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RESEARCH ARTICLE

A Seven Year Retrospective Comparative Study of All-Ceramic Crowns versus Metal Ceramic Crowns

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Abstract

Aims: This paper presents a comparative study of all ceramic crowns and metal ceramic crowns placed on premolars and molars by dental students at the University of Manitoba, Rady Faculty of Health Sciences, Dr. Gerald Niznick College of Dentistry. The aim of the paper is to show where improvement is required in the clinically acceptable crown. The objective was to determine if all-ceramic crowns or metal ceramic crowns placed on premolar and molar teeth would reveal a difference in final results treated in the hands of dental students.

Method: A systematic patient chart review was conducted and data was drawn from the Fixed Prosthodontic under-graduate recall criteria of the Dr. Gerald Niznick College of Dentistry.

Results: The study revealed that the all-ceramic crowns and metal ceramic crowns in both molars and premolars did not show a statistical significant difference in the average errors produced by the two methods.

Conclusion: While both types of crowns were clinically acceptable, molar all- ceramic crowns demonstrated problems with regards to shade and marginal adaptation.

Keywords: All ceramic crowns, metal ceramic crowns, premolars, molars, comparative analysis.

Introduction

An increasingly complex question dentists have to deal with is making the decision to provide a patient with a metal ceramic crown or an all-ceramic crown. The introduction of new material choices requires dentists to understand the success of these materials, this in turn enables them to educate their patients and help them to make informed decisions. Dentists need to be proficient in the fabrication of all dental types of dental crowns.

Dental crowns have been a treatment modality in dentistry since 1889. The choice of materials has traditionally been all metal or porcelain fused with a metal alloy. With the increased popularity of all ceramic crowns there are now additional choices for patients [1, 2].

The first application of use with porcelain consisted of porcelain overlaid onto platinum foil resulting in the porcelain jacket crown when Dr. Charles H. Land filed the first USA patent [1]. In 1962, M. Weinstein, S. Katz and A. B. Weinstein, filed their first patent on the use of gold alloys, that were compatible with the use of porcelain [1]. Metal ceramic crowns are crowns made with alloys overlaid with porcelain.[1] The experimentation with the coefficient of thermal expansion differences between porcelain and metals, in combination with oxide layers and vacuum firing allowed for a bond to be created which led to more stability in the crowns with less porcelain fractures [1].

Today, metal ceramic crowns are fabricated with a variety of metals with varying porcelain combinations. Crowns may be just a porcelain facing or include total coverage of the metal. Traditionally gold based alloys, which include platinum and palladium and other base metals have been used. The metals found in the ceramo-metal alloys are combined in such a ratio, that the coefficient of thermal expansion of the alloy is slightly greater than the coefficient of thermal expansion of porcelain. This minimizes stresses formed at the interface, and possess adequate mechanical properties such as strength, high modulus of elasticity, hardness and high-temperature strength.[1] With the increase in recent years of the cost of gold, platinum and palladium, the use of low gold, platinum and palladium containing alloys and the increase in the use of base metals have kept these restorations affordable to patients. The adaptability of high noble metal alloys at the margin have contributed to the ability to closely contour the crown margin to the tooth margin [3]. The overall color and translucency of metal ceramic restoration has continued be an esthetic problem.

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The increased esthetic demands and dental I Q of patients today have led to an increased demand for tooth coloured restorations [4-7]. The demand for more esthetic dentistry has driven the profession to develop more predictable all ceramic crowns. Dentists and their patients of today face a diversity of material choices [8, 9]. The increased demand for esthetic crowns fueled the research into all ceramic restorations, from the early days of all porcelain jacket crowns, that were prone to fracture, to the current lithium disilicate and zirconia based crowns [6, 7]. All ceramic crowns were initially piloted in the 1960s. Mica reinforced cast glass crowns existed in the 1960s, but due to fracture strength problems in posterior teeth they were not considered for routine use. The evolution of all ceramic crowns began with the attempt to strengthen conventional feldspathic ceramics with the addition of aluminous porcelain. Felspathic porcelain on its own is a very brittle material and only suitable to anterior regions of the mouth [10, 1]. The next development was glass-infiltrated alumina (InCeram alumina).[14] However, the increased stability created by the addition of alumina crystals led to a high opacity, therefore the material could only be used as a core material. The late 1980s brought the advent of CAD/CAM technology and with it the use of partially sintered alumina as a core material for improvement in strength and esthetic. The continued development of ceramics lead to the development of a bilaminar version of monophasic heat-pressed ceramics for use in single and limited multiunit restorations with lithium disilicate as a core that increased the strength without significant esthetic compromise.

