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Longevity and failure mode of posterior ceramic crowns and fixed partial denture

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***Abstract*---**The purpose of this review is to analyse the longevity of posterior all-ceramic crowns and fixed partial dentures; in addition to determine the failure mode. It seeks to assess the risk factors that should be considered with posterior all-ceramic restorations. The review of literature revealed an acceptable longevity for posterior all-ceramic restorations in a 5-year follow up period. This accompanies their aesthetic outcome especially with improving of mechanical properties of glass ceramic by adding reinforcement crystalline phases or using core. The loss of vitality and secondary caries were the common biological complications while ceramic fracture and chipping were the most frequent mechanical complications. Also, the para-functional activity and using implant as an abutment increase the risk of failure especially on posterior teeth.

***Keywords*---**all-ceramic crowns, partial denture, longevity, survival rate, failure, risk factors.

Introduction

In 1885, Land founded the all-ceramic crown by using a glass feldspathic material, however it did not satisfy practitioners as it was not strong enough (1). Metal coping was introduced to reinforce the strength, but the aesthetic outcome was not as natural as tooth due to differences in the transparency, light reflection, existence of metal and opaquer, and thickness of porcelain at the cervical area. Dental ceramic materials possess favourable properties; for example, biocompatibility, aesthetic, chemical resistance, a coefficient of thermal expansion similar to those of enamel, and low thermal conductivity. However, ceramic is brittle and has a low fracture resistance (2). All ceramic restorations are reinforced by adding a crystalline phase of leucite or lithium- disilicate to the glass ceramic. Another method is to use the alumina or zirconia core and veneer them with feldspathic porcelain (3). Many systems of all-ceramic crowns are

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available due to the demand for aesthetics even for posterior restorations with improvement in the mechanical properties. The failure of ceramic restorations is caused by either biological causes such as caries and loss of vitality, or technical causes such as fracture and loss of retention (3). The available studies showed that catastrophic fracture was one major issue of all-ceramic restorations. Furthermore, this problem often occurred in the posterior restorations and fixed partial dentures (FPDs) where high force was applied (4). Therefore, the purpose of this review is to analyse the longevity of posterior all-ceramic crowns and FPDs, and to determine the failure mode both biologically and technically; also, it seeks to assess the risk factors that should be considered with posterior all -ceramic restorations.

Longevity

In this paper longevity of ceramic restorations was categorised into 3 groups: Glass ceramic, Alumina based ceramic, Zirconia. The relevant studies with their conclusion are elaborated in Table 1.

Type of Ceramic Restoration	**Type of material**	**Study**	**Study design**	**Conclusion**
Glass Ceramic	Glass Ceramic (Dicor)	Sjögren et al., 1999	CT	Of the 98 crowns, 82% were rated satisfactory. For marginal integrity, 51% were rated excellent.
		Malament et al., 1999	CT	Probabilities of survival of "typical" acid-etched Dicor and nonacid-etched Dicor restorations were 76% and 50%, respectively, at 14.1 years.
	Leucite reinforced glass ceramic	Sjögren et al., 1999	RS	Based on the CDA criteria, 92% of the crowns were rated "satisfactory." 86% were rated "excellent" for margin integrity. Fracture was registered in 6% of the crowns.
		Fradeani et al., 2002	RS	Leucite-reinforced glass-ceramic crowns showed a low clinical failure rate and excellent esthetics after up to 11 years.

		Conard et al., 2007	SR	No evidence to support the universal application of a single ceramic material and system for all clinical situations.
	Lithium disilicate glass ceramic	Esquivel-Upshaw et al., 2004	CT	A clinical success rate of 93% after 2 years of a lithia disilicate-based core ceramic for use in posterior fixed partial dentures (FPD).
		Valenti et al., 2009	RS	The overall survival rate was 95.5%. Lithium disilicate ceramic restorations had a low clinical failure rate after up to 120 months.
		Wolfart et al., 2009	CT	The 8-year survival rate according to Kaplan-Meier was 93%.
		Kern et al., 2012	CT	Success rate was 91.1% after five years and 69.8% after 10 years.
		Gehrt et al., 2013	CT	The cumulative survival rate according to Kaplan-Meier was 97.4 % after 5 years and 94.8 % after 8 years.
Alumina based ceramic	Alumina	Sorensen et al., 1998	CT	Amongst 40 posterior FPDs, 11 % of premolars and 24 % of molars failed after 3 years.
		McLaren et al., 2000	CT	The 3-year survival rate was 96% in all In-Ceram crowns. Anterior crowns tended to have a slightly higher 3-year survival rate (98%) than premolars or molars (94%).
		Steyern et al., 2001	CT	Survival rate was 90% in 5 years as the

