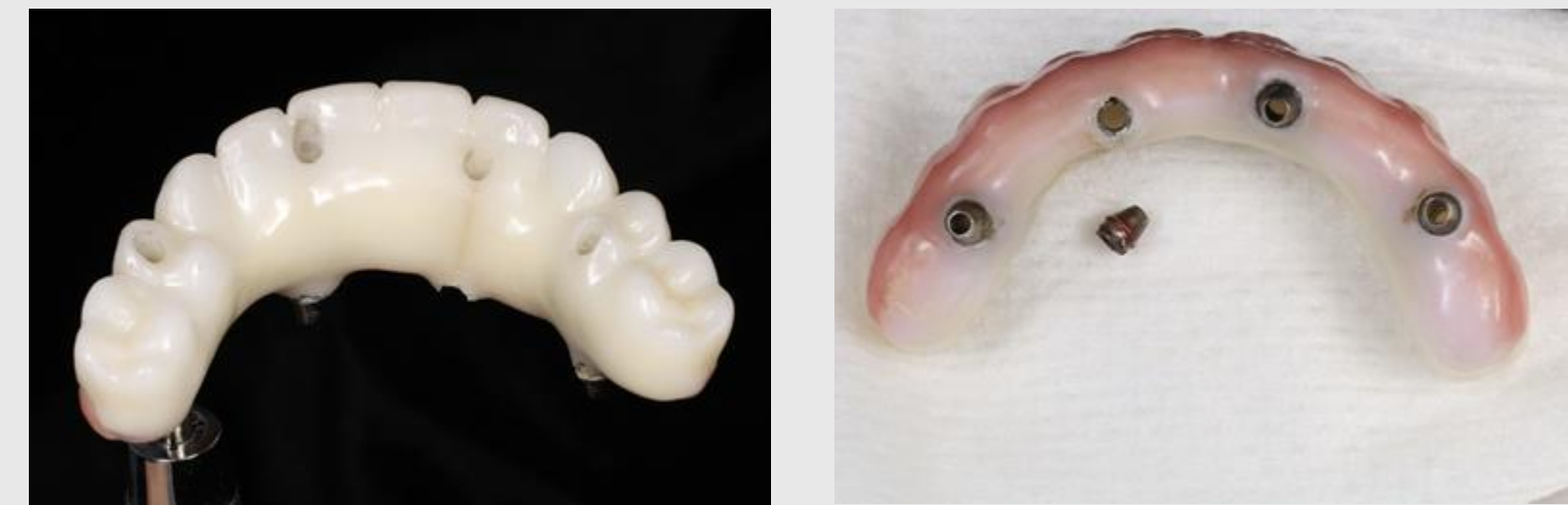


Fig. 1A - Lingual view of sample 1 with crack line at abutment site #10
Fig. 1B - Gingival view of sample 1 with fracture titanium abutment at site #10

Sample 2 exhibited a complete fracture separating the prosthesis into two parts after 5 months in function.



Fig. 2A and 2B show fracture site of sample 2 at the connector of pontic sites #24, 25

Both samples were examined at the Core Center of Excellence in Nano Imaging at USC using **XRD (Bruker D8 Advance)** to assess zirconia phases and **SEM (Apreo 2S SEM)** to evaluate fracture surface characterization.

Sample 1 was further evaluated through a light microscope at the titanium abutment site.

Conclusion

While there are many variables between the clinically retrieved prostheses, the analysis of this study revealed different fracture patterns and zirconia phase dominance between the early and late failures of complete arch implant-supported zirconia.

Recommendations

Further investigation of phase transformation beneath glazing layers and consideration of patient functional factors, cross-sectional thickness of the prostheses, particularly in high-function patients, is necessary to minimize future failures of complete arch zirconia prostheses.