More recently the densely sintered high strength ceramics such as lithium disilicate and zirconia have led to higher success rates in all ceramic restorations. Lithium disilicate crowns are composed of quartz, lithium dioxide, phosphoroxide, alumina, potassium oxide and trace elements. These powders are combined to produce a glass melt. Once the proper viscosity is achieved, the glass melt is poured into a steel mold and left to cool into ingots. This glass flow process produces minimal pores or other internal defects. This manufacturing process yields a shock-resistant glass ceramic due to low thermal expansion. The ingots are then milled using CAD/CAM (computer aided design/computer-aided manufacturing) procedures [11-15].

Lithium disilicate has the advantage of high edge strength vs. traditional glass ceramic materials; therefore they can be finished thinner without chipping. The low viscosity of heated ingots enables pressing to very thin dimensions enabling minimal preparation or no preparation veneers. The high translucency creates a “chameleon effect” that creates lifelike esthetics. The combination of high strength, high esthetics and ease of use and the potential one appointment visit vs. the multiple appointments required of a metal ceramic crown leads to highly desirable product. Patients now demand shorter and fewer appointments due to busy lifestyles. Lithium disilicate crowns increased in popularity with the marketing of CEREC crowns. CEREC or Cerec (Chairside Economical Restoration of Esthetic Ceramics or CEramic REContruction) is a system utilizing CAD/CAM restoration fabrication developed by W. Mormann and M. Brandestini. There are other in-office machining systems available such as the Planmeca PlanScan E4D system. The ability of these technologies to capture images of the patient’s teeth and save it as an accurate 3-D model allows for on site office milling of crowns [11]. This has made this procedure desirable from the patient stand point allowing a one-appointment visit with no temporization needed. The ceramic milling ingots are available as layered colors or can be layered with porcelain and stained and glazed in the conventional manner, the unsintered crowns can also be adjusted prior to final sintering. The recent introduction of Zirconia as a ceramic material for fixed prosthetics has been established in recent studies. Zirconia has better mechanical properties, is biocompatible and esthetic and can withstand both tensile and compressive stress [16].

The cementation method used is dependant on the type of material used for the prosthesis. Cements included zinc phosphate, glass ionomer, resin modified glass ionomer and adhesive-resin cements. Studies have shown that the type of cement used can affect the possible long-term outcome with respects to fracture resistance and adhesion of the restoration [12, 13]. Newer generations of resin luting cements have made the use of ceramic crowns a more predictable process with higher success rates.

This paper explores how well dental student’s fabricated all ceramic crowns and metal ceramic crowns survive. The analysis will ultimately demonstrate where students need further improvement to achieve highly esthetic and functional results clinically. The aim of the paper is to show where there is a need for improvement in the clinically acceptable final product. The objective was to determine if all ceramic crowns (ACC) or metal ceramic crowns (MCC) placed on premolars and molar teeth would reveal a difference in final results treated in the hands of dental students.

Materials and Methods

A systematic patient chart review was conducted of charts from 2007 to 2014 of all ceramic crowns (ACC) and metal ceramic crowns (MCC) placed on premolars and molars treated by third and fourth year dental students at the University of Manitoba, College of Dentistry. The inclusion criteria was single tooth supported crowns placed on premolars or molars in the maxillary or mandibular arches. This study did not differentiate the different cement used under the restoration. The exclusion criteria are all crowns placed in the maxillary or mandibular arches in the anterior regions, as were any crowns placed on implants at any site intraorally. All crowns used as fixed partial denture abutments were also excluded. Permission to use the accumulated data was obtained for all patients included in the study as required by the University of Manitoba Health Research Ethics Board.

The College of Dentistry utilizes the “AxiUm” clinical management program for under-graduate clinic record keeping. An AxiUm search was undertaken to seek out all ceramic and metal ceramic crowns and cross-match their

location. The all ceramic crown data search dated back to 2007 due to the limited number of such restorations done by the students. The metal ceramic crown data search only dated back to 2013 to allow for a balanced sample size. Student clinicians are required to recall all crowns post insertion. A randomized chart review was done using the student data collected. Where there was inadequate data charted regarding the recall information, the patients were contacted and seen by the principle investigator. All examinations were conducted subjectively by the students and the investigator and done only using visual examination with a mirror, dental explorer, dental floss and articulating paper.

