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Prevalance of fracture in metal-ceramic restorations – A review article

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Abstract

Metal ceramic restorations are commonly used in fixed prosthodontics because of its excellent bio-compatibility and superior Esthetic value. Fracture of ceramic veneer is a common problem in clinical practice, although the fracture of such restorations does not mean the failure of the restoration.

The renewal process is both time consuming and costly. Fracture in anterior region is an Esthetic problem and there is impaired chewing function if fracture occurs in posterior region. There may be discomfort for the patient also. The reasons of fracture covers a wide range from iatrogenic to laboratory mistakes or because of factors related to the inherent structure of the ceramic or simply to trauma.

Keywords: Fixed Prosthodontics, Veneer, Fracture of Ceramic, Restorations.

Introduction

Metal –ceramic restorations are widely used in dentistry with a high degree of success. Increased effort was given to improve the bond strength between the ceramic and the metal. But still fracture of ceramic veneer occurs on occasion under clinical condition.

The reasons for such failures are frequently repeated due to stress and strain during chewing or trauma. Clinical studies indicated that the prevalence of ceramic fractures range between 5-10% over 10 years of use.[1]

Ceramic fractures are serious and costly problems in dentistry. Moreover, they pose an Esthetic and functional dilemma both for the patient and the dentist. Therefore, the interest of this paper is to review the published literature on the reasons for fracture concentrating on the data obtained both from in-vitro and in-vivo studies.

Evaluation of metal-ceramic bonding and failure

A perfect test to determine the metal-ceramic bond does not exist, but a push out shear test is commonly employed.

Other tests used are flexural test, tensile and torsional loading test. Six possible locations of failure have been identified. (Fig 1-6) Fractures are rarely observed through the metal but are commonly observed through the oxide layer.

Metals resistant to the formation of oxides (gold or platinum) usually fracture at the interface.

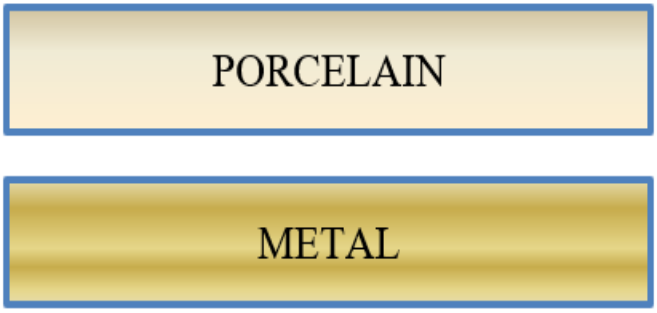

Fig 1: Metal - Porcelain

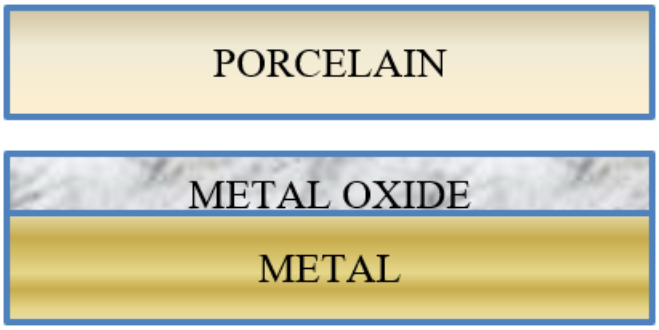

Fig 2: Metal-oxide – Porcelain

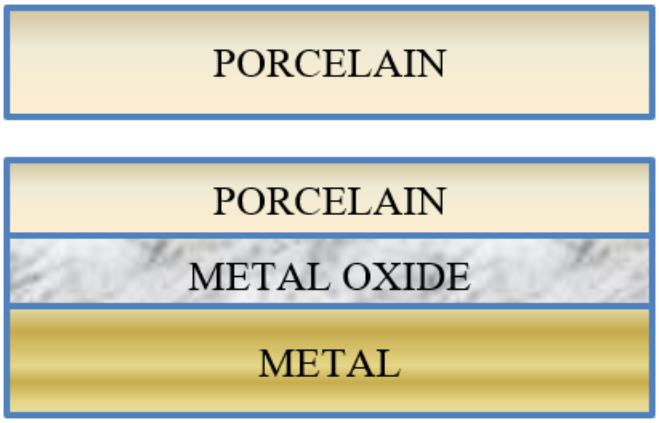

Fig 3: Through Porcelain

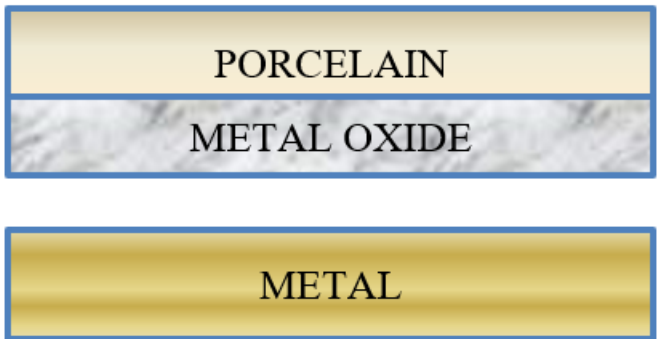

Fig 4: Metal – Metal-oxide.