Introduction

Zirconia restorations are valued in restorative dentistry for their mechanical strength, biocompatibility, and esthetics. However, clinical failures such as fracture of the restorations do occur, posing a significant challenge for clinicians. While SEM analysis enables detailed characterization of fracture morphology and XRD allows identification of phase transformations at fracture sites, comprehensive analysis of failed restorations is crucial in understanding the etiology of the failure and preventing future complications by design modifications.

Purpose

This study aims to analyze the mode of failure and further characterize the fracture surface morphology and zirconia phase composition of the failed complete arch zirconia restorations.

Results

Visual inspection revealed Sample 1's failure with vertical fracture line of zirconia surrounding the titanium abutment (Fig. 1A and 1B) and a partial absence of cement between the zirconia and the abutment (Fig. 3B), while sample 2 showed complete fracture at a non-abutment site (Fig. 2A and 2B).



Fig. 3A - Fracture site with crack line along the zirconia

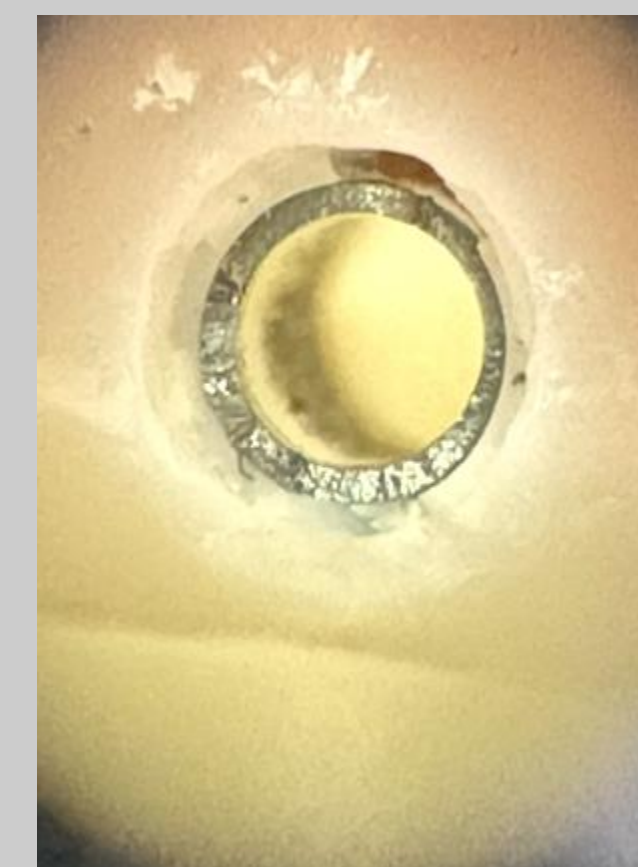


Fig. 3B - Partial absence of cement between zirconia and titanium abutment

XRD analysis

Sample 1 revealed predominantly tetragonal phase (Table 1), while **Sample 2** exhibited both tetragonal and monoclinic phases (Table 2)