Factors examined were based on, but did not include all of the College of Dentistry, Fixed Prosthodontics Recall criteria for crown recalls. The criteria examined included: patient gender, prosthesis tooth number, and prosthesis type, for the purpose of data separation. The clinical exam evaluated tooth sensitivity specifically to hot, cold, sweet/acid, biting pressure, and gingival sensitivity. Duration of the sensitivity was examined as immediate relief, < 1 minute, > 1 minute. Prosthetic defects examined included, proximal silhouette: over or under contoured, vestibular silhouette: over or under contoured, polish or glaze: excessive or insufficient, convex furcal restoration, marginal integrity failure, inappropriate occlusal anatomy, caries presence, overhangs presence, contact point: tight, open or rough, surface roughness, perforation of the restoration, porcelain fracture, marginal adaptation: insufficient (a thin margin), excessive, or open, inadequate color match, fremitus: present or not, and proximal contacts: good, tight, flat or open. Occlusal analysis was based on occlusion at maximum intercuspation, working side occlusion, balancing or non-working side occlusion and protrusive excursions.

Statistics Employed

The analysis was based on whether or not the average errors between the two methods, ACC or MCC on premolars and molars would be significantly different. The formula used to generate the test value was: $T= x_1-x_2/SpoolSQRT1/n_1+1/n_2$

$Spool = SQRT(n_1-1)s^2+n_2-1)s_2^2/n_1+n_2-2$

X = average errors

S = standard deviations

n = sample size

1 = ACC

2 = MCC

See stack sheets 1-4 (Tables 1-4).

Results

A total of 79 crowns were reviewed with 32 all ceramic crowns and 47 metal ceramic crowns. The analysis was based on whether the average number of errors between the two methods, ACC or MCC would be significantly different. The statistical analysis demonstrated that for molars the difference of 1.941 vs. 1.312 average numbers of errors was compared. Using the relevant formula a T value of 1.581 was produced. This T value was compared against a "critical value" in a T distribution critical values table to see whether there is

Table 1: Stack 1- MOLARACC

Stack 1- MOLARACC		
Patient #	**Tooth #**	**Errors**
1	16	1
2	47	1
3	36	4
4	46	3
5	46	3
6	47	0
7	16	1
8	27	0
9	36	2
10	46	2
11	16	1
12	46	3
13	47	2
14	46	1
15	46	4
16	36	2
17	36	3
AVG	1.941176	
STD DEV	1.248529	
Variance	1.558824	

Table 2: Stack 2- MOLAR MCC

Stack 2- MOLAR MCC		
Patient #	**Tooth #**	**Errors**
1	16	1
2	26	3
3	46	2
4	36	0
5	46	1
6	16	2
7	36	0
8	46	1
9	16	3
10	36	2
11	46	0
12	26	1
13	46	2
14	16	0
15	26	2
16	47	1
AVG	1.3125	
STD DEV	1.014479	

Table 3: Stack 3- Premolar ACC

Stack 3- Premolar ACC		
Patient #	**Tooth #**	**Errors**
1	15	6
2	24	0
3	25	1
4	14	2
5	14	2
6	25	1
7	25	0
8	15	1
9	14	4
10	15	3
11	25	0
12	15	0
13	24	1
14	14	0
15	24	1
AVG	1.466667	
STD DEV	1.726543	
Variance	2.980952	

Table 4: Stack 4 Premolar MCC

Stack 4 Premolar MCC		
Patient #	**Tooth #**	**Errors**
1	24	1
2	35	3
3	24	0
4	45	0
5	45	0
6	35	0
7	44	1
8	35	0
9	25	0
10	35	0
11	35	3
12	14	0
13	35	2
14	45	0
15	25	0
16	14	0
17	25	3
18	34	0
19	15	0
20	24	1
21	25	1
22	15	0
23	14	0
24	14	0
25	15	4
26	45	1
27	44	7
28	15	1
29	24	0
30	14	0
31	25	0
AVG	0.903226	
STD DEV	1.599059	
Variance	2.556989	

a significant difference or not. The T critical value is 1.697 and was chosen because the DOF (Degrees of Freedom) for our sample is 31 (n_1+n2-2) (smallest sample size- 1) and is at a 95% degree of confidence. This basically means that we are 95% confident in our result or that if this experiment was done infinite times, 95% of the time we would have this result. Our calculated value is 1.581 and that is smaller than our critical value of 1.697. This means that there is no statistically significant difference between the two averages. So we can say that the two methods produced no significant difference in generation of errors for the molars. This makes sense, since the average errors were 1.941 vs. 1.312, a somewhat reasonable difference given the small sample sizes, but it is very close to being within the standard deviations, that is why the 1.581 test value is not much lower than the 1.697 T critical value. It is different, but not critically different, and it only holds up at 95% degree of confidence. At the 99.9% confidence level the T critical value is 3.385 and the calculated T value is lower therefore there is no statistical difference and thus the methods can directly be compared.

