A 30-year retrospective study of single-unit and splinted implant supported crowns and their effects upon adjacent tissues and teeth in a Canadian Dental School Environment

By Isabella Sarzynski

Abstract

Objective: A retrospective study at a Canadian dental school evaluated the survivability of single-unit and splinted implant supported crowns and their effects on adjacent tissues. Methods: Data from patients of all ages was collected from the institution's computer patient management software (AxiUm) and physical charts. Results: A total of 678 implant supported crowns (586 single-unit and 92 splinted) were placed at the University of Manitoba Dr. Gerald Niznick College of Dentistry between September 10, 1989 to January 1, 2020. Of the implant cases, 249 (36.7%) of them were smokers, 64 (9.44%) were diabetic and 96 (14.2%) were reported to experience bruxism. Within the duration of the study, 17 (2.90%) single-unit crowns and 5 (5.43%) splinted crowns failed and warranted a replacement. Furthermore, 371 single-unit (63.3%) and 46 splinted (50.0%) implant crowns were a complete success as they had no complications with the crown itself or adjacent tissues. Therefore, 215 single-unit (36.7%) and 46 splinted (50.0%) crowns endured some type of complication with the crown or adjacent tissues which may have led to its failure. Overall, 96.8% of cases experienced no failure as of the study end date and a log rank test was performed to determine if there were differences in the survival distribution for the single-unit and splinted implant supported crowns ($\chi 2(2) = 1.285$, $p = 0.257$). Conclusion: The survival distribution of single-unit and splinted implant supported crowns was not statistically significant as they both presented with high success rates and minimal complications. Although some limitations and challenges

were present, this study highlights the longevity and complications of implant supported crowns in order to improve their functionality and lifespan as well as to maintain the health of adjacent teeth.

Introduction

A goal of modern dentistry is the preservation of natural tooth structure. To preserve natural tooth structure and replace missing teeth the treatment option for edentulous spaces in the oral cavity is the placement of implant supported crowns. Dentists are implementing implant treatment option for edentulous spaces in their practices as they come with several advantages over a fixed partial denture. These advantages include a decreased risk of caries and endodontic treatment of abutment teeth (and therefore a decreased risk of abutment tooth loss), a decreased risk of decay and periodontal disease in adjacent teeth due to easier access for cleansing, maintenance of bone in the edentulous site, and physiological advantages (Chrcanovic et al., 2019). Implant treatment is providing a unique opportunity for growth of interprofessional collaboration, leading to the creation of more accurate surgical and biomedical protocols (El Askary, 2007). We can achieve outstanding treatment success as we have entered an era of clinical predictability (El Askary, 2007).

The placement of implant supported crowns have shown to have high success rates. A literature review spanning from 1981 to 2001 done by Goodacre et al. showed a survival rate of 97% for single-unit implant supported crowns in all regions of the mouth (Goodacre et al., 2003). Another study found that implant supported crowns had a survival rate of 93.8% which is greater than the 51.9% survival rate of fixed partial dentures over a ten-year period (Teichmann et al., 2016).

Despite these high success rates, implant supported crowns are not free from complications as data indicates complications can occur in approximately half of patients after ten years of function (Lang et al., 2004). Implant complications can be divided into two categories: biological or technical (Jung et al., 2008). Biological complications include peri-implantitis and bone loss, while technical complications can include screw loosening and fracture of luting cement. These complications can not only affect the prosthesis itself, but the adjacent tissues as well. Although single-unit implants and their prostheses have been thoroughly investigated, there is a lack of studies on their effects on adjacent structures (Krennmair et al., 2003). One study looking at the adjacent teeth of single tooth replacement of posterior implants found that interproximal decay developed in 5% of adjacent teeth and 0.4% needed root canal treatment due to decay or restoration (Misch et al., 2008).

In addition to determining the longevity of implants and their effects on surrounding tissues, the factor of whether the crowns were placed as single-units or splinted prostheses was investigated. Single crowns are one of the more common restorations in implant dentistry as they offer a comfortable prosthetic approach with more esthetic emergence profiles and better access for oral hygiene than other fixed partial denture restorations (Al-Aali et al., 2019). A recent study using three-dimensional finite element analysis found that splinted prostheses exhibited better stress distribution for the implant and its components (Lemos et al., 2018). In a prospective study with three years of follow-up, it was determined that both splinted and non-splinted prostheses had similar survival rates, marginal bone loss and peri-implant soft tissue conditions over the observation period (Guarnieri et al., 2019). Therefore, a question that this study explored

was whether a single or splinted crown had any effect on the longevity of the prosthesis or the adjacent tissues.

Taking this all into account, the placement of implants can result in three outcomes – success, survival, and failure. In the context of this study, success can be defined as having the dental implant and prosthesis present in the mouth without any complications. Survival means that the implant and prosthesis are present in the mouth but have encountered some type of complication with the unit itself or with adjacent tissues. These can be managed such that the restoration functions with no further complications. Lastly, failure can be described as the implant and/or prosthesis are no longer in the mouth and has been replaced. The aim of this retrospective study was to determine the survival rate and reason for failure of implant supported crowns and their effect upon adjacent tissues in a Canadian dental school environment. Investigating the longevity and complications involved with implant supported crowns is beneficial to improve their functionality and lifespan as well as to maintain the health of adjacent teeth. This will guide our understanding of the reasons behind failures as well as define the components necessary for a successful implant to reduce the cost and increase efficiency when manufacturing single tooth restorations.

