Chapter 27
Clinical Chipping of Zirconia All-Ceramic Restorations

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Abstract Advancements in CAD/CAM systems employed in dentistry have made possible the application of yttria tetragonal zirconia polycrystal (Y-TZP) in zirconia-based all-ceramic restorations. Y-TZP has excellent flexural strength and fracture toughness and is used in molar crowns as well as frameworks of fixed partial dentures (FPDs). The use of Y-TZP in clinics has increased over the past several years, and it is now used in implant abutments and denture frameworks. While the demand for Y-TZP is increasing, chipping of porcelain used in the zirconia framework has been noted as a problem in zirconia-based all-ceramic restorations from a clinical point of view. We have previously used Cercon® smart ceramics with Y-TZP frames in clinics but have noticed the chipping of porcelain in a large number of cases over time. This review article focuses on the chipping of zirconia all-ceramic restorations by taking into account the following aspects: (1) clinical performance of zirconia all-ceramic restorations, (2) influence of frame thickness and porcelain firing schedules, and (3) reduction in porcelain chipping.

Keywords All-ceramic restoration • Chipping • Fracture toughness • Veneer porcelain • Zirconia

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27.1 Introduction

Porcelain fused to metal restorations, which in recent years have been commonly used in clinical practice as esthetic restorations show several problems caused by the metal [1]. The metal component used in porcelain fused to metal restorations may be eluted because of corrosive changes caused by saliva, food debris, and the like, trigging harmful biological effects such as metal allergies. Recovery of esthetics in porcelain fused to metal restorations also has limitations such as the occurrence of a black margin caused by gingival recession or when the labiobuccal gingiva is thin, or discoloration of the gingiva in the cervical region of the tooth due to metal elution. However, owing to the development of dental CAD/CAM systems, there has been implementation of all-ceramic restorations using yttrium-doped partially stabilized zirconia or yttria tetragonal zirconia polycrystal (Y-TZP). Y-TZP has excellent flexural strength and fracture toughness [2], and has been used as a framework for crowns and FPDs for the posterior teeth. Applications of Y-TZP for implant abutments as well as for denture frameworks have recently become possible, and the use of Y-TZP has become widespread in clinical practice [3]. It is regarded that zirconia all-ceramic restorations do not pose the problems caused by metal restorations owing to their excellent esthetics and biocompatibility. However, with the increasing demand for zirconia all-ceramic restorations, chipping of porcelain fired onto the zirconia frame has been noted as a clinical problem [4]. We therefore here discuss chipping of porcelain in zirconia all-ceramic restorations, and the prevention of the chipping, which is one of the challenges faced in clinical practice.

27.2 Clinical Performance of Zirconia All-Ceramic Restorations

Table 27.1 shows the clinical results for zirconia all-ceramic restorations as reported from 2010 to 2013. Reports based on implants are excluded here. Therapeutic methods for zirconia all-ceramic restorations have been established for the past 10 years or more. Further, reports with a follow-up period greater than 10 years have had widely ranging sample numbers in one compilation by Sax et al., at 11 to 1,132 cases, with few reports that have exceeded 100 cases. Numerous reports have made references to porcelain fracturing, with a rate of occurrence of 0.9–29.1 %.

Clinical reporting on porcelain fracturing in zirconia all-ceramic restorations has shown a high rate of occurrence of short-term cohesive failure of porcelain, a rate of occurrence that is significantly higher than that in the case of porcelain fused to metal restorations. In one report, a chipping rate of 0–88.9 % in a one- to eight-year follow-up period has been mentioned [28]. Moreover, the most common form of clinical failure is porcelain chipping [29], and prevention of the fracturing

Table 27.1 Clinical performance of zirconia all-ceramic restorations

Authors [Ref] (Year)	Mean time (years)	Sample size	Type of restorations	Veneer porcelain fracture (%)
Rinke et al. [5] (2013)	7	80	3–4 unit FPDs	28.8
Burke et al. [6] (2013)	5	33	3–4 unit FPDs	24.2
Monaco et al. [7] (2013)	5	1,132	Single crowns	Unknown
Vavřičková et al. [8] (2013)	3	102	Single crowns	Unknown
Rinke et al. [9] (2013)	3	52	Single crowns	5.8
Raiqrodski et al. [10] (2012)	5	23	3 unit FPDs	21
Ortorp et.al. [11] (2012)	5	143	Single crowns	3
Vigolo et.al. [12] (2012)	5	39	Single crowns	7.7
Schmitter et.al. [13] (2012)	5	30	4–7 unit FPDs	26.7
Schmitt et.al. [14] (2012)	5	25	3–4 unit FPDs	28
Kern et.al. [15] (2012)	5	20	3–4 unit FPDs	Unknown
Sorrentino et.al. [16] (2012)	5	48	3 unit FPDs	6.3
Sagirkaya et.al. [17] (2012)	4	107	Single crowns	0.9
Peláez et.al. [18] (2012)	4	20	3 unit FPDs	10
Salido et.al. [19] (2012)	4	17	4 unit FPDs	29.1
Ohlmann et.al. [20] (2012)	2	11	3–4 unit FPDs	18.2
Poggio et.al. [21] (2012)	1	102	Single crowns	2.0
Sax et.al. [22] (2011)	10	57	3–5 unit FPDs	28.0
Tartaglia et.al. [23] (2011)	3	463	Single or multiple-unit	Unknown
Roediger et.al. [24] (2010)	4	99	3–4 unit FPDs	13
Beuer et.al. [25] (2010)	3	68	Single or multiple-unit	7.4
Schmitt et.al. [26] (2010)	3	17	Single crowns	5.9
Tsumita et.al. [27] (2010)	2	21	3 unit FPDs	14.3

