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Abstract

Introduction

The process of restoring a tooth with a crown leaves many opportunities for pulpal irritation. The objective of this study was to identify and analyze the factors that contribute to the incidence of nonsurgical root canal therapy (NS-RCT) after the delivery of single-unit full-coverage restorations.

Methods

Insurance claims from 88,409 crown placements in the Delta Dental of Wisconsin insurance database were analyzed from the years 2008–2017. The Cox regression model was used to analyze the effect of the predictor variables on the survival of the tooth. Untoward events were defined as NS-RCT, tooth extraction, retreatment of root canal, or apicoectomy as defined by the Code on Dental Procedures and Nomenclature.

Results

Of 88,409 crowns placed, 8.97% were complete metal, 41.40% were all ceramic, and 49.64% were porcelain fused to metal (PFM). The probability of survival of all teeth with crowns placed was 90.41% after 9 years. NS-RCT was the most common untoward event. PFM crowns exhibited a higher rate of untoward events than complete metal crowns and a lower rate than all-ceramic crowns. Crowns placed on individuals 50 years of age and younger had higher rates of untoward events than those placed on individuals ages 51 years and older.

Conclusions

The risk of endodontic treatment after the placement of crowns is low. This risk increases with the placement of all-ceramic or PFM crowns and as the age of the patient decreases.

Key Words

Crown, endodontics, full coverage, insurance, root canal, root canal treatment

Significance

The processes involved in crown synthesis and delivery present many opportunities for pulpal irritation. The present study uses an insurance database to evaluate the relationship between factors such as crown material, patient age and provider type, and pulpal health.

For centuries, full-coverage restorations have been used to support and protect teeth after extensive caries removal, root canal therapy, or cracks. Crowns have become routine procedures for dental practitioners, and much research and development have been directed toward making these procedures more convenient for the patient, faster to complete, and have more predictable outcomes1.

However, the procedure to prepare a tooth for a crown and subsequently restore it leaves many opportunities for pulpal irritation. Crown preparations open dentinal tubules to the oral environment, allowing a pathway for microbes to enter the pulp chamber2. This problem may be exacerbated by ill-fitting provisional crowns, which can expose tubules for days to weeks until the final crown has been synthesized. Excessive heat generated from high-speed handpieces can inflict irreversible damage to the pulp tissue3, 4, 5. Other irritants such as desiccation, cements, or marginal leakage can impact pulpal health as well6, 7, 8, 9, 10. Additionally, teeth undergoing crown procedures often have preexisting conditions that contribute to pulpitis. These can include caries, previous restorative procedures, and cracks3.

Teeth presenting with symptomatic irreversible pulpitis during the provisional restoration period or after crown placement are not uncommon. Although past studies have shown that crowned teeth have a probability of 8%–

15.6% of pulpal pathology after 10 years, these studies were limited by small sample sizes and variable follow-up periods11,12. Goodacre et al13 found that younger age and a greater amount of coronal tooth destruction were significant predictors of root canal therapy after crown placement. However, further corroboration of these findings is limited.

To further evaluate the incidence of root canal therapy after crown placement and related predictors, an insurance database study was completed. This type of study provides a real-word evaluation of treatment being rendered in a private practice environment and supplies a large population to garner meaningful results. Delta Dental of Wisconsin provided electronic insurance claims records and enrollment data encompassing a 10-year period from 2008–2017. These claims were analyzed to predict survival rates for individual teeth after receiving full-coverage restorations. Variables such as patient age, tooth location, and crown material were examined to define predictors for adverse events.

Materials and Methods

The data for this study were obtained from the electronic insurance enrollment and claims database for Delta Dental of Wisconsin. The database contained claims data representing 13,329,249 patient encounters between January 1, 2008, and December 31, 2017. From the data set, 88,409 patients who underwent full-coverage crown deliveries were identified based on the Code on Dental Procedures and Nomenclature (CDT) codes for full-coverage crown delivery. CDT codes are used to properly and uniformly document dental treatment procedures in patients' health records and to process insurance claims.