Materials and Methods

The retrospective study received approval from the University of Manitoba's Research Ethics Board to review and analyze patient charts. The charts were reviewed both digitally, using the Dr. Gerald Niznick College of Dentistry dental management software (AxiUm), and physically by examining patient paper charts. All single-unit and

splinted implant supported crowns placed between September 10, 1989 and January 1, 2020 were flagged.

The implant supported crowns were categorized as failures, survivors, and complete successes. An implant was considered a failure if it was removed and replaced. An implant crown was considered a survivor if issues with the crown itself or complications with adjacent teeth occurred and could be managed without removing the implant. An implant crown was considered a complete success if no complications occurred to the crown and adjacent teeth. The daily treatment record of each chart was reviewed to verify if the failure or complication occurred and the reason. Patient demographics including gender, smoking status and whether the patient was a diabetic and bruxer were documented to determine if this had any effect on the outcome.

The span of time from the date of delivery to the date of failure, in months, was also recorded to observe the length of survivability. A Kaplan-Meier survival estimate with an associated *P* value was done to estimate the survival function of the single-unit implant crowns and splinted crowns over the time interval to see if there was a statistically significant difference. A log-rank test was also performed to determine if there were differences in the survival distribution for the different prostheses. The goal of the survival estimate was to determine single-unit and splinted crown survival probabilities over the duration of the study and to determine whether the two curves were statistically different.

Results

A total of 678 implant supported crowns (586 single-unit and 92 splinted) were placed at the Dr. Gerald Niznick College of Dentistry between September 10, 1989 and January 1, 2020. Although 678 implants were placed, there were only 403 patients within this pool, with 178 (44.2%) of them being male and 225 (55.8%) percent of them being female. Of the implant cases, 249 (36.7%) of them were smokers, 64 (9.44%) were diabetic and 96 (14.2%) were reported to experience bruxism. The implant supported crowns were placed 52.1% of the time in the maxilla and 83.9% of the time in the posterior region of the mouth. Regarding the material of the prostheses, the most common implant system used was Nobel Biocare (77.7%) with Zimmer Biomet being the second most used (10.6%). The most frequent type of crowns placed on the implants were metal-ceramic crowns (MCC) and all-ceramic crowns at 68.6% and 17.8% respectively.

Within the duration of the study, 17 (2.90%) single-unit crowns and 5 (5.43%) splinted crowns failed and warranted a replacement. The causes of failure are detailed in Figure 1 below.

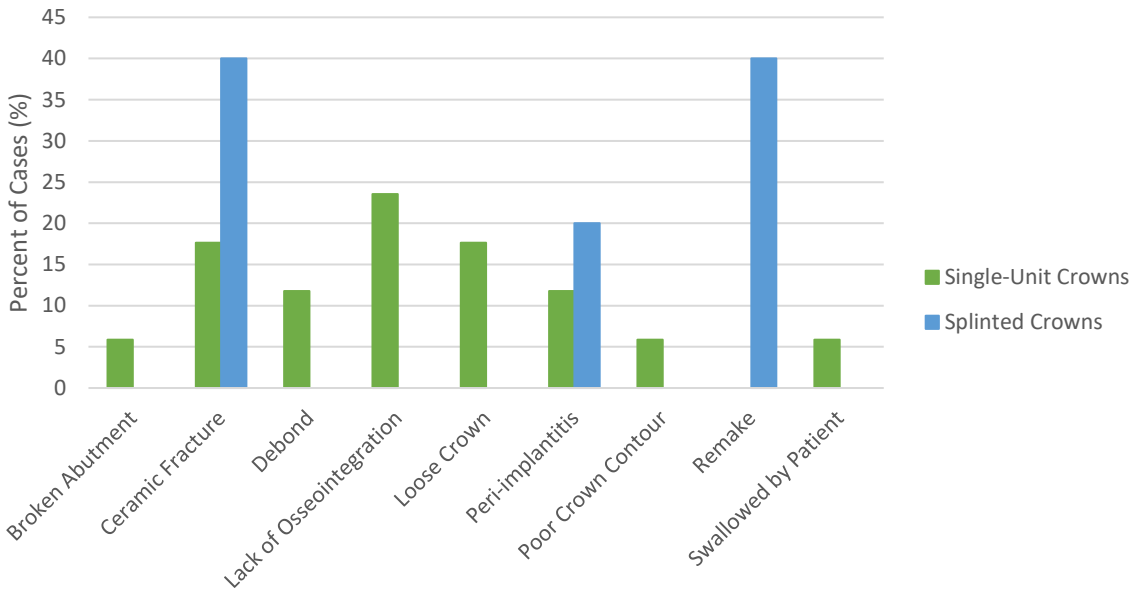
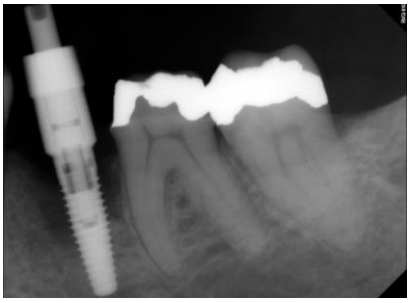


Figure 1. The causes of failure of both single-unit and splinted implant supported crowns placed at the Dr. Gerald Niznick College of Dentistry.