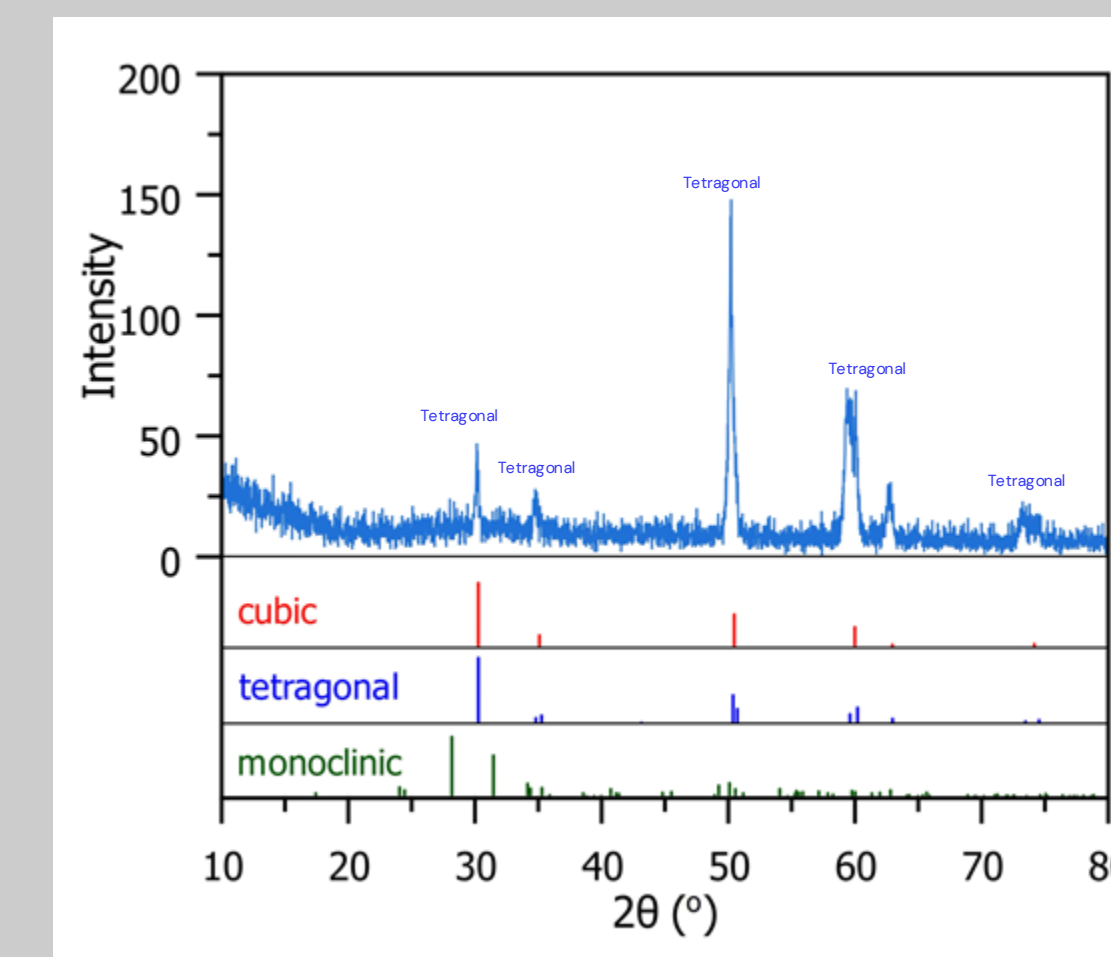


Table 1
X-ray diffraction profiles presenting the phase configurations on the crack line of sample 1