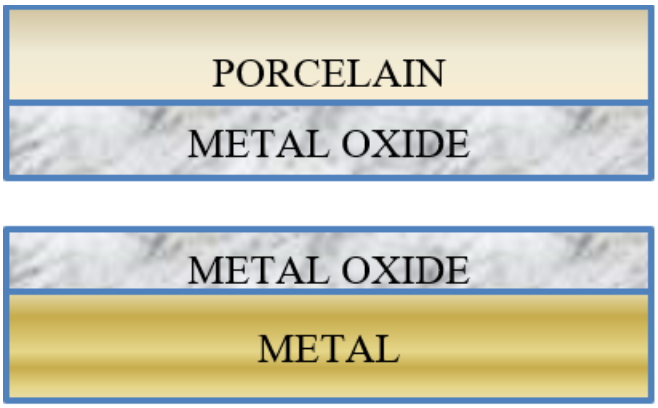

Fig 5: Metal-oxide – Metal-oxide.

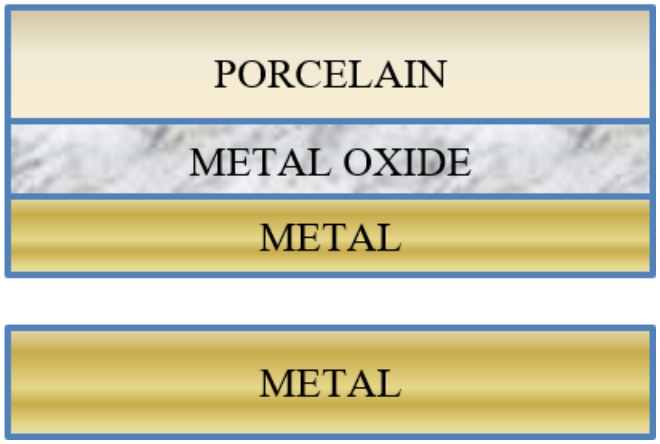

Fig 6: Through Metal.

Causes of failure

Failure of the restorations is in-fact a multifactorial problem which could be related to a combination of different reasons. Optimization of the metal-ceramic restorations requires knowledge of the failure phenomenon. Numerous studies over the years have focused on the reasons of failure.

Mechanical failures of metal-ceramic systems are not surprising considering the vast differences in modulus

between the metal and the ceramic materials. When feldspathic dental porcelain is cooled, the leucite crystals contract more than the surrounding glass matrix leading to the development of tangential compressive stresses around the leucite particles as well as to micro-cracks within and around the crystals. [2]

Some studies attributed the reasons for failures to the environmental factors and particularly to the moisture 20%-30% reduction in metal-ceramic strength was found in a moist environment[3] indicated that silicate bonds in the glossy ceramic matrix are susceptible to hydrolysis by environmental moisture in the presence of mechanical stress. The porcelain restoration functions in a moist environment, which may allow static fatigue to cause the propagation of fracture along the micro-cracks resulting in failure of the restoration.

The environment of the oral-cavity was found to aggravate the strength of the dental ceramics. The silicon-oxygen bond becomes weaker between the metal and ceramic in the presence of moisture which abet failure in many way primarily because of the water propagation at the crack tip.[4]

The most frequent reasons for ceramic failures are related to the cracks within the ceramic. The minute scratches present on the surfaces of nearly all materials sometimes behave as sharp notches whose tips are as narrow as the spacing between atoms in the materials. Thus the stress concentration at the tips of these minute scratches causes the stress to reach the theoretical strength of the material at relatively low average stress. When the theoretical strength of the material is exceeded at the tip of the notch, the bond at the notch tip breaks. As the crack propagates through the material, the stress concentration is maintained at the crack tip until the crack moves completely through the material; the stress concentration is maintained at the crack tip until the crack moves completely through the material.[5] Long anterio-posterior metal substructures also flexes under heavy or complex loading causing porcelain fracture[6]. The cracks exiting within the ceramic are important issues to be considered in the survival of fixed partial dentures. Especially in long span bridge, crack propagation might then result in catastrophic failure of the restoration.

It was also noted that other reasons for the ceramic failures are technical mistakes during the preparation of the restoration and claimed that occasional presence of the pore inside the ceramic could account for their weakness and eventful fracture at the site.[7] The same results were also found by Olio (1988) who agreed that such mistakes markedly increase the failures.

Further studies demonstrated the importance of micro-cracks existing in the ceramic micro-cracks in ceramic could also be caused by the condensation, melting and sintering process of the ceramics on metal because of thermal co-efficient differences.[8] Faulty design of the metal substructure, incompatible thermal co-efficient of expansion between the metal substructure and ceramics, excessive porcelain thickness with in-adequate metal support, technical flaws in the porcelain application occlusal force or trauma were also included a the failure reasons.[9] Because of the heterogeneous nature of many dental materials, they are likely to contain defects or flaws in various amounts and sizes such flaws remain at fixed length unless under load but then they become unstable and propagate, catastrophically culminating in fracture.[10] In order to minimize the formation of micro-cracks a fairly uniform thickness was recommended, which may occur during the firing of the ceramic. Avoidance of acute line angled preparations was advised as they enhance the formation of micro-cracks within the porcelain during firing process.[11]

The result of these studies definitely favoured the requirement of technical skill and meticulous work in ceramic build-up. Clinical part of the process could have been performed ideally however, when high level of skill in ceramic build-up is not performed, the failure of the restoration could be inevitable. The important question is whether it would be to avoid any flaws during ceramic build up.