				failure was all technical complications that required reconstructing.
		Christensen et al., 2010	RCT	Alumina frameworks were the worst, with a 65% survival rate in three years
		Ortorp et al., 2012	CT	In their 5-year clinical performance, 88% of crowns did not have any complications and 9% of the restorations were judged as failures.
		Chaar et al., 2015	CT	Using the Kaplan-Meier method the 10-year cumulative survival rate was 93.6%.
Zirconia	Zirconia	Sailer et al., 2007	CT	The success rate of the zirconia frameworks was 97.8% for posterior fixed partial dentures (FPDs) after 5 years of clinical observation.
		Tinschert et al., 2008	CT	Within the mean observation time of 3 years, zirconia-based FPDs demonstrated a sufficient success rate (100%) under clinical conditions.
		Roediger et al., 2010	CCT	The overall survival rate after 48 months was 94%.
		Sorrentino et al., 2012	CT	All FDPs completed the study, resulting in 100% cumulative survival rate and 91.9% and 95.4% cumulative success rates for patients wearing one and two FDPs, respectively.
		Rinke et al.,	CT	They concluded that

		2015		no significant difference was found between the survival rate of PFM and ZC after 3 years (PFM: 97.6%, ZC: 95.2%, respectively).

Glass ceramic

Sjögren *et al.*(5) studied the quality of glass ceramic (Dicor) all-ceramic crowns performed by general practitioners. They assessed 98 crowns, 63 of which were in posterior teeth. According to California Dental Association's (CDA) quality evaluating system, 82% of crowns were acceptable, and 36% of failures were in posterior teeth. Malament & Socransky(6) recruited 417 participants in a study which examined the survival rate of 1444 restorations, 541 of which were posterior, made from Dicor glass ceramics. Since they mentioned the survival rate for each tooth separately, the mean of the survival rate of the posterior restorations was 73.4% after 14 years. The failure criteria were fractured ceramic pieces that necessitated remake of restoration. However, they did not include other technical and biological causes. Based on lack of strong evidence to support use of glass ceramic posteriorly, it seems glass ceramic is not a recommended material choice for posterior restorations.

Leucite reinforced glass ceramic

Few studies have assessed the survival rate of leucite-reinforced glass ceramic crowns since this material cannot be used for bridge fabrication (Conard *et al.* 2007). Retrospective study of Fradeani & Redemagni(2) showed that the survival rate for 32 IPS Empress posterior crowns was 84.4% after 11 years. The criteria of failure were porcelain fracture or partial de-bonding that impaired the aesthetic or function. Although, they tried to reduce the confounders and variability by excluding patients with para-function, periodontitis, poor oral hygiene, or high caries risk, selecting participants from convenient patients was still vague which might lead to sample bias. Moreover, the sample size in this study is very small. On the other hand, the long period of follow up and precisely evaluated and presented data gave this study advantages in comparison to other studies. From 110 leucite-reinforced glass ceramic (IPS Empress) crowns inSjögren *et al* study(7),67 restorations were placed on posterior teeth. The failure rate was 19%, and the predictable survival rate was 91% after 5 years. However, the recruiting of patients was not explained clearly and the technique for manufacturing the crowns was not clear. Accordingly, posterior leucite reinforced glass ceramic might have shown high survival rate in posterior crowns but it has to be considered with caution and no evidence to use it for posterior bridge.