The most common cause of failure for single-unit crowns was a lack of osseointegration of the implant (Figure 2) whereas the most common cause of failure for splinted crowns was ceramic fracture (Figure 3) and having to remake the crown for functional purposes. Out of the single-unit crowns that failed, 5 patients were smokers, none were diabetic and 5 were bruxers. For the splinted crown failures, 2 patients were smokers, 1 was diabetic and none were bruxers.

a)  b) 

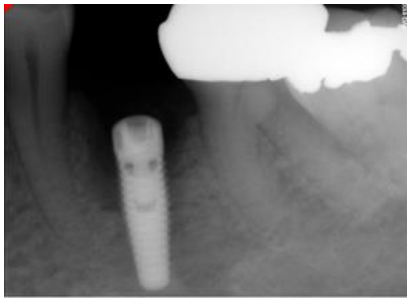
c) 

Figure 2. Radiographs depicting a single implant placed at the site of tooth 35 in the Dr. Gerald Niznick College of Dentistry in September 2012 (a). The implant that had a lack of osseointegration and was subsequently removed in February 2013 (b) and replaced with a new implant in January 2014 (c).

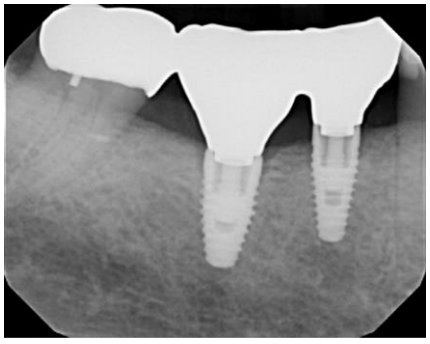
a)  b) 

Figure 3. Radiographs depicting splinted metal-ceramic implant crowns placed in the Dr. Gerald Niznick College of Dentistry in November 2017 (a) and the resulting fracture of ceramic on tooth 45 in March 2018 (b).

Furthermore, 371 single-unit (63.3%) and 46 splinted (50.0%) implant crowns were a complete success as they had no complications with the crown itself or adjacent tissues. Therefore, 215 single-unit (36.7%) and 46 splinted (50.0%) crowns endured some type of complication with the crown or adjacent tissues, leading to the failure of 17 single-unit and 5 splinted prostheses. The average amount of complications that a tooth presented with can be seen in Table 1 below, and the most common types of complications that were seen in the crowns and adjacent teeth can be see in Figures 4 and 5 respectively.

Table 1. The average amount of complications experienced by single-unit and splinted implant supported crowns placed at the Dr. Gerald Niznick College of Dentistry.

Crown Type	Mean	Standard Deviation	Minimum	Maximum
Single-Unit Crown Complications	0.403	0.808	0	6
Adjacent Tissue Complications with Single-Unit Crowns	0.178	0.492	0	3
Splinted Crown Complications	0.0929	0.440	0	4
Adjacent Tissue Complications with Splinted Crowns	0.196	0.815	0	7

The single-unit crowns experienced more complications with the crown itself with a maximum of 6 complications occurring for single crown. The splinted crowns

experienced more adjacent tissue complications on average with a maximum of 7 complications for a single splinted crown.