Widerhorn[12] (1968,1974) stressed that during actual masticatory conditions, restorations are subject to repeated loading over long periods, with superposed tangential motion and further claimed that, especially in chemically active aqueous environments, this could greatly exacerbate damage build up. He stated that the ceramic fracture process might be accelerated by the environment. It was reported that facings may crack, be fractured or damaged as a result of trauma, para functional occlusion or inadequate retention between the veneer and metal.[13] In clinical practice however, the magnitude and direction of Macedonian forces cannot be controlled.

Evan et al[14] (1990) indicated not every effort should be made to minimise air entrapment between ceramic particles as porosities does occur during ceramic application and can impair aesthetics as well as remote fracture.

Another reason for porcelain fracture was attributed to inadequate tooth preparation, which result in too little inter-occlusal space for the metal substructure and porcelain. It was concluded that the improper design of the restorations for occlusion is the major cause of failure.[15] the possible failure of ceramics was sometimes attributed to in adequately registered occlusion, material type, spanning of the restoration or inadequate marginal adaptation. Niedermeier et al[16] in 1998 stated that when occlusion is not registered correctly and articulation is not checked properly, the premature contacts would act as stress bearing zones on the ceramics.

Amorphous materials like glass or glossy material do not possess an ordered crystalline structure as do metals. Bertolotti in 1997[17] described the reasons in detail why ceramic materials do not yield in the same manner as metals.

Stress direction in another contributory factor for failure as sometimes failure occurs at sites of relatively low stress. The majority of the ceramic fractures were observed to occur during normal chewing function followed by either trauma or some kind of accidents being mostly the anterior region Ozcam & Niedermeier, 2001[18]. The findings of this study is clearly indicate that the reasons for ceramic failures might be also external factors other than technical reasons in real life.

Complications involving fixed partial dentures can also occur during the pre-prosthetic operation phase. Raustia & Salonen 1998[19] noted that the clinical skill of the dentist our dental students are extremely important.

Prevalence of failure

In clinical follow-up study by Co-ornaert et al (1984)[01], the prevalence of fractures in metal ceramic crown was found to be approximately 5% over 10 years of function. Studies by Karlsson (1986)[20] revealed a 93% success rate for bridge restorations during a 10year period, while Palmquist and Swartz (1993) [21] reported bought a 79% success rate over an 18 - 23-year period.

The survival rate obtained by Glantz et al (1993)[22] as a function of time between 1979 and 1994 indicated that most of the debondings occurred over 15 years and almost all recorded dislodgements were observed within 05 years of placement.

Subsequent clinical results from Hankinson and Capetta (1994)[23] and Kelsey et al (1995)[24] exhibited 2 - 4% failure rate after two years of function, rising from 20 -

25% after 4 to 5 years because of consistent repeating occlusion contacts.

In another clinical retrospective analysis, 1219 three-unit fixed bridges and 1618 single crowns in the anterior region were evaluated between 1969 and 1989 Kerschbanm, Seth & Teeuwen, 1997[25] the result supported the study done by KERLSSON (1986)[26].

Statistical analysis however, showed that after 10 years, 88.7% of the metal-ceramic crowns and 80.2% of metal-ceramic bridges were still in function.

Conclusion

Fracture of porcelain is often considered as emergency treatment and restoration processes can present a difficult challenge to the dentist. Clinical studies indicated that the prevalence of ceramic fracture ranged between 5% to 10% over 10 years of use.[1] there is consistent epidemiological evidence that mechanical failure of a dental prosthesis occurs after a number of years of service. Therefore prosthodontic structures typically do not fail as a consequence of a single episode of stress application but rather as the cumulative effect of a large number of comparatively small loadings.

Because of the nature of porcelain processing, new porcelain cannot be added to the existing restoration intraorally. The manual fabrication of metal frame box and porcelain veneers is time-consuming and requires a high level of skill (Freelich et al ,1998)[27]. It is an unpleasant experience for the patient and for the dentist to remove these restorations from month. The replacement of the failed restoration is not necessarily the most practical solution because of the cost and the complex nature of the restoration (Fam, 1991)[28].

When the crowns are cemented intraorally, factors other than inherent mechanical strength of the material come into play. Under continuous application of the mechanical environ mental loads, progressive degradation may lead to crack initiation and growth and ultimately to our catastrophic failure of the restoration.

Although failure of ceramic fused to metal restoration can be overcome by either some repair techniques or renewal of the restoration, it is beneficial to know the reasons for failures, especially those because of iatrogenic or technical mistakes which would help to increase the service time of such restorations.

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