CAD/CAM Ceramics

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CAD/CAM ceramics present a promising alternative to metal-ceramic fixed dental prostheses.

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1. Introduction

In the past decades, metal-ceramic restorations have represented the gold standard in fixed prosthetics in dentistry. Zirconium-ceramic crowns are a good alternative to metal-ceramic crowns. They achieve similar incidence rates for biological complications (e.g., secondary caries) and technical aspects (e.g., loss of retention) and reveal better aesthetic properties [1]. There is a steadily increasing demand for alternatives made of all-ceramic materials. Reasons for this may be a growing awareness of biocompatibility and aesthetics [2]. Systematic reviews could already show promising results for the long-term survival of CAD/CAM fabricated lithium disilicate ceramic restorations [3][4]. Studies with a 10-year follow-up period were able to provide survival rates of 96.5% for monolithic as well as for two-layer disilicate ceramics [5].

Dental ceramics are increasingly finding their way in today's dentistry. In addition to a high degree of stability and aesthetics, they also demonstrate excellent biocompatibility [6]. All-ceramics is a generic term for a tooth-colored, mineral material used to manufacture dental restorations without a metal base [7]. Compared to metal-ceramic systems, all-ceramics show clear advantages for aesthetic appearance with rich color stability due to light-conducting and light-refracting features [8]. In terms of biocompatibility, they convince with low plaque accumulation on their glazed surfaces [9][10]. This can be explained by the fact that ceramics do not dissolve, even in the electrolyte-containing environment of the acidic oral milieu, and behave entirely neutrally toward other materials. Their biocompatibility is even higher than that of alloys containing highly noble metals [11]. Unlike metals, ceramics have the characteristic of thermal insulation and thus have another fundamental advantage. As this prevents thermic transmission, irritation of the vital tooth can be minimized [12].

Similar to the observed progress in dental ceramics, CAD/CAM is increasingly finding its way into modern dentistry. Particularly, in the processing of ceramic materials, significant progress has been made. CAD stands for 'computer-aided design' and describes a virtual design of the restoration. CAM stands for 'computer-aided manufacturing' and describes the production of dental restorations by using machine units. This technology has become widespread in dentistry and seems indispensable today [13]. In the first step, the three-dimensional anatomy of the respective tooth is recorded with a scanner [14][15]. The next step is digital processing and subsequent transfer to the milling unit [14]. Three production systems can be distinguished here: (1) chairside, where everything takes place in the dental practice; (2) laboratory production, where the milling takes place in the dental technician's laboratory; and (3) centralized production in an external milling center [14]. Two scanning methods can be distinguished: direct intraoral scan of the teeth and the extraoral scan on a conventional stone cast [14].

With the help of such systems, it is possible to produce ceramic inlays and crowns within one session as a 'chairside' procedure [16].

One of the most obvious advantages is the reduced number of appointments and simplified laboratory work compared to conventional restorations [17].

Digitization also provides a decisive advantage in terms of archiving. All clinical data can be stored electronically and allows the restoration to be remade if damaged without a clinical appointment. Compared to the conventional method, CAD/CAM methods reveal a more accurate and reproducible fabrication process [18][19]. The greater accuracy and operator-independent digitalization of the workflow can result in better esthetic outcomes [20]. Due to the shorter production time and reduced number of consultations, less movement of the tooth is likely to occur. This is crucial for accurate and less traumatic restoration of the tooth [21][22]. For these reasons, it is important to question the current gold standard and examine the results of CAD/CAM-made ceramic restorations.

2. Clinical Performance of CAD/CAM All-Ceramic Tooth-Supported Fixed Dental Prostheses

We aimed to evaluate the clinical performance of CAD/CAM manufactured all-ceramic fixed dental prostheses. The available evidence provided a sufficient amount of data to allow for a satisfying conclusion on the success and survival of such dental therapies. We estimated survival rates of up to 94.66%, 91.1%, and 82.2% for the 3-, 5-, and 10-year survival data based on the available evidence in the literature. The low range variability between the study groups supports the assumption of good accuracy of survival. Similar satisfying results were seen for the success rates focusing on any intervention on FDPs after insertion without considering failures as events. The estimated lowest success rates were up to 96.77%, 94.62%, and 89.25% for the 3-, 5-, and 10-year success data, respectively. Despite the higher variability of success values than survival values between the different follow-up groups for the 5- and 10-year success rate estimates, these values were still in a satisfying area of success.