Looking at the premolars, we see the T value of 1.091 is much lower than the 1.684 T critical value at 95% confidence levels. This means that there is not a significant difference in the average errors produced by the two methods. This calculation also makes sense, since the average errors between these two methods were 1.467 and 0.903 with the standard deviation being higher than the average. There was a lot more variance in the numbers (which you can see in the data, as errors ranged from 0-6 at times). This larger variance means it is harder to say for sure that those averages are statistically the same. So basically, ACC vs. MCC produced no significant difference in errors generated for molars or premolars at the 95% confidence levels. A comparison of ACC vs. MCC procedures regardless of premolar or molar shows calculated average errors of 1.719 and 1.043 respectively. The T value calculated is 2.031 with a degree of freedom of 77. The T critical value is 1.664 at 95% confidence levels, this means there is an overall significant difference at these confidence levels for the separate procedures.

The data examined on individual criteria provides results that are more relevant. Closer examination of the premolars showed that for the 31 MCCs examined, 6 cases reported post-operative sensitivity. Prosthetic defects involving proximal and vestibular silhouette involved 5 crowns. Insufficient glazing was found on 2 crowns and also surface roughness on 4 crowns. Inappropriate occlusal anatomy was found on 2 crowns and 2 cases had proximal contact problems, one was flat and one with an open contact. The largest amount of error in a single category involved inadequate color matching with 6 crowns. Fremitus was noted on 1 crown. The other criteria examined did not reveal any errors. Comparatively the examination of 15 ACC revealed the following: post-operative sensitivity was found only in 1 case. Prosthetic defects of over contoured proximal silhouettes in 2 cases, and an under-contoured proximal silhouette in 1 of the cases were seen. Vestibular silhouette showed 1 over contoured and 1 under

contoured case. An examination of the fit of the restoration is more revealing with contact problems in 3 cases with 2 too tight and one open contact, marginal fit and adaptation errors in 5 cases including one case of a marginal integrity failure, inadequate color match occurred in 6 cases. The other criteria examined did not reveal any errors

The molar data collected for the 16 MCCs showed only 2 cases of post-operative sensitivity. For prosthetic defects, 1 case of an over-contoured proximal silhouette and 1 each of over and under contoured vestibular silhouette. Marginal fit revealed 1 case of an overhang, 1 case of marginal insufficiency and 2 cases of inappropriate occlusal anatomy, proximal contacts had 1 flat contact, 2 tight contact and 2 open contacts. Inadequate color match occurred 4 times and fremitus in 1 case. The other criteria examined did not reveal any errors. The molar ACC cases are more revealing of problems as reflected in the aggregate data results. Sensitivity occurred in 3 cases, prosthetic defects involving under-contoured proximal silhouette occurred in 1 case, vestibular silhouette had 3 over-contoured cases. Marginal fit and adaptation revealed 1 open margin case, 1 case of marginal insufficiency and 2 cases of marginal excess, with 2 cases of surface roughness. Inappropriate occlusal anatomy occurred in 1 case and there were 5 cases of contact problems, with 4 tight contacts and 1 open-contact case. As in the previous cases there were 8 cases of inadequate color match, and fremitus was noted in 3 cases. The other criteria examined did not reveal any errors. This reflects the aggregated data collected more closely with the associated problems exhibited in the ACC category.

See Compiled Data Table (Table 5 and Table 6)

Discussion

This study utilized a small sample size, however literature reviews demonstrate these results to be consistent with studies of a larger sample size. The results are consistent with the literature that shows that metal ceramic crowns have better survival rates posteriorly and have the longest track record.[6] With the newer ceramic restorations available and the more precise milling accuracy available, the difference between the restorations should begin to be less significant.