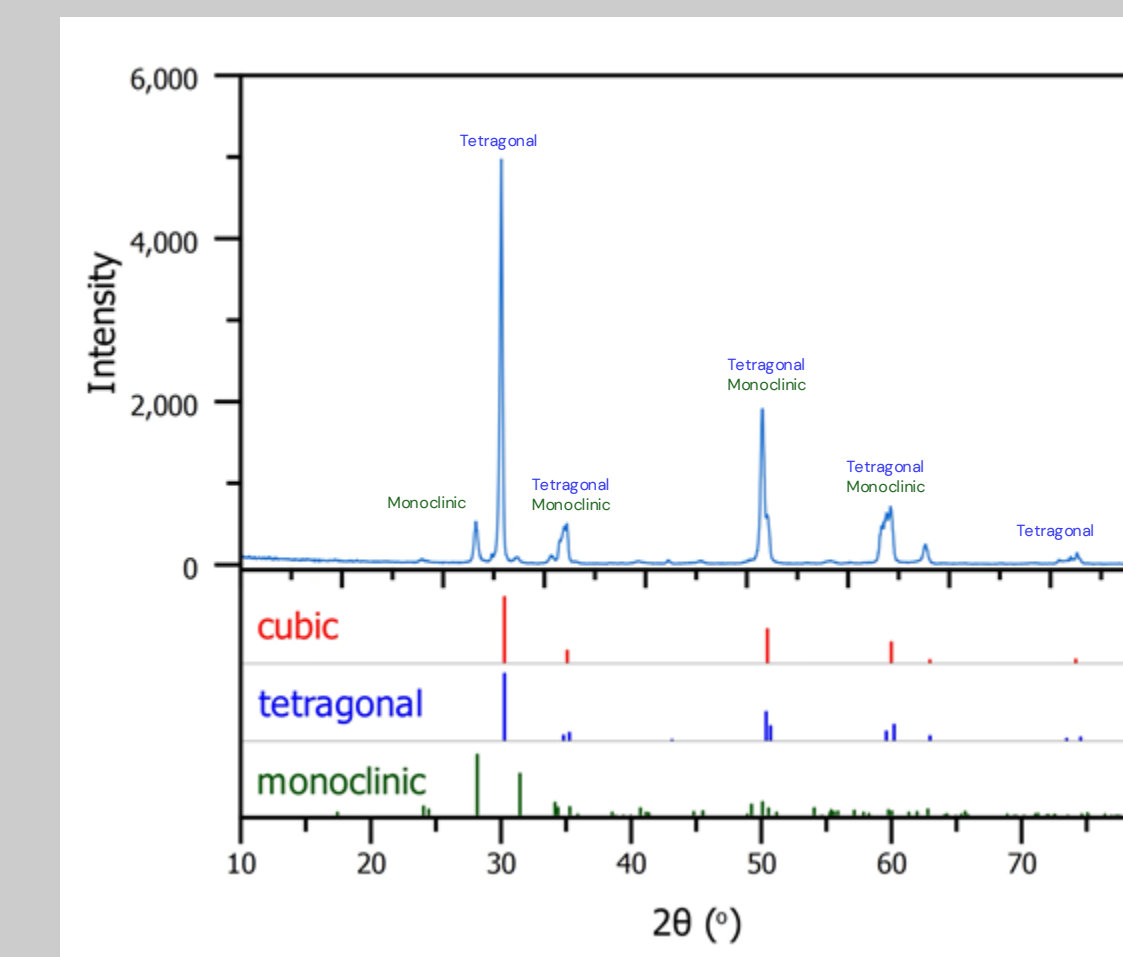


Table 2
X-ray diffraction profiles presenting the phase configurations on the crack line of sample 2