Notably, the only three studies observing failures in Group 1 had a follow-up period of 3 to 3.8 years [23][24][25] and reported a survival rate of 84.8%, 93%, and 90.5%, respectively. These reported rates were lower than the estimated rates of 93.8% to 94.66% for the 3-year survival based on a meta-analysis of the included studies' data. Reich et al. (2014) used lithium disilicate ceramics as a base, the other publications mainly used zirconia [25]. Therefore, the survival rates of 93% after 4.7 years described by Reich et al. must be considered critically. Furthermore, FDPs in the premolar region were examined, exposed to lower force effects than FDPs in molar regions [25]. The different mechanical properties of the two ceramic composites were not taken into account here and likely make a direct comparison inaccurate. However, the study's overall quality was satisfying as assessed with the risk of bias tool, allowing the support of the study results provided for lithium disilicate bases. In contrast, data of the five studies [24][26][27][28][29] in Group 2 reporting survival rates of 85% to 97% for the 5- to 7-year study period were comparable to the 5-year survival estimates of 89.67% to 91.1%, calculated for all studies. This translates to a satisfying correlation and reliability for the 5-year data. The outliner with the highest reported survival rates was Burke et al., providing a survival rate of 97% for the 5-year observation [24]. The least comparable data were found in Group 3, reporting survival rates of 75%, 93.6%, and 95% for the approximately 10 years of observation [30][31][32]. The corresponding estimates calculated from the meta-analysis were lower, with values from 79.33% to 82.2%. In fact, the studies within Group 3 showed high variability in the reported survival rates. The most comparable survival rate was provided by Rinke et al. reporting survival rates of 75% for the 10-year observation period [31]. Overall, there seems to be a more pronounced drop in survival rates between the 5-year and 10-year data. Thus, more data on 10-year survival are warranted to draw a reliable conclusion on the long-term performance of CAD/CAM all-ceramic FDPs.

The most common reason for failure for the pooled included studies was secondary caries. The occurrence of secondary caries has been described by five studies [30][26][31][33][29] involving a total of 26 cases, of which 14 led to a failure of the FDP. Interestingly, a systematic review from Sailer et al. did not find a significant difference in caries incidence for abutment teeth [34]. However, Pjetursson et al. showed a higher caries prevalence on all-ceramic restorations compared to metal-ceramic restorations for multi-unit bridges [35].

The second common reason for failure was chipping. Eight publications showed either chipping or cracks of the ceramic, requiring replacement of the restoration [24][28][29][36]. This accounts for 10/52 (19.2%) of all observed failure cases. In a systematic review, Heintze and Rousson et al. were able to show a significantly higher chipping rate of the veneering ceramic in bridges with zirconia frameworks than in conventional metal-ceramic bridge restorations [2]. No difference was found between 3- and 4-unit bridges. Furthermore, they reported that 24% of all zirconia FDPs examined revealed chipping, which is in accordance with our results, not considering drop-outs (127/603, 21.06%). In comparison, 43% of the metal-ceramic FDPs showed chippings. However, they reported that when comparing only studies that directly compared zirconia and metal-ceramic FDPs, chipping frequency was higher for zirconia FDPs [2]. Sailer et al. (2009) found chipping in 33% of all-ceramic bridges after three years. In comparison, chipping was found in 19.4% of the metal-ceramic restorations [37]. However, they found no difference in terms of survival rates after three years of function [37]. In order to replace metal-ceramic restorations as the gold standard, an improvement in the bond between the veneer and the framework ceramic must be achieved. In vitro studies showed that the leading cause of chipping was lying in the veneering ceramic [38], which can often be treated by polishing. The reasons for chipping can be the different layer thicknesses and the design of the framework as well as different temperature expansion coefficients of the ceramics [23][37]. Further attempts to reduce chipping were investigated by Guess et al. (2010) by comparing monolithic lithium disilicate crowns with veneered zirconia crowns [38]. Monolithic restorations performed better, although further research is needed to be able to assess this conclusively [38]. In summary, it can be concluded that more focus should be set on framework-veneering interfaces and veneering ceramics properties to reduce chipping rates in the future. One way to accomplish this task could be the improvement of the design of the framework itself or strengthening the veneering ceramics.

Regarding framework fractures of all-ceramic restorations, Sulaiman et al. (2020) were able to provide low failure rates of 1.35% for lithium disilicate as well as for monolithic restorations in a follow-up period of up to 7.5 years. Similar to the chipping behavior results, monolithic restorations were also found to be at lower risks for framework fractures [39]. Focusing on CAD/CAM produced all-ceramics, Belli et al. (2016) was able to show equivalent fracture rates of 1.4% over a period of 3.5 years [40].

Loss of retention as another type of complication leading to either failure or repair without replacement of the FDP was addressed by six studies [23][24][30][27][29][36] and occurred in 22/603 (3.65%) of all cases, not considering drop-outs. Five of these studies reported the cementation material and used adhesive [33][29] or conventional [23][30][31] methods. Most of the loss of retention cases were reported by Rinke et al. (12/22, 54.55%) and Chaar et al. (6/22, 27.27%), both using conventional cementing methods [30][31]. Similar results regarding the loss of retention in zirconia frameworks have been described by Tinschert et al. for conventional cementing techniques as well as Sailer et al. for adhesive cementation [33] [41].

3. Conclusions

CAD/CAM zirconia- and lithium disilicate-based FDPs revealed satisfying survival and success rates for up to 10 years of exposure. Certain associated complications such as chipping and secondary caries were frequently seen in the included studies, and a future in-depth analysis of their underlying factors would be of clinical relevance. More prospective studies focusing on long-term performance are needed to strengthen the evidence currently available in the literature.

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