of porcelain fired onto the zirconia frame has become a clinical challenge. In particular, the parameters of occlusion are a factor and the usage of a night guard or press ceramics has been proposed [28, 29].

27.3 Influence of Frame Thickness and Porcelain Firing Schedules

It is thought that owing to differences in the physical properties of metal frames, zirconia frames might more readily experience chipping from thermal factors during porcelain firing. The reason for this is that the thermal conductivity of zirconia is about 1/100 that of gold [30]. Porcelain firing is thus thought to proceed gradually inward starting not from the frame side but rather from the porcelain surface layer, which more readily conducts heat, and the fired porcelain interior is possibly more susceptible to partially incomplete firing or distortion. In addition, the heat capacity of the zirconia is about 3.5 times that of gold [30]. For this reason, a temperature gradient is believed to possibly occur in the process of cooling after firing, creating a shrinkage difference between the inner and outer surfaces of the sintered body and triggering cracking and other defects. The presence of the frame and thermal factors is thus expected to be a significant factor that triggers partially incomplete firing and defects. Modeling all-ceramic crowns mimicking clinical forms, Benetti et al. measured the temperature differences in porcelain interiors because of the differences between zirconia frames and metal frames and differences in cooling rates after firing. They noted that the specific heat, heat capacity, and thermal expansion rate of a material impacts early fracturing of all-ceramic crowns [31]. Nonetheless, though their research investigated temperature changes during sintering and cooling, there was no assessment of physical properties of porcelain caused by this. We have investigated how differences in the firing conditions of porcelain and frame material impact the fracture toughness of porcelain, in order to study how these factors impact the mechanical properties of porcelain. Our results showed that under conditions of faster heating rates, the fracture toughness decreases than that under manual conditions [32]. Regarding the thermal expansion coefficients of porcelain and zirconia, a zirconia frame has a slightly (about 10 %) greater thermal expansion coefficient than porcelain [33]. Owing to thermal expansion, the porcelain side experiences a compressive stress during the cooling process after porcelain firing and there is little possibility for cracking to occur.

27.4 Prevention of Porcelain Chipping

One factor causing chipping is the support of porcelain by a non-uniform frame thickness. In porcelain fused to metal restorations, which have been fully established, the metal frame is adjusted so that porcelain is given a uniform thickness by cutting back and waxing up, depending on the anatomical form [34]. A design with excessively thick porcelain or too thin frame is also a factor for errors, and porcelain supported by a frame with an anatomical form is reported to have little chipping [35]. It has also been reported that spontaneous cracking increases under conditions of firing with a higher cooling rate in a thicker layer of porcelain [36]. Accordingly, to prevent the occurrence of cracking in porcelain, it is desirable that the frame and porcelain have a favorable relationship of thermal expansion, the frame design results in the porcelain having a uniform thickness, and the cooling rate after firing is low.

If a restoration is considered structurally with a composite of porcelain and frame, however, then designing the frame with a color imparted to the lingual-side margin from the adjacent surface has been reported as being important for improving the strength of the restoration [37]. The molars in particular can possibly experience a large bite load in the lingual-side cervical region of the teeth. However, because this is a region that matters little in terms of esthetics, it seems best for the lingual-side margin to be given a form where the zirconia frame is exposed, in order to prevent chipping. In our clinical studies, chipping did not occur in the front teeth area but did occur in bicuspids and molars [38], and mechanical problems such as occlusion could possibly be factors responsible for chipping. It seems important that the frame design also take occlusion factors, habits, and the like into consideration as well.

27.5 Conclusions

There are numerous reports that point to the prevention of porcelain chipping as a clinical challenge for zirconia all-ceramic restorations. Causes of chipping, clinically speaking, include occlusion factors; physically, they include the cooling rate after porcelain firing, excessively large porcelain thickness arising because of poor frame design, and the like. A prospective study should be carried out in the future that takes these factors into consideration.

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