Lithium disilicate glass ceramic

Valenti & Valenti(8) followed the failure rate of lithium- disilicate glass ceramic crowns (IPS Empress 2) over 10 years, and they found that the failure rate in the posterior crowns (160 crowns) was 1.99%. The survival rate estimation for the posterior crowns was 95.8% according to the Kaplan-Meier test; however, this study has limitations regarding sample bias, and the external validity. Study of Esquivel-Upshaw *et al.* (9)reported that the survival rate of lithium disilicate glass ceramic fabricating 3-unit posterior FPDs was 93% in the first two years. Gehrt *et al.* (10) evaluated the use of IPS e.max Press for posterior crowns prospectively. Among all samples, 20 posterior crowns showed 100 % survival rates in 9 years follow-up. This study is comparable with Wolfart *et al.*(11) study of 30 posterior FPDs performed by 13 clinicians; the treatment sensitivity of clinicians' factor reduced in this study. They revealed only 2 failures in 8 years follow-up considering that fracture is the failure criterion. The small sample size and not considering all biological and mechanical complication, make us to consider result of this study with caution. In another study, Kern *et al.*(12) examined prospectively the outcome of 30 posterior FPDs performed by prosthodontics. The success rate after five years was 91% and after 10 years 69.8%, highlighting that any technical or biological complications were considered failure. Furthermore, the catastrophic fractures happened after approximately 8 years in molars. It can be concluded that lithium disilicate glass ceramic is promising ceramic in both crowns and short spans bridges in posterior teeth.

Alumina based ceramic

Christensen and Ploeger(13) compared the performance of alumina, zirconia and metal fabricating posterior FPDs in un-blinded randomized control trail study. A total of 293 units were placed by 115 clinicians; 106 general dentists and 9 prosthodontists. The clinicians assessed the restorations annually according to 17 criteria including biological and technical measures, and two independent examiners evaluated them in vitro by using gold dies, scanning electron micrographs, and photographs. They found that alumina frameworks were the worst, with a 65% survival rate in three years; they discontinued using it for the rest of the study. Nly & Orm (14) evaluated prospectively the use of Alumina In-ceram to fabricate FPDs considering all technical causes lead to replacement as failure criteria. They found that the survival rate was 90% in 5 years as the failure was all technical complications that required reconstructing. However, this study had a small sample size and sample bias as clinical procedure of 23 FPDs was performed by 4 clinicians which one of them placed 50% of samples. McLaren *et al.* (15) prospectively assessed the survival rate of 100 infiltrated alumina posterior crowns performed by a private dentist. They found that 94% of them survived after 3 years. This study had limitations, such as selection bias since the clinical procedures were accomplished by a single operator; also, the restorations were not performed at the same time. As they called non-attendant patients for a telephone survey, insufficient data of unserviceable crowns may have been obtained. Sorensen *et al.* (16) tested prospectively the longevity of the In-Ceram FPDs. Patient selection, procedure, and evaluation criteria were created; therefore, reduced variability could be expected. They concluded that amongst 40 posterior FPDs, 11 % of premolars and 24 % of molars failed after 3 years. Chaar*et al.*(17) evaluated prospectively the survival rates of 65 posterior FPDs fabricated from In-Ceram Zirconia placed by 19 clinicians. He found that 4 FPDs failed, which means a 10-year survival rate using the Kaplan-Meier test was 93.6%, considering all biological and technical complications. Ortorp*et al.*(18) studied retrospectively 168 posterior Pocera crowns placed by a general dentist.

Among 168 posterior restorations, 16 crowns suffered from either technical or biological complications, so the success rate was 95%. Although, one operator and the absence of a control group weakened the intervention. The sample size and 5 years of evaluation increased the attention of the results. Finally, in spite of some failures in posterior alumina crowns and FPDs, they have shown reasonable survival rate in a period up to 5 year.