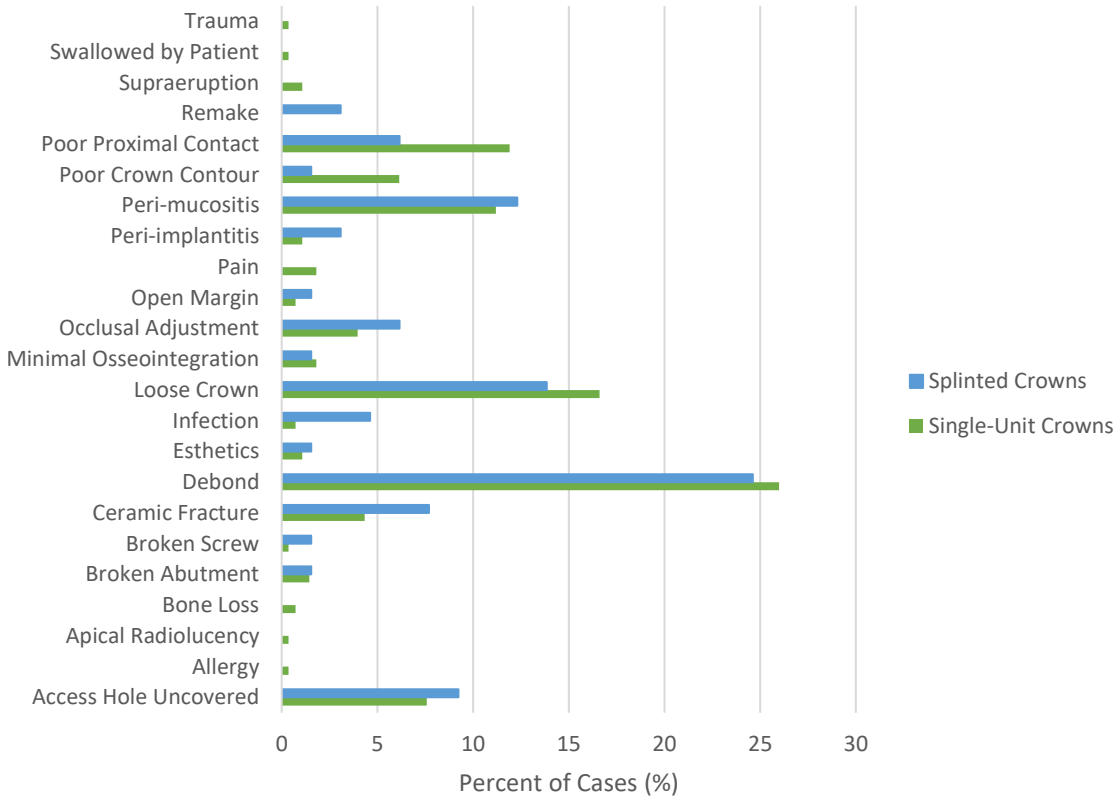


Figure 4. The causes of complications of single-unit and splinted implant supported crowns placed at the Dr. Gerald Niznick College of Dentistry.

The most common causes of complications of single-unit crowns were debonding and loosening of the crowns. Regarding the single-unit crowns experiencing any periodontal effects, 58.6% of the complications occurred with crowns that were cement-retained as opposed to screw-retained. The opposite is true for single-unit crowns that became loose, in that the complications occurred more often in screw-retained crowns (71.7%) as opposed to cement-retained crowns. For splinted crowns, the most common causes of failure were also debonding and loosening of the crowns. For the splinted

crowns experiencing any periodontal complications, 62.5% of the complications occurred with crowns that were screw-retained as opposed to cement-retained. Similarly, for crowns that became loose, the complications occurred more often in screw-retained crowns (88.9%) as opposed to cement-retained crowns.

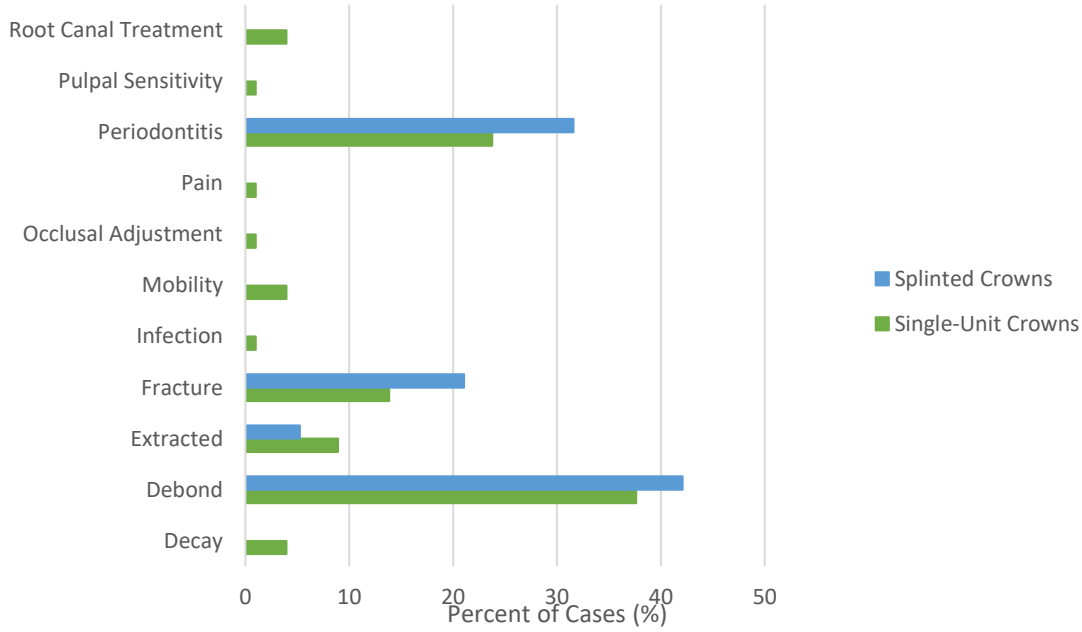


Figure 5. The causes of complications of adjacent teeth and tissues next to single-unit and splinted implant supported crowns placed at the Dr. Gerald Niznick College of Dentistry.

For single-unit crowns, as well as splinted crowns, the greatest causes of adjacent tissue complications were periodontitis and debonding of a previously existing crown. As can be seen, more single-unit crowns experienced adjacent tissue complications than splinted crowns, but this may be due to the smaller sample size of splinted crowns. Another avenue explored in this study is the effects that smoking, diabetes and bruxism have on adjacent teeth and tissues. The average amount of complications for each category can be seen in Table 2 below.