SEM analysis

Sample 1 demonstrated mixed transgranular-intergranular fracture

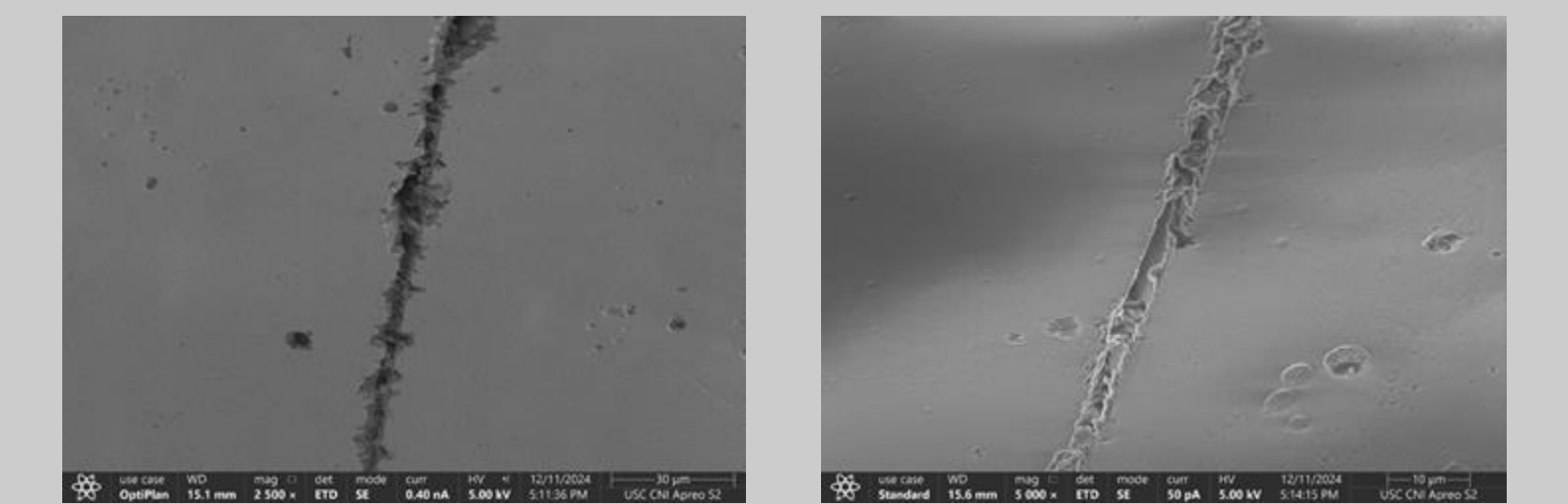


Fig. 4A and 4B - SEM images at 2500x and 5000x of crack line in sample 1 respectively

Sample 2 exhibited predominantly intergranular fracture, grain pull-out, and interconnected cracks

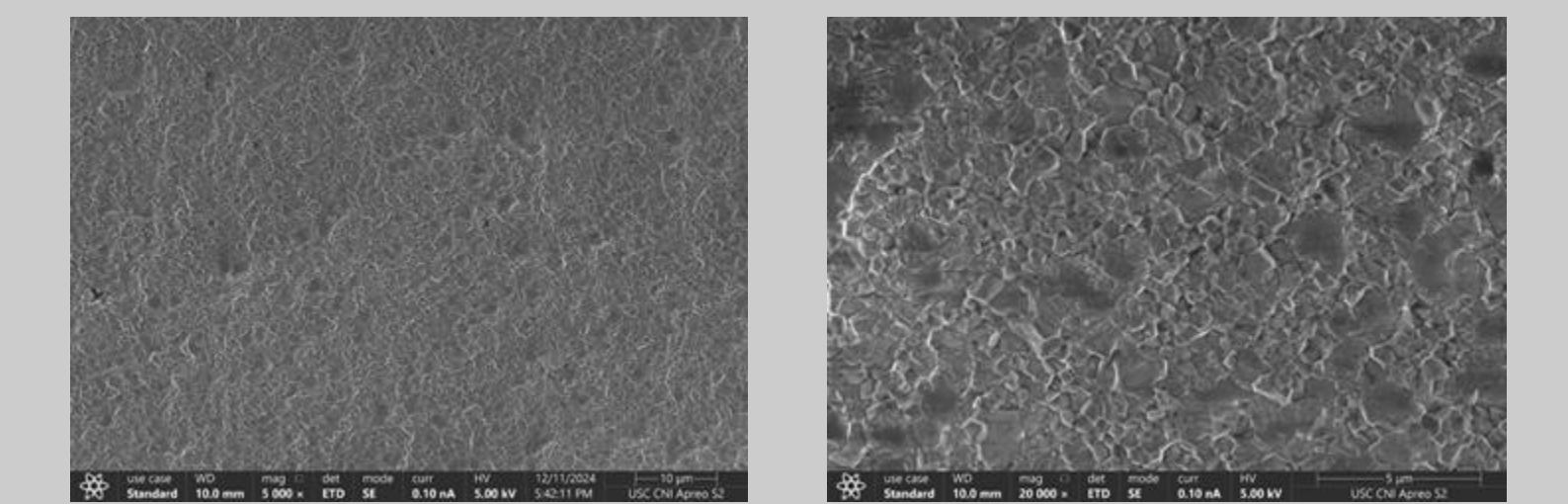


Fig. 5A and 5B - SEM images at 5000x and 20000x of crack line in sample 2 respectively

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