Table 5: Compiled Data Table

			Premolar	Premolar	Molar	Molar
			MCC	ACC	MCC	ACC
Gender						
		Male	6	3	3	11
		Female	25	12	13	6
Sensitivity						
		Hot	2		1	
		Cold	2			2
		Sweet/ Acid	1			
		Biting Pressure	1		1	1
		Gingiva		1	1	
Duration Till Relief						
		Immediate				
		< 1 min				
		>1 min				
Prosthetic Defects						
	Proximal Silhouette					
		Over Contoured	2	2	1	
		Under Contoured		1		1
	Vestibular Silhouette					
		Over Contoured	2	1	1	3
		Under Contoured	1	1	1	
	Polish Or Glaze					
		Excessive				
		Insufficient	2			
	Caries					
	Convex Furcal Restoration					
	Overhang				1	

Table 6: Compiled Data Table

----------	----------	----------	Premolar	Premolar	Molar	Molar
----------	----------	----------	MCC	ACC	MCC	ACC
----------	Marginal Integrity Failure	----------	----------	1	----------	----------
----------	----------	Tight Contact		1		3
----------	----------	Open Contact		1	1	
----------	----------	Rough Contact				
----------	----------	Surface Roughness	4			2
	Inappropriate Occlusal Anatomy		2		2	1
	Perforation					
----------	Marginal Insufficiency (Thin)	----------		1	1	1
----------	Marginal Excess	----------		2		2
----------	Open Margin	----------		1		1
----------	Porcelain Fracture	----------				
----------	Inadequate Color Match	----------	6	6	4	8
----------	Fremitus	----------	----------	----------	----------	----------
----------	----------	Yes	1		1	3
----------	----------	No				
----------	Proximal Contact	----------	----------	----------	----------	----------
----------	----------	Good				
----------	----------	Tight		2	2	4
----------	----------	Flat	1		1	
----------	----------	Open	1	1	2	1
----------	----------	Lone standing				

Student clinician handling of the two types of crowns demonstrates the same problems found in the literature. The data shows that there is not a significant statistical difference in the results for the premolar or molar regarding ACC or MCC, in the hands of student dentists. However comparing the ACC vs. MCC data overall reveals clinical differences. With regards to molars there is a more significant difference in the data for ACC vs. MCC. The criteria examined revealed issues with sensitivity. As the sensitivity observed for all ACC crowns was of a fleeting nature, there were no crowns where patients complained of any lasting sensitivity. ACC molar prosthetic defects were of a concern. Many of the observed defects were not corrected properly. Crown contacts, marginal fit and color in the molars appeared to be an issue. The MCC crown margin is more closely adapted clinically than the ACC crown margin to the tooth. Additionally, although students receive the ACC crowns in the unsintered state to allow for adjustments, contacts and marginal fit are still a concern even after adjustments are made. Examination of the data in this manner reveals that students have a more difficult time controlling factors generated by the external dental labs and the milling process of the CAD/CAM crowns. Students have more difficulty in shade selection and staining and glazing the crowns as evidenced in the larger amount of inadequate color matches in all the crowns examined, both ACC and MCC premolars and molars. Clinically, the inability to select restoration shade and properly stain and glaze a crown is not as important as the marginal fit of the crown. The long- term success of a restoration depends upon the restoration not being compromised with caries. The poor marginal fit of a crown subjects the tooth to an increase in caries susceptibility. The color of a crown is important esthetically, but this is subject to the patient's perception of beauty. Ultimately, the patient is mostly concerned with their perceptions of the esthetics and the comfort of the crown during mastication. Patients were not as observant of the other criteria examined, even though from a teaching standpoint the criteria reviewed required students to examine these areas. One must also keep in mind that in a teaching setting, students are exposed to varied opinions from staff members and that there is significant subjectivity involved. The final clinical inspection by instructors and self-grading by the students reflects that clinically acceptable standards are met, however there still remains areas for improvement. The choice of an all-ceramic crown or metal-ceramic crown is clinically acceptable in both the premolar and molar sites. Student clinicians must ultimately present the pros and cons of the restoration to the patient and the final decision rests with the patient.

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Conclusion

The comparison of all ceramic crowns vs. metal ceramic crowns in the premolars and molars placed by student clinicians revealed the most problems with all ceramic crowns on molars. Based on the research data collected on the crowns placed by student dental clinicians, the results show that even though all the work was judged to be clinically acceptable, patients accepted the prosthesis that was fabricated even if there were still minor problems noted. The most significant problems were noted with color of the final restoration in both the ACC and MCC categories both in the premolars and molars. The marginal fit on the ACC molars were also noted to be an issue with open and poorly adapted margins being observed. The advent of newer precision milling with updated CAD/CAM machines should ensure that future all-ceramic crowns have fewer marginal adaptation problems.

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