Table 2. The average amount of complications of adjacent teeth and tissues next to single-unit and splinted crowns in patients that were smokers, diabetics and bruxers placed at the Dr. Gerald Niznick College of Dentistry.

Patient Type		Mean	Standard Deviation	Minimum	Maximum
Single-Unit Crown	Smoker	0.223	0.561	0	3
	Non-Smoker	0.151	0.446	0	3
Splinted Crown	Smoker	0.147	0.436	0	2
	Non-Smoker	0.224	0.974	0	7
Single-Unit Crown	Diabetic	0.200	0.535	0	3
	Non-Diabetic	0.176	0.489	0	3
Splinted Crown	Diabetic	0.692	1.97	0	7
	Non-Diabetic	0.114	0.358	0	2
Single-Unit Crown	Bruxer	0.382	0.715	0	3
	Non-Bruxer	0.141	0.431	0	3
Splinted Crown	Bruxer	0.286	0.756	0	2
	Non-Bruxer	0.188	0.824	0	7

In single-unit crown cases, smokers, diabetics and bruxers experienced more adjacent teeth and tissue complications than their counterparts. For splinted crowns, diabetics and bruxers experienced more complications, but interestingly, it was the non-smokers that experienced more complications on average than the smokers.

The last component of this study was the survival estimate of both single-unit and splinted implant supported crowns. The survival rates of single-unit and splinted crowns were 97.1% and 94.6% respectively. A Kaplan-Meier survival estimate can be seen in Figure 6 below.

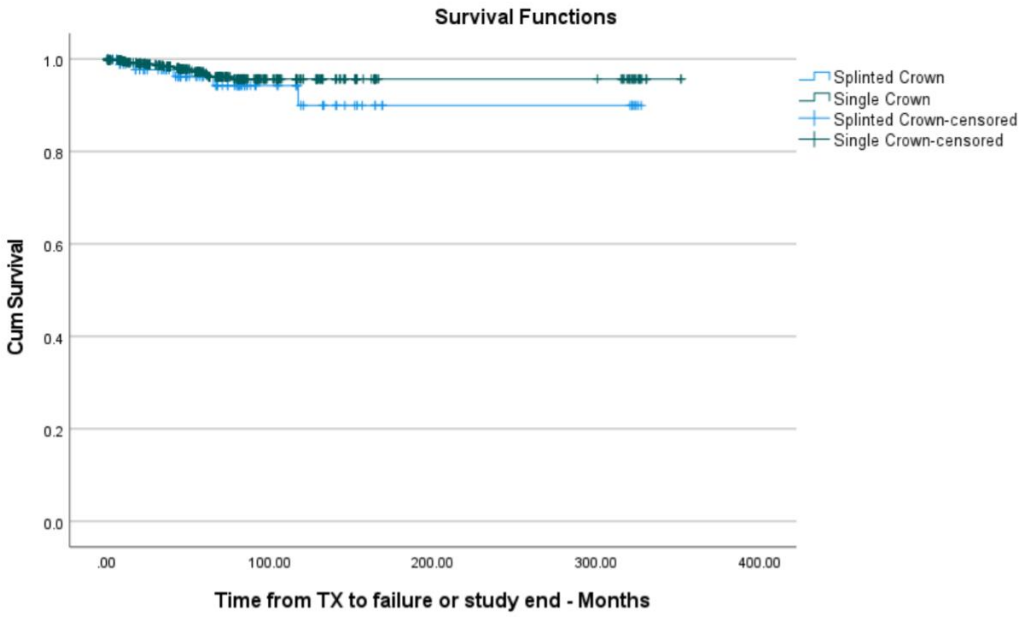


Figure 6. Kaplan-Meier survival estimate for the survival of single-unit and splinted implant supported crowns placed at the Dr. Gerald Niznick College of Dentistry. Censored, vertical lines indicating lost to follow-up.

A log rank test was performed to determine if there were differences in the survival distribution for the different types of crowns. The survival distribution for the single-unit versus splinted implant supported crowns was not statistically different, $\chi 2(2) = 1.285$, $p = 0.257$.

Discussion

Implant supported prostheses present with high implant and restoration survival rates, however, biological and technical complications occur in about half of cases after 5 years of function (Lang et al., 2004). There are many studies that investigate the longevity of implant supported crowns and their causes of failure, but few studies investigate the impact that these restorations have on adjacent tissues. The aim of this

study was to retrospectively determine the survival rate and reason for failure of implant supported crowns and their effect upon adjacent tissues in a Canadian dental school environment over a 30-year period. By conducting this study on restorations placed in a teaching facility, it allows for dental schools to observe how dental students perform in a clinical environment and to see if the implemented techniques are successful.