Zirconia

Rinke *et al.*(19) compared the clinical performance of porcelain fused to metal (PFM) and zirconia crowns (ZC) prospectively. A total of 105 posterior restorations (PFM: 50/ZC: 55) were placed by a single operator. Participants were convenient patients and they chose the type of restoration after receiving an explanation from the clinician; there was no randomisation. There may have been some bias, as understanding of the clinician explanation could have varied. They concluded that no significant difference was found between the survival rate of PFM and ZC after 3 years (PFM: 97.6%, ZC: 95.2%, respectively). Roediger *et al.*(20) studied the performance of 99 Y-TZP posterior FPDs prospectively. All frameworks were fabricated by a CAD/CAM system and milled a soft pre-sintered zirconia; it seems the variability is reduced in comparison to lab technicians. The survival rate was 94% after 4 years (loss of 7 restorations). Sailer*et al.*(21) conducted a prospective study to define the success rate of zirconia frameworks for posterior FPD. The human factor was assumed to be reduced, as they used a machine and followed the same clinical and technical procedure. A total of 33 FPDs from 57 FPDs were assessed after 5 years, and they found that only 1 framework was fractured; a 97.8% success rate. Another prospective study evaluated the performance of 48 posterior zirconia FPDs completed by 4 prosthodontists. After 5 years, a clinical examination was conducted by 2 evaluators who did not contribute to the clinical procedures; they revealed a 100% survival rate and 91.9% and 95.4% success rates for patients wearing one and two FPDs, respectively(22). Tinschert *et al.*(23) evaluated the failure rate of 65 anterior and posterior FPDs with DC-Zirkon coping for 3 years. The results showed that 4 of the 50 posterior FPDs chipped at the veneering material, 2 FPDs were de-cemented, and 3 teeth needed root canal treatment. The success rate was 100% as the fracture of the FPD framework was the only criterion for failure. Based on these evidence, using zirconia for posterior crowns and FPDs may provide more promising restorations in a 5-year period of time.

Causes of failure

The relevant studies analyzing causes of failure with their conclusion are elaborated in Table 2.

Causes of Failure	**Types**	**Study**	**Study design**	**Conclusion**
Biological	Loss of vitality	Tinschert et al., 2008	CT	6% of the abutments of zirconia bridge lost their vitality.
		Chaar et al., 2015	CT	10.8% of endodontic treatment occurrence on

				In-Ceram Zirconia restorations in 10 years.
	Secondary caries	Sailer et al., 2007	CT	21.7% of the zirconia FPDs are affected by recurrent caries.
		Chaar et al., 2015	CT	10-year cumulative complication rate of recurrent caries was 8.7% on In-Ceram Zirconia restoration.
	Periodontal disease	Olsson et al., 2003	CT	No adverse effects to either periodontal or pulpal tissues were recorded in a retrospective assessment of up to 9 years of patient records.
		Gehrt et al., 2013	CT	None of the abutments of IPS e.max Press crowns had periodontitis during the 9 years of service.
Technical	Material problems (ceramic chipping or ceramic fracture)	McLaren et al., 2000	CT	Crowns were lost because of core fracture, porcelain fracture, and removal without failure. Failure tended to be more common for molar and premolar crowns than for anterior crowns.
		Sailer et al., 2007	SR	The most frequent reason for failure of FDPs made out of glass-ceramics or glass-infiltrated ceramics was fracture of the reconstruction (framework and veneering ceramic). However, when zirconia was used as framework material, the reasons for failure were primarily biological and technical complications other than framework fracture.
		Pjetursson et al., 2007	SR	Fracture of the core and the frameworks is the most common technical cause for failure of all ceramic crowns and bridges.
		Sailer et al., 2007	CT	15.2% chipping rates on zirconia-based restoration.

		Roediger et al., 2010	CCT	8% to 30% chipping rates of on zirconia-based restoration.
	Loss of retention	Sailer et al., 2007	SR	Loss of retention was 2.8% for all-ceramic crowns and 2.3% for all ceramic FPDs in 5 years for either anterior or posterior teeth.
		Sailer et al., 2007	CT	Only one loss of retention from 57 zirconia frameworks for posterior FPDs occurred after 5 years.
		Wolfart et al., 2009	CT	6% of 30 three-unit FPDs of IPS e.max Press lithium-disilicate glass–ceramic lost their retention when they were cemented with glass-ionomer cement or composite resin.
		Gehrt et al., 2013	CT	No loss of retention among posterior lithium disilicate crowns cemented adhesively with composite resin and conventionally with glass-ionomer cement.
		Chaar et al., 2015	CT	Retention was lost in 6 out of 65 posterior FPDs of In-Ceram Zirconia
	Marginal Fit	Mörmann et al., 2002	CT	80% alpha ratings and 18% beta ratings for In-Ceram Alumina core crowns and 84% alpha ratings and 15% beta ratings for In-Ceram Spinell core crowns were recorded.
		Wolfart et al., 2005	CCT	Marginal integrity of all lithium disilicate FPDs were rated as excellent
		Sailer et al., 2007	CT	Secondary caries was found in 21.7% of the FPDs.
Risk factors	Para-functional activity	Conrad et al., 2007	SR	Ceramic restorations are contraindicated for patients with severe parafunctional activity.
		Papaspyridakos et al., 2013	CT	The presence of parafunctional activity,

