

Invitro Fracture Resistance and Marginal Accuracy of Zirconia Inlay-retained Fixed Partial Denture: A Systematic Review

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Abstract

Objectives: To determine the fracture resistance and marginal accuracy of Inlay-Retained Fixed Partial Denture (IRFPD) fabricated from monolithic zirconia to determine whether it can replace full coverage zirconia restoration. **Methods:** Search was made in three databases including Pubmed, ScienceDirect and Cochrane databases, the terms yttria stabilized tetragonal zirconia, inlay, full coverage and fixed partial denture were used, title and abstract were screened; according to the exclusion and inclusion criteria articles which did not follow the inclusion criteria were excluded. Included papers are then read carefully for a second stage filter, this was followed by manual searching. **Results:** The search resulted in 5 included papers, four papers concerning the fracture resistance of Inlay-Retained Fixed Partial Denture and one determining the fracture resistance of full coverage three unit fixed partial denture. No papers were found studying the marginal accuracy of monolithic zirconia Inlay-Retained Or Full Coverage Fixed Partial Denture. From the included studies zirconia Inlay-Retained Fixed Partial Denture can successfully replace zirconia full coverage fixed partial denture in terms of fracture resistance.

Keywords: Fracture Resistance, Inlay-Retained FPD, Marginal Accuracy, Zirconia

1. Introduction

In the past three decades, the interest in partial coverage retainers such as inlays and onlays have increased drastically because these restorations are able to provide a more conservative option requiring minimal tissue removal thus preserving healthy tooth structure to a maximum extent. If a patient rejects an implant treatment and enough sound tooth structure is available it would be desirable to restore a missing tooth with Inlay-Retained Fixed Partial Denture instead of full coverage retained one¹.

The use of all-ceramic materials for inlays and onlays in restorative dentistry is becoming more popular than gold alloys although gold has performed well in terms of durability. The proper selection of restorative materials, careful preparation design and adequate adhesion

between tooth/restorative material interfaces considered important factor to prevent failures².

Zirconia was introduced into dentistry in the 1990s. The high initial strength and fracture toughness of zirconia results from a physical property of partially stabilized zirconia known as transformation toughening. On the other hand, its white color, similar to the color of natural teeth and its ability to transmit light makes it useful in aesthetically important areas³.

Zirconia frameworks are produced by milling from both fully sintered and partially-sintered zirconia blocks or by slip-casting technique as with In-Ceram zirconia. Following the veneering procedure, resin bonded luting or conventional luting could be performed for cementation^{4,5}.

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Nowadays extra translucent zirconia is implicated for esthetic (100% full-zirconia restorations). This material considered suitable for implants and in cases of heavy occlusal forces avoiding chipping due to the absence of veneering.

Inlay Fixed Partial Denture restoration may have increased the risk of fracture due to the relative small size of restorations compared to the complete coverage restoration. An unfavorable distribution of stresses between the ceramic inlay and tooth structure may result in marginal deterioration around the inlay or its failure^{6,7}.

The direction of forces on the occlusal surface of Inlay Fixed Partial Denture may lead to the phenomenon of sub-margination, ceramic fracture, wear at interface and postoperative hypersensitivity which remain a problem that require further investigation. One of the most important factors in the success and longevity of a restoration is to have an accurate marginal fit. Ideally, the cemented restoration should precisely meet the finish line of the prepared tooth. In reality, clinical perfection is challenging to achieve and to verify.

The importance of a well-fitting restoration can be illustrated when considering the implications that occur with an ill-fitting restoration, Luting agent dissolution, microleakage, caries, hypersensitivity and periodontal inflammation⁸. In addition, the poor margin can affect the restoration itself as variation in the fitting can create stress concentrations which may reduce the strength and long-term success of the restoration⁹.

In 1989 Holmes et al.¹⁰ defined the internal gap as the measurement between the axial wall of the prepared tooth and the internal surface of the casting while the same measurement at the margin is called “marginal gap”. Furthermore, an angular combination of marginal gap and extension error is an “absolute marginal discrepancy” which specifically defines the linear distance from the surface finish line of the preparation to the margin of the restoration.

From a systematic review done on the fit of zirconia, it has been concluded that there are several factors which affect the marginal accuracy of a restoration which includes; the fabrication procedure, the span length, framework configuration, veneering, and aging¹¹.

The purpose of the conducted search was to determine the fracture resistance and marginal accuracy of inlay-retained fixed partial denture fabricated from monolithic zirconia in an attempt to determine whether it can replace full coverage zirconia restoration in a certain situation for the preservation of the tooth structure.