The results from this long-spanned study provide notable findings for future research. As with all fixed prostheses, the potential benefits verses risks must be considered and discussed with the patient before placement. Fortunately, the option of implant supported crowns has proven to have high success rates and can provide many benefits to the patients such as esthetics and longevity. In this study, the survival rates of the single-unit and splinted implant supported crowns were determined to be 97.1% and 94.6% respectively. Out of those cases, 371 (63.3%) of single-unit crowns and 46 (50.0%) of splinted crowns were a complete success as they experienced no complications regarding the prosthesis itself or adjacent tissues. The overall survival rates are comparable to a study done by Priest over a 10-year period in which he had a survival rate of 97.4% with only 3 failures, although his study only focused on single-tooth implants (Priest, 1999). Additionally, a systematic review by Jung et al. found a survival rate of 94.5% for implant supported single crowns after 5 years of function, therefore it can be reasonably concluded that high survival rates for implant supported crowns can be expected (Jung et al., 2008). Less information can be found on splinted implant supported crowns, however, in a prospective study they found no statistically significant difference between the prosthetic design and the rates of technical complications of splinted crowns were lower than that of single crowns ($p = 0.036$) (Guarnieri et al., 2019; Al Aali et al.,

2019). In the present study, a Kaplan-Meier survival estimate (Figure 6), and log rank test was performed to determine if there were differences in the survival distribution for the different types of crowns, and it was found to not be statistically significant, $\chi 2(2) = 1.285$, $p = 0.257$. There is a large percent of right censored cases, specifically a total of 96.8% of cases where there was no failure as of the study end date (January 1, 2020). This will have implications on how much the Kaplan-Meier estimate be deciphered, and results should be interpreted with this caveat as the statistical power here is very low.

The rates of failure of the implant supported prostheses have remained low with a 2.90% failure rate for single-unit crowns and a 5.43% failure rate for splinted crowns. These failure rates are similar to those found by Wittneben et. al. in their study detailing the complications and failures rates of implant supported prostheses in a 10-year retrospective study (Wittneben et al., 2013). Out of 397 prostheses, 18 of them failed (4.50%) after a mean observation period of 10.8 years (Wittneben et al., 2013). Within the 18 failures, 9 were unrelated to a prosthetic cause and the remaining 9 failures could be associated with a prosthetic-cause (Wittneben et al., 2013). In the present study, the most common causes of failure for the single-unit crowns were a lack of osseointegration of the implant (23.5%) and a loose crown (17.7%). For the splinted crowns, they were ceramic fracture (40.0%) and having to remake the crown for functional purposes (40.0%). The reason for the remakes were to switch from single-unit to splinted crowns to distribute the functional load. Other causes of failure include broken abutment, debonding, peri-implantitis, poor crown contour and being swallowed by the patient. Out of the single-unit crowns that failed, 5 patients were smokers, 0 were diabetic and 5 were bruxers. For the splinted crown failures, 2 patients were smokers, 1 was diabetic and 0

were bruxers. The lack of osseointegration would certainly lead to the failure of prosthesis as the implant is the foundation on which the prosthesis functions. A possible reason for this is that 5 of the patients who had failed single-unit crowns were smokers. It is known that cigarette smoking has a detrimental effect on early bone tissue response around implant surfaces, however, further studies evaluating the clinical and radiographic long-term success of implant supported restorations in smokers are needed (Bezerra et al., 2016). Regarding the loose crown failures, there is a recommendation to tighten the screw of the crown a second time after the prosthesis is installed to reduce the risk of screw loosening (Chrcanovic et al., 2019). Be that as it may, it was not possible to know whether this recommendation was followed by all students or whether the patient came back for an appointment to do so. Lastly, possible reasons for ceramic fracture may be the presence of nonanatomic substructure design, unsupported ceramic veneering, weaker porcelain, thermal expansion/contraction mismatches and/or poor porcelain bonding, and patient parafunctional habits (Wittneben et al., 2013). The validity of these etiologies cannot be confirmed in the present study as the manufacturing process of the material choice is unknown.

As mentioned earlier, biological and technical complications occur in about half of implant cases after 5 years of function (Lang et al., 2004). In this study, 36.7% and 50.0% of single-unit crowns and splinted implants respectively were observed to have some sort of complication to the crown itself or to its adjacent tissues. In Table 1, the number of complications each prostheses type experienced is documented and it can be seen that single-unit crowns suffered, on average, more complications to the crown itself than splinted crowns, with a range of 0-6 complications per crown. The most common

causes of these complications for single-unit prostheses, as seen in Figure 4, are debonding of the crown (26.0%) and having a loose crown (16.6%) and the same goes for splinted prostheses, with 24.6% of them debonding and 13.8% of them becoming loose. The reason that single-unit crowns experienced more complications, on average, is possibly because the sample size of this study was larger for the single-unit crowns as that is the most common type of implant prosthesis done at the college. It was also found that loose crowns occurred more often in screw-retained crowns rather than cement-retained in both cases, which was also the case in another retrospective study (Chrcanovic et al., 2019). With debonding and loosening of the crowns being the major complications of both single-unit and splinted prostheses, the reasoning behind these issues should be investigated further. Debonding tendency occurs with a frequency as high as 25% to 31% which requires recementation every time it occurs (El Askary, 2007). In this study, not every student indicated what type of cement they used when placing the final restoration, however, one study suggests that cement film thickness has an influence on the retentive strength of cemented implant-retained crowns (Mehl et al., 2013). They found that all cements exhibited a significant decrease in crown retention when bonded with a cement gap thickness of 50μm and above when compared to the minimal cement thickness possible for the cement used (Mehl et al., 2013). This may be due to the fact that cements rely on micromechanical interlocking which is lost when centering the abutment in the crowns with larger cement gaps (Mehl et al., 2013). At a cement thickness of 15μm, resin cement was found to be the most retentive, followed by polycarboxylate and then glass ionomer cement ($p \leq 0.05$) (Mehl et al., 2013). Although it may not be feasible to measure the cement thickness every time an implant supported crown is cemented,