				were associated with all the incidents of ceramic chipping.
		Koenig et al., 2013	RS	Presence of parafunctional habits had an influence on the zirconia restoration. Practitioners can reduce chipping failures by the presence of a ceramic restoration as an antagonist, or the presence of implants as support. The use of an occlusal nightguard can also decrease failure rate.
	Implant-supported restorations	Hämmerle et al., 1995	CT	The mean threshold values for implants were 8.75 times higher than for teeth. More than 8-fold higher threshold value for tactile perception exists for implants compared with teeth.
		Pjetursson et al., 2007	SR	Compared with tooth-supported FDPs, the incidence of technical complications was significantly higher for the implant-supported reconstructions.
		Spies et al., 2015	SR	Implant retained zirconia-based all-ceramic crowns did not show acceptable survival and success rates.

Table 2 – Various studies on causes of failure of different ceramic restorations with their conclusion

Biological causes

Loss of vitality

Loss of tooth vitality is one of the most frequent biological complication of abutments. Based on various studies in different full ceramic restoration including e-max, lithium disilicate and alumina based ceramics loss of vitality varies between 2-4%(4,10, 11,13,24,25). However, Chaar *et al.*(17) recorded a higher percentage of endodontic treatment occurrence on In-Ceram Zirconia restorations, almost 10.8% in 10 years. Tinschert *et al.*(23) reported that 6% of the abutments of zirconia bridge lost their vitality. Loss of vitality happened less times for leucite or lithium-disilicate reinforced glass ceramic in comparison to glass-infiltrated alumina crowns (26).

Secondary caries

Studies based on clinical examination only recorded secondary caries (Figure 1) on Dicor, Empress and lithium disilicate 3%,2% and 0% respectively (5, 7, 24). By using radiograph and clinical examination, the 40% of failure of glass infiltrated alumina restorations were caused by recurrent caries. Chaar *et al.*(17) concluded that 10-year cumulative complication rate of recurrent caries was 8.7% on In-Ceram Zirconia restoration. Sailer*et al.*(21) found that 21.7% of the zirconia FPDs are affected by recurrent caries. Conversely, secondary caries is more related to the host response than the fixed prostheses' materials (27).


Figure 1. Secondary caries

Periodontal disease

Several studies revealed that periodontal disease might occur after restorations placement, yet none of the studies showed FPDs failure because of periodontitis (28). Gehrt *et al.*(10) confirmed that none of the abutments of IPS e.max Press crowns had periodontitis during the reviewing time. Similar results were found In-Ceram Alumina FPDs(29). However, 2 out of 30 IPS emax Press and 1 out of 99 zirconia abutments failed due to severe periodontitis(12, 20).

Technical causes
Material problems (ceramic chipping or ceramic fracture)

Pjetursson *et al.* (4) and Sailer *et al.*(28) concluded that the fracture of the core and the frameworks is the most common technical cause for failure of all ceramic crowns and bridges. A total of160 posterior lithium disilicate restorations were evaluated over 10 years, 4 of them failed due to either ceramic chipping or fracture (30). McLaren *et al.*(15) found out that porcelain and core fracture was the only cause for failure of 233 In-Ceram alumina crowns after 3 years.Roediger *et al.* (20) reported that chipping rates of 8% to 30% on zirconia-based restoration. Similarly, another study of zirconia revealed that chipping occurred in 15.2% of cases (21). In summary, ceramic still suffers from crack propagation and inheriting fracture property.