2. Materials and Methods

The PRISMA (Preferred Reporting Items for Systematic Reviews) was followed as much as possible.

2.1 Search Strategy

A literature search focusing on the purpose previously mentioned was performed electronically using the PubMed, Cochrane, and ScienceDirect databases through 2nd November 2015.

2.2 Pico Statement

2.2.1 Problem

Missing tooth possesses a problem that affects esthetics and occlusion.

2.2.2 Intervention

Inlay-retained fixed partial denture constructed from monolithic high strength Yttria Stabilized Zirconia (Y-TZP).

2.2.3 Comparison

Full coverage retained fixed partial denture constructed from monolithic high strength Yttria Stabilized Zirconia.

2.2.4 Outcome: Primary Outcome

Fracture resistance,

2.2.5 Secondary Outcome

Marginal accuracy.

2.3 Research Question

Will the Inlay-Retained Fixed Partial Denture constructed from monolithic zirconia provide durability regarding the fracture resistance and marginal accuracy for replacing single missing posterior tooth?

2.4 Inclusion and Exclusion Criteria

Mentioned in Table 1.

2.5 Study Characteristics

The initial PubMed search resulted in 68 papers while that of Cochrane resulted in 0 while that of ScienceDirect resulted in 23. After duplicate removal, the final search

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Bridge	Single crown
Inlay retained FPD	Metal ceramic restoration
Full coverage FPD	Review articles
Monolithic Y-TZP	Finite element analysis
Fracture resistance	Implant
Marginal accuracy	Pressable ceramic
In-vitro study	Veneered zirconia
	In-vivo study

resulted in 91 papers. After screening and taking into consideration, the inclusion and exclusion criteria 4 articles were included. This was followed by manual searching where searching was performed in references of the included papers which resulted in 1 more article with a total of 5 included articles (Diagram 1). Full-text reading of the included study was done and summarized according to the inclusion criteria. (Table 2)

2.6 Data Extraction

Summarized in Table 2.

3. Results

Five laboratory¹²⁻¹⁶ studies were included in the systematic review. Following the exclusion and inclusion criteria studies that dealt with veneered zirconia, finite element analysis, implant supported prosthesis and single crowns were excluded. Four studies were included after database searching and then search was completed by a manual search through references of the selected studies which resulted in adding one more study.

There was no limit for publication date; studies included were published between the years 2004 and 2012. These studies differ greatly in their methodology and sample size which makes it impossible to make a meta-analysis.

Only one study (Preis et al. in 2012¹²) dealt with monolithic zirconia fixed partial denture, the other studies were for Inlay-Retained Fixed Partial Denture all were fabricated using zirconia replacing only one missing posterior tooth. Four studies¹³⁻¹⁶ used cast metal models and three¹³⁻¹⁵ of them covered the roots with a soft silicone layer to simulate periodontal movement while one study

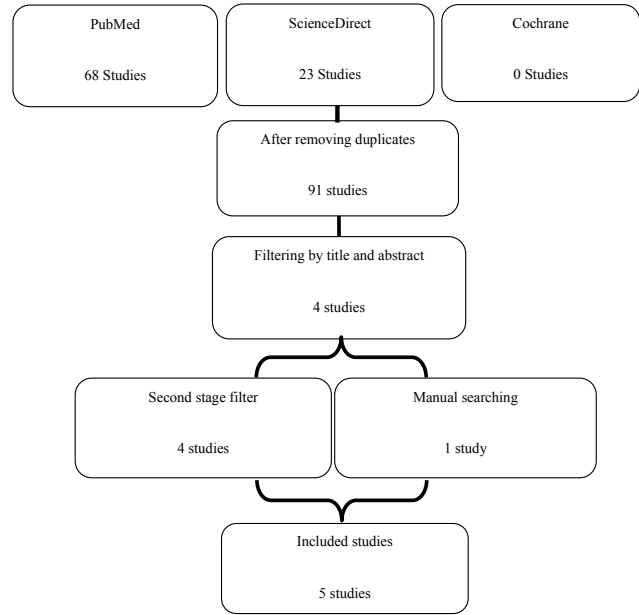


Diagram 1. Search flow diagram based on Prisma

(Kilicarson et al. in 2004¹⁶) did not place silicone layer around the root; one study (Preis et al. in 2012¹²) used artificial PMMA teeth.