keeping cement thickness to a minimum and using a resin cement may improve the retention of these crowns, resulting in a reduced number of future complications. The loosening of crowns is another major complication found in this study, with rates of 16.6% for single-unit crowns and 13.8% for splinted prostheses. These values fall somewhere in the middle of rates reported in other studies. For instance, a study by Villarinho and his colleagues found that 28.3% of their prosthetic crowns were loose which is typically higher than other rates found in literature (Villarinho et al., 2017). Contrarily, Mezzomo et al. had a prosthetic complication rate of 2.8% in their systematic review (Mezzomo et al., 2014). However, these authors call attention to the fact that this is an under-reported complication in literature and thus these rates should be interpreted with caution (Mezzomo et al., 2014). The causes of crown loosening can stem from occlusal overload, implant location (occurs more frequently in the molar area), inadequate fit of the prosthesis, design of the prosthesis (increased mesiodistal crown measurement had increased incidence of prosthesis loosening), progressive bone loss, metal fatigue, implant diameter, manufacturing defects, and galvanic activity (Kim et al., 2010). From a clinical point of view, prosthetic crown loosening is complication requiring further clinical intervention but is easily repairable (Villarinho et al., 2017). It is imperative that the patients receive a strict maintenance protocol to avoid this complication evolving to a replacement of the prosthesis (Villarinho et al., 2017).

Another facet of this study was looking at the complications beheld by the teeth and tissues adjacent to the implant supported crowns. On average, splinted implant supported crowns experienced more complications to adjacent tissues compared to single-unit crowns, with a range of 0-7 complications each (Table 1). This may be

because splinted prostheses may be more challenging to clean, resulting in periodontal issues to surrounding tissues. The causes of adjacent tissue complications can be seen in Figure 5, with debonding of adjacent crowns (37.6% for single-unit and 42.1% for splinted) and periodontitis (23.8% for single-unit and 31.6% for splinted) being the most common issues. The higher incidence of adjacent crown debonding cannot be explained easily, but it is thought that the manipulation of the implant supported prosthesis in and out of the mouth multiple times during try-in and putting pressure on the adjacent crowns may have caused an already precarious crown to fail. The occlusion may also have changed with the insertion of the new prosthesis, potentially adding unfavourable contacts causing the dislodgement of the crown. Under fixed prostheses, natural teeth that serve as abutments have an incidence of decay that approximates 20% and endodontic procedures approximates 15% (Krennmair et al., 2003). In the present study, the incidences of decay and root canal treatments were 3.96% for single-units and 0% for splinted crowns. These values are similar to another study which found an incidence of 5% for interproximal decay and 0.4% incidence of adjacent teeth having to be root canal treated, however this study only looked at single-unit implants (Misch et al., 2008). This shows that adjacent teeth are at less risk when a missing tooth is replaced with an implant as opposed to serving as an abutment (Krennmair et al., 2003). A report looking at single-unit implants compared the periodontal status of adjacent teeth at crown placement and at follow-ups and revealed that there were no differences for plaque and bleeding indices or for pocket depths (Krennmair et al., 2003). This study also had patients attend regular follow-ups at intervals of three months for the first year and then every six months thereafter and all patients were instructed in optimal oral hygiene and visited a hygienist

at least once a year (Krennmair et al., 2003). Factors to be taken into consideration are that a patient of the dental college in which this study takes place can be assigned to more than one student and can be passed along to a new student every year. This means that it can be difficult to keep up strict maintenance protocols for patients and have a standardized way to measure differences in the conditions of adjacent teeth, which can explain the higher incidence of periodontal complications. The clinical status of teeth adjacent to implant supported crowns, and therefore the complete complex of the restored edentulous space, is seldomly reported (Krennmair et al., 2003). Although this topic is more commonly explored with single-unit crowns, there is a lack of information comparing the status of adjacent teeth next to splinted implant supported crowns and would therefore benefit further investigation.