Loss of retention

The incidence of loss of retention was 2.8% for all-ceramic crownsand 2.3% for all ceramic FPDs in 5 years for either anterior or posterior teeth (4)(28). Gehrt *et al.*(10) noticed no loss of retention among 22 posterior lithium disilicate crowns cemented adhesively with composite resin and conventionally with glass-ionomer cement. However, 6% of 30 three-unit FPDs of IPS e.max Press lithium-disilicate glass–ceramic lost their retention when they were cemented with glass-ionomer cement or composite resin (11). Also, after 18.6 years, three crowns were lost the retention among 109 posterior conventionally luted In-Ceram crowns. (25). Chaar *et al.*(17) reported that retention was lost in 6 out of 65 posterior FPDs of In-Ceram Zirconia. Sailer *et al.*(21) revealed that only one loss of retention from 57 zirconia frameworks for posterior FPDs occurred after 5 years. On the other hand, a loss of retention of the zirconia FPDs was one of main cause of failure for posterior FPDs conventionally luted with zinc-phosphate cement(20). Finally, loss of retention frequency was not mentioned in the most of identified studies, not even in the evaluation criteria. The application of these results is questionable, as the explanation for loss of retention vary from the abutments proximal walls and thickness and application of the cement; consequently, this may reduce the validity of these results.

Marginal fit

Proper marginal adaptation is essential criterion to prevent cement dissolution, plaque accumulation, and secondary caries (31). The maximum marginal discrepancies should not exceed 120 µm (32). Wolfart *et al.*(24) rated the marginal integrity of all lithium disilicate FPDs as excellent and acceptable while they categorised non-detectable margins with the probe as excellent and small detectable steps as acceptable. Similarly, the marginal adaptation of 43 In-Ceram alumina and In-Ceram Spinell crowns were graded as alpha or beta (33) (Mörmann). However, secondary caries as subsequent of marginal discrepancy caused failure of 6 zirconia FPDs (21). Since the open margin restorations are not acceptable to deliver to the patient, the marginal discrepancy should not be easily recorded in the evaluation period.

Risk factors

Parafunctional activity

Koenig *et al.*(34) considered teeth grinding, masticatory muscle discomfort, or wear facets on teeth as parafunctional habits. They reported that the presence of parafunctional habits had an influence on the zirconia restoration and the influence was exaggerated by the presence of a ceramic antagonist. Likewise, the presence of parafunctional activity was ascertained as risk factors mainly with ceramic chipping (35). Conrad *et al.*(3) declared that the ceramic restorations are contraindicated for patients with severe parafunctional activity, it seems that why numerous studies excluded participants with parafunctional habits.

Implant-supported restorations

Systematic review of Pjetursson *et al.*(36) approved the success rate of FDPs tooth-supported after 5 years was significantly higher than implant-supported FDPs using different restorative materials, 84.3% and 61.3%, respectively. Regarding the success of ceramic in comparison to other materials, the authors stated that the tooth supported FDPs had lower risk of ceramic failure (2.9%) compared to the implant- supported FDPs (8.8%). This observation was confirmed by result of Spies *et al.*(37) which implant retained zirconia-based all-ceramic crowns did not demonstrate acceptable survival and success rates. The factor of implant-supported should be considered because of the difference of biomechanical support between tooth- and implant-supported restorations (Figure 2). The implant had threshold values of 8.75 times higher than teeth (38). For that, functional forces on the implant may be induced and increase ceramic fracture (39). Hence, patients should be aware that implant-supported restorations have a higher risk of complications.

Figure 2. Fractures ceramic of implant supported crown

Conclusion

Current evidences of posterior all-ceramic restorations show an acceptable longevity that accompanies their aesthetic outcome. The survival rate has significantly enhanced with improving of mechanical properties of glass ceramic by adding a crystalline phase of leucite or lithium- disilicate to the glass ceramic or use the alumina or zirconia core. Lithium disilicate glass ceramic, Alumina based ceramic and Zirconia have shown promising result as a restorative material in posterior teeth in studies up to 5 year. More long term studied needed to evaluate long term success of those. Also, studies proved that loss of vitality and secondary caries were the common biological complications while ceramic fracture and chipping were the most frequent for mechanical complications. Also, the parafunctional activity and using implant as an abutment increase the risk of failure especially on posterior teeth.

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