After fabrication of the FPD, four studies¹²⁻¹⁵ adhesively cemented the restorations on the corresponding models while one study (Kilicarson et al. in 2004¹⁶) cemented the restorations using eugenol-free provisional luting cement. Three studies^{12,14,15} performed thermocycling (6000 cycles, 5 and 55 °C) and fatigue loading (1,200,000 loading cycles) to simulate 5 years clinical service; though they differed in the timing of each cycle, where one study (Preis et al. in 2012¹²) performed thermocycling for 2 min each cycle while two studies (Puschmann et al. in 2009¹⁴, Wolfart et al. 2007¹⁵) performed it for 60 sec each cycle, one study (Mehl et al. in 2010¹³) made only fatigue loading without thermocycling and one study (Kilicarson et al. in 2004¹⁶) did not perform neither thermocycling nor fatigue loading.

One study¹³ evaluated the effect of the direction of load by applying centric and eccentric loading and found that there was statistically significant difference between specimens that were centrally loaded which showed fracture resistance of 1749 N while those subjected to eccentric loading showed fracture resistance of 880 N.

Two studies^{14,15} showed the effect of the connector dimension on fracture resistance. These studies showed that zirconia can be used for fabrication of Inlay-Retained

Table 2. Summary of the studies included

Study	Material used	Design	No.of samples	Fabrication technique	Connector dimension	Cementation
Preis et al in 2012 ⁽¹²⁾	Y-TZP	3 unit FPD	56	CAD/CAM (Cercon brain, Degudent, Germany)	- 6x4.5 mm, at first abutment and 6x4 mm, at second abutment	Adhesively cemented
Mehl et al in 2010 ⁽¹³⁾	Y-TZP	3 unit IRFPD	42	Industrial manufactured yttria-stabilized tetragonal zirconia (Gapless, Umkirch, Germany)	- 3x3 mm	Adhesively cemented
Puschmann et al in 2009 ⁽¹⁴⁾	Y-TZP	3 unit IRFPD	24	CAD/CAM (Cerec 3 inlab; Sirona, Bensheim, Germany)	- 3x3 mm - 3x2 mm	Adhesively cemented
Wolfart et al 2007 ⁽¹⁵⁾	-IPS Empress II -Y-TZP	3 unit IRFPD	64	CAD/CAM (Cercon brain, Degudent, Germany)	- 3x3 mm - 4x4 mm	Adhesively cemented
Kilicarslon et al in 2004 ⁽¹⁶⁾	-Metal ceramic -Empress II -Zirconia based ceramic	3 unit IRFPD	32	CAD/CAM (Cercon; Degussa Dental, Hanau, Germany)	- 4x4 mm	Provisional cementation

Continue Table 2. Summary of the studies included

Study	Thermocycling	Fatigue loading	Test	Results
Preis et al in 2012 ⁽¹²⁾	6000x5°x55° 2min each cycle	1.2x10 ⁶ x 50 N	Fracture resistance	1173.5- 1316.0 N
Mehl et al in 2010 ⁽¹³⁾		Centric loading between 10-1200 N & Eccentric loading between 10- 600/500N	- Quasi-static Fracture strength	- 1749 N for centric loading - 880 N for eccentric loading
Puschmann et al in 2009 ⁽¹⁴⁾	6000 cycles, 5 and 55°C for 60 sec each	1,200,000 cycle	Fracture resistance	859 N
Wolfart et al 2007 ⁽¹⁵⁾	6000 cycles, 5 and 55°C for 60 sec each	1,200,000 cycle	Fracture resistance	- 3180 N for zirconia with 9mm ² connector - 3120 N for zirconia with 16mm ² connector
Kilicarslon et al in 2004 ⁽¹⁶⁾			Fracture resistance	-1247.70 ± 262.51 N for zirconia

Fixed Partial Denture with dimension 3 x 3 mm as Wolfart et al. in 2007¹⁵ found no statistically significant difference between samples constructed with 3 x 3 mm connector and those with 4 x 4 mm connector; also, Puschmann et al. in 2009¹⁴ found no statistically significant difference

between samples with and without cyclic loading with connector dimension 3 x 3 mm but when the connector dimension decreased to 3 x 2 mm there was statistically significant difference between samples with and without cyclic loading.

According to the included studies, the fracture resistance of Inlay-Retained Fixed Partial Denture fabricated from yttria stabilized tetragonal zirconia ranged from 859 N to 3180 N. No studies were found measuring the marginal accuracy of monolithic zirconia inlay-retained or full coverage fixed partial denture, studies addressing the marginal accuracy of monolithic zirconia were only for single crown restoration.

4. Discussion

This systematic review aimed in studying the fracture resistance and marginal accuracy of monolithic inlay-retained and full coverage fixed partial denture.

In recent years the desire for Inlay-Retained Fixed Partial Dentures (IRFPD) to preserve tooth structure and restrict abutment preparation has increased. Pulpitis and long-term pulpal reactions seem to be considerable risks of crown preparation. In a recent study, irreversible pulpitis and pulpal necrosis had occurred after 10 years in 15.6% of the teeth treated with single crowns and in 32.5% of teeth restored with bridge prosthesis, respectively. Approximately 63–73% of coronal tooth structure is removed when teeth are prepared for all-ceramic crowns¹⁷.

Due to these facts, it is desirable to restore a missing tooth with an Inlay-Retained Fixed Partial Denture instead of a full coverage fixed partial denture when sufficient sound tooth structure is available and the patient has good oral hygiene¹⁸.

Research on metal-free, tooth-colored materials for IRFDP has been encouraged due to the visibility of the metal retainer and the change in natural tooth translucency of metal IRFDP. Many new materials and techniques have been introduced to create all-ceramic Fixed Dental Prostheses (FDPs) that are suitable for aesthetic rehabilitation in a wide scope of indications. In particular, all-ceramic materials based on zirconia showed remarkable aesthetic properties, combined with high biological compatibility and excellent mechanical characteristics^{19,20}.

Studies have shown that the most common complication of all-ceramic restoration is chipping or fracture of the veneer; however the introduction of the monolithic restoration have overcome this problem. The development of the monolithic zirconia promises an end to the fracture of the esthetic porcelain²¹.

Marginal fit and fracture resistance were chosen as they are among the critical factors that determine the

success and longevity of a restoration. For a restoration to achieve acceptable longevity it is mandatory to achieve an accurate fit. Ideally, the cemented restoration should precisely meet the finish line of the prepared tooth. In reality, clinical perfection is challenging to achieve and to verify.

Measuring methods are different as they mainly span two approaches; invasive and noninvasive as in sectioning and direct view techniques respectively. Experimental setups can differ at the stage of testing the fit such as before or after cementation and involve other variables (i.e. sample size, measurements per specimen). Furthermore, ceramic systems differences in construction techniques (i.e. CAD/CAM, cast and Slip ceramics) can affect the restoration fitting accuracy^{22,23}.

The direct view technique using the microscope is the most commonly used followed by the cross-sectioning method and then the impression replica technique. The use of the direct view technique using microscope at different magnifications does not incorporate sectioning or replications of the cement space before measuring the gap; hence making it cheaper and less time consuming than other techniques and reduce the chance of error accumulation that may results from multiple procedures and ultimately impact the accuracy of results. However, this method can only be used in vitro as it requires direct examination of the marginal gap under high power microscopy, which is crucial for the accuracy of this method²³. With regard to our search no papers were found concerning the marginal accuracy of monolithic inlay-retained or full coverage fixed partial denture.

The variations in the methodology of the studies as the difference in the connector dimensions, whether thermocycling and fatigue loading were performed or not, the direction of load and type of cementation affected the difference in the fracture resistance values among the studies.

According to the included studies the connector dimension had a significant effect on the fracture resistance of the zirconia Inlay-Retained Fixed Partial Denture; cyclic loading was found to have a significant effect only when the connector dimension was 3 x 2 mm while there was no significant difference when the connector dimension was 3 x 3 mm.

In literature the average masticatory forces were found to fall in the range of 8-800 N depending on age, sex, type of measurement and other factors; the data obtained from the included studies showed a fracture resistance of Inlay-Retained Fixed Partial Denture ranging between

859-3180 N, hence can be successfully used to replace missing posterior tooth.

The most common type of failure of zirconia fixed partial denture according to the included studies was at the connector area; the maximum stress values always concentrated at the margin of the abutment, the cervical area of the pontic and the connector area with the last one is the highest.

5. Conclusions

Within the limitation of this systematic review, it has been found that:

- Zirconia can be used for fabrication of three unit Inlay-Retained Fixed Partial Denture.
- There are a lot of factors which can affect the fracture resistance of the IRFPD including the fabrication technique, connector dimensions, cementation technique and direction of the load applied.
- No data was found concerning the marginal accuracy of the Inlay-Retained Fixed Partial Denture; hence studies are required in this field.

6. Declaration of Conflict of Interest

The author declares that there is no conflict of interest. There was no any form of material or financial support from commercial or scientific parties of Kuraray.

7. Fund

This research was not funded by any organization or research committee.

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