All-ceramic crown (D2740), porcelain fused to metal (PFM) crown (D2750, D2751, and D2752), and complete metal (D2790, D2791, and D2792) crown codes were identified as initiating events. Teeth that had root canal treatment performed before crown placement were excluded from the analysis. Teeth that received crowns within the first 12 months of the time period studied or within 12 months of the start of their insurance coverage were also excluded. This was done to eliminate teeth that may have had root canals performed just before the start date of the available data set or the initiation date of insurance coverage for a specific individual. Untoward events were defined as having initial root canal therapy (D3310, D3320, and D3330), extraction (D7140 and D7210), endodontic retreatment (D3346, D3347, and D3348), or apicoectomy (D3410, D3421, and D3425) as defined by CDT codes. Treatments were determined successful until an untoward event or a lapse in the patient's enrollment status occurred.

For each encounter, information was collected regarding crown material, age of the patient, location of the tooth, and type of provider placing the crown. Crowns were divided based on the type of material into 3 groups (ie, all-ceramic crowns, PFM crowns, and complete metal crowns) as determined by the CDT code. Patients were divided into 6 groups based on their age: under 30 years, 31–40 years, 41–50 years, 51–60 years, 61–70 years, and 71 years and older. Location of the tooth consisted of groups of anterior teeth, premolar teeth, and molar teeth. Provider type included groups of general dentists, prosthodontists, and “other” providers as defined by the Delta Dental database. The category of “other” consisted of all the providers not categorized as prosthodontists or general dentists.

Data were analyzed using SAS 9.4 software (SAS Institute Inc, Cary, NC). Survival time was taken from the time of crown placement to the time of an untoward event, and the loss of continuous dental coverage was treated as censoring. The effect of predictors on tooth survival was analyzed. Hazard ratios were calculated using a univariate Cox proportional hazards regression model. A robust sandwich variance estimate was used to adjust for potential correlation because of multiple crowns in the same individual. The variable of tooth location did not satisfy the proportional hazard assumption in the model, and, therefore, analysis was stratified on tooth location. Kaplan-Meier curves were plotted for each variable, and log-rank tests were performed to identify

differences of Kaplan-Meier curves in each variable group. A significance level (alpha) of $P < .05$ was used throughout all analyses.

Results

After the exclusion criteria were applied to the data set, 88,409 teeth with crowns placed were identified. The vast majority of crowns placed were all ceramic (41.50%) or PFM (49.64%). Complete metal crowns only represented 8.97% of all crowns placed. General dentists placed almost all of the crowns, with prosthodontists and "other" providers constituting the remaining 1.23% of crown providers. Over half of the patients receiving crowns were between the ages of 51 and 70 years. Molar teeth represented 75.39% of the teeth being crowned followed by premolars (20.52%) and anterior teeth (4.09%) (Table 1).

Table 1. A Descriptive Summary of Initiating Events Based on Key Predictors

Variable	Number of crowns	Percentage
Crown material		
Complete metal	7834	8.87
All ceramic	36,692	41.50
PFM	43,883	49.64
Provider type		
General dentist	87,318	98.78
Prosthodontist	745	0.84
Other	346	0.39
Age group		
Under 30 y	2472	2.80
31–40 y	7269	8.22
41–50 y	15,862	17.94
51–60 y	30,317	34.29
61–70 y	27,377	30.97
71 y or older	5108	5.79
Tooth location		
Anterior	3617	4.09
Premolar	18,144	20.52
Molar	66,648	75.39

PFM, porcelain fused to metal.

Of the 88,409 teeth that were crowned, 4.82% of teeth underwent an untoward event during the time period studied. Of these 4259 teeth that underwent an untoward event, 72.41% of events were primary root canal therapy. Apicoectomies and nonsurgical root canal retreatments only constituted 5.40% of all untoward events, and extractions accounted for the remaining 22.19% of events. The complete summary of untoward events with respect to crown material and patient age is provided in Table 2.