In this study, the influence of smoking, diabetes, and bruxism on complications with adjacent tissues and teeth was explored. As seen in Table 2, patients with single-unit implant supported crowns experienced more complications if they were smokers, bruxers or had diabetes. With splinted crowns, the patients had more issues with adjacent tissues if they were a bruxer, a diabetic, and interestingly, a non-smoker. As mentioned previously, cigarette smoking has a negative effect on early bone tissue response around implants, so it can be assumed that it may have detrimental effects on adjacent tissues as well (Bezerra et al., 2016). Smoking is often cited in literature as a risk factor in soft tissue healing and periodontal health, however it should be mentioned that it did not significantly influence the approximal bone resorption of the teeth adjacent to single-tooth implants (El Askary et al., 2007; Krennmair et al., 2003). In a study by Park et al. looking at the long-term outcomes of adjacent and antagonistic teeth after implant

restoration, they found that there was a significant difference in the treatment rate of adjacent teeth between smokers (25.3%) and non-smokers (12.3%) (Park et al., 2021). In many studies, the relationship between caries and periodontitis and smoking has been established in natural teeth, and the study by Park and colleagues implies that caries were the cause of adjacent teeth complications in their study (Park et al., 2021; Nobre & Malo, 2017). They also found that smokers had a lower level of dental knowledge and a high proportion of poor oral hygiene (Park et al., 2021). To be eligible for a dental implant at the dental college, patients must have gone through smoking cessation, hygiene appointments and implant consultations so it is unlikely that these patients had decreased dental knowledge or poor oral hygiene upon implant placement. It could be that the adjacent teeth were already pre-disposed to complications before the implant placement due to the patient being a current or former smoker. The interesting finding of non-smoking patients with splinted crowns having experienced more complications than smokers could be attributed to the fact that there were a higher proportion of non-smokers compared to smokers with splinted crowns, and that they are more difficult to access for hygiene.

Regarding diabetes, both single-unit and splinted crowns had more complications in adjacent teeth in diabetic patients compared to non-diabetics. Endocrine systemic diseases should be approached with caution because 75% of patients with uncontrolled diabetes exhibit increased alveolar bone loss and inflammatory gingival changes that may negative affect osseointegration and possibly adjacent tissues (El Askary, 2007). It was found that diabetic patients experienced more infection in clean wounds than non-diabetics and this is thought to be due to thinning and fragility of the blood vessels which

alters the blood supply in the area (El Askary, 2007). The diabetic status of the patients in this study, whether controlled or uncontrolled, are not known but it can be assumed as part of the implant work-up at the school, the patients would have received a medical consult in the case of uncontrolled disease as per the college protocol. When controlled, diabetes does not often result in a greater risk of failure than in the general population and it was found that along with smoking, it does not influence the approximal bone resorption of adjacent teeth (El Askary et al., 2007; Krennmair et al., 2003). In the study by Park et al., they found that patients with diabetes did not have a higher rate of treatment of adjacent teeth than those without diabetes (Park et al., 2021). However, diabetes has been proven to be a risk factor of periodontal diseases, and in the present study, periodontitis was a common complication in adjacent teeth of both single-unit and splinted implant supported crowns (Park et al., 2021).

The same pattern was found with bruxism, in that patients with single-unit and splinted crowns both had a higher average of complications with adjacent teeth if they were a bruxer. This could be one of the factors that came into effect leading to the increased number of debonded adjacent crowns due to unfavourable forces being exerted. In a study by Chrcanovic et al., bruxers presented with a higher implant failure and fracture rate than non-bruxers although without statistically significant differences (Chrcanovic et al., 2019). Although lacking significance, it does not agree with the results of studies showing that bruxism has a significantly negative effect on both the implant failure and fracture rates (Chitumalla et al., 2018; Chrcanovic et al., 2018). No explanation for this could be found in that study, however, the diagnosis of bruxism was based on self-report and/or a clinical examination and patients were not evaluated by

polysomnography (Chrcanovic et al., 2019). The same goes for patients at the dental college, wherein the cases of bruxism are often based on self-reporting or clinical examination, therefore it is not fully known whether this diagnosis of patients in the present study is accurate. As bruxism has been shown to have a negative impact on implants, these findings may be extrapolated to adjacent teeth, however, as there are minimal studies looking at the effects of bruxism on implant-adjacent teeth, it cannot be said with certainty.

As with most literature, there are some limitations in this study. The main limitation is that this study is its retrospective design, which inherently results in weaknesses such as gaps in information and incomplete records. Minimal information is given on the manufacturing process of the prostheses, choice of cements, selected occlusal schemes, oral hygiene status, elaborations on failures and complications, as well as pre-existing clinical and anatomical conditions of the patients. It is also not known whether the diagnosis of bruxism in patient is accurate due to the self-reporting nature and/or brief clinical exam. Additionally, as this study was not a prospective one and involved multiple clinicians, the treatment was not standardized. Recommendations include fine-tuning the templates in patient charts to document the exact reasonings behind prosthetic complications and failures and what will be done to correct them. Stressing the importance of proper note taking to students is vital to both future studies and dental practices.

Conclusion

Within the duration of the study, 17 (2.90%) single-unit crowns and 5 (5.43%) splinted crowns failed and warranted a replacement. Furthermore, 371 single-unit

(63.3%) and 46 splinted (50.0%) implant crowns were a complete success as they had no complications with the crown itself or adjacent tissues. Therefore, 215 single-unit (36.7%) and 46 splinted (50.0%) crowns endured some type of complication with the crown or adjacent tissues which may have led to its failure. The survival distribution of single-unit and splinted implant supported crowns was not statistically significant as they both presented with high success rates and minimal complications. Although some limitations and challenges were present, this study highlights the longevity and complications of implant supported crowns to improve their functionality and lifespan as well as to maintain the health of adjacent teeth.

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