Table 2. A Descriptive Summary of Untoward Events Based on Crown Material and Age of Patient

Variables	Outcome				*P* value
	Total, *N* = 4259 (row %)	**Extraction, *n* = 945 (row %)**	**Root canal, *n* = 3084 (row %)**	**Surgery or apicoectomy or retreatment, *n* = 230 (row %)**	
Crown material					<.001∗
Complete metal	326 (100.0)	104 (32.7)	212 (66.7)	10 (3.1)	

All ceramic	1505 (100.0)	267 (18.4)	1166 (80.3)	72 (4.8)	
PFM	2428 (100.0)	574 (24.7)	1706 (73.5)	148 (6.1)	
Age group					<.001∗
Under 30 y	112 (100.0)	15 (15.0)	82 (82.0)	15 (13.4)	
31–40 y	427 (100.0)	67 (16.6)	326 (80.7)	34 (8.0)	
41–50 y	941 (100.0)	155 (17.4)	721 (80.7)	65 (6.9)	
51–60 y	1442 (100.0)	301 (21.7)	1070 (77.1)	71 (4.9)	
61–70 y	1102 (100.0)	310 (28.9)	755 (70.3)	37 (3.4)	
71 y or older	235 (100.0)	97 (41.8)	130 (56.0)	8 (3.4)	

PFM, porcelain fused to metal.
∗Chi-square test.

The Cox regression model results compared survival times of teeth based on the variables studied. Larger hazard ratios equate to a greater likelihood of an untoward event in 1 variable compared with another variable (Table 3). Tooth location did not satisfy the proportional hazard assumption in the regression model, and, therefore, analysis was stratified with respect to tooth location.

Table 3. Hazard Ratios and Confidence Intervals for Variables

Description	**Hazard ratio**	**95% confidence interval**		***P* value**
Crown				
Complete metal vs PFM	0.73	0.65	0.82	<.001
All ceramic vs PFM	1.09	1.03	1.17	.0081
Provider				
Prosthodontist vs general dentist	1.10	0.80	1.52	.5525
Other vs general dentist	1.55	1.07	2.23	.0198
Age group				
Under 30 y vs 51–60 y	1.38	1.14	1.67	.0014
31–40 y vs 51–60 y	1.45	1.30	1.61	<.0001
41–50 y vs 51–60 y	1.30	1.19	1.41	<.0001
61–70 y vs 51–60 y	0.89	0.83	0.97	.0049
71 y or older vs 51–60 y	0.94	0.82	1.08	.3251

PFM, porcelain fused to metal.

Complete metal crowns have a hazard ratio of 0.73 when compared with PFM crowns, indicating that they had a 27% lower hazard rate ($P < .0001$). All-ceramic crowns have a hazard ratio of 1.09 when compared with PFM crowns ($P < .01$). There was no significant difference between the survival rates of teeth treated by prosthodontists compared with those treated by general dentists. When analyzing patient age, the interval from 51–60 years of age was used as a reference group. Groups 30 years and under, 31–40 years, and 41–50 years of age all had significantly higher hazard rates than the group from ages 51–61 years. The group consisting of patients 61–70 years of age had significantly lower hazard rates than the group 51–60 years of age. There was no significant difference in hazard rates when comparing the age groups 71 years and older with 51–60 years (Table 3). The estimated survival of all crowns drops from 97.3% after 1 year to 90.4% after 10 years. The overall probability of survival for all teeth with crowns is provided in Table 4.

Table 4. Overall Estimates for Survival of Teeth with Crowns

Time in years	**Number at risk**	**Observed events**	**Survival probability**
1	62,989	17	.9727

2	48,300	5	.9595
3	36,587	0	.9492
5	20,379	1	.9322
9	4087	0	.9041

Figure 1 shows the cumulative incidence of the first untoward event occurring over time after placement of a single-unit crown. Plots were created to display survival rates between variables, including crown material, tooth location, provider type, and age of the patient (Figs. 2 and 3). Significant differences were observed in survival rates with respect to age groups, tooth location, and crown material ($P < .0001$).

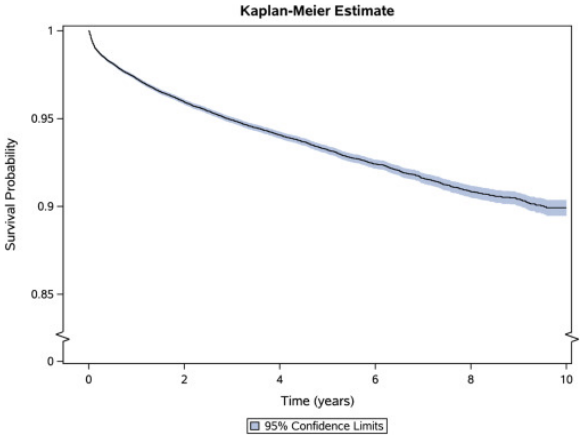

Figure 1. Survival estimates of all teeth after crown placement.

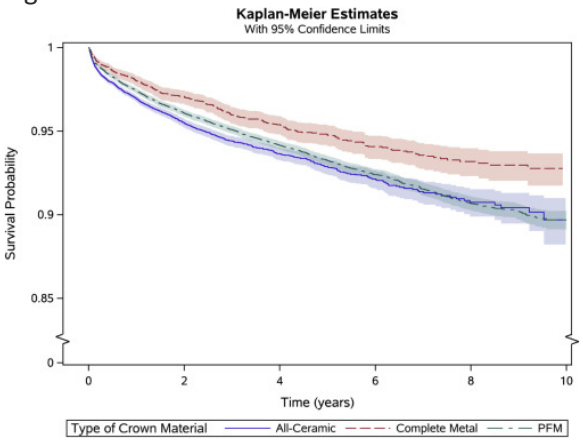

Figure 2. Survival estimates of all teeth after crown placement based on crown material.

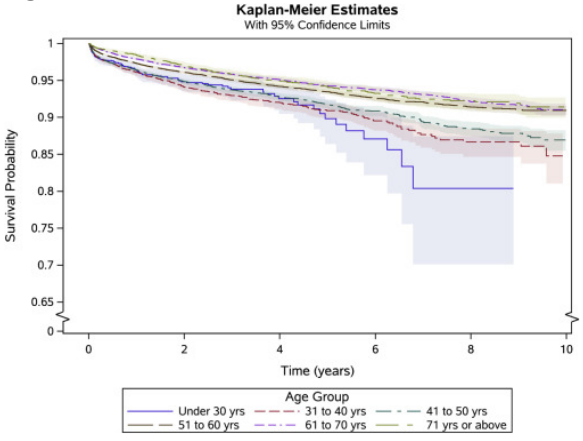

Figure 3. Survival estimates of all teeth after crown placement based on patient age.

Discussion

The primary objective of this study was to identify variables affecting the likelihood of endodontic intervention after placement of a full-coverage, single-unit restoration. By using the Delta Dental of Wisconsin insurance database, a substantial number of records were available for analysis, contributing power and meaning to the results.

To more closely approximate a population of teeth that had intact pulpal tissues before the placement of a crown, 2 exclusion criteria were applied to our data. The first was to eliminate any tooth in which endodontic therapy had been performed before placement of the crown. This was only effective for teeth that had the procedure completed during the 10-year span of our insurance coverage. Teeth with crowns placed within the first year of the coverage period were also excluded. This eliminated teeth that had recently undergone endodontic therapy just before the data set was made available for analysis and received full-coverage restorations during the data set as a result.

Even with these exclusion criteria, some endodontically treated teeth were inevitably included in the study. This can be confirmed by the few teeth that had untoward events consisting of endodontic retreatments and surgeries (Table 3). In time-to-event analyses, such as a survival analysis, decisions on the inclusion or exclusion of study subjects cannot be made based on future events, and, therefore, these data points must remain in the data set in order for statistical analysis to be accurate. Removing these events would result in a biased sample of teeth undergoing untoward events. However, retaining these data points allows calculation and examination of their impact on the overall population. Fortunately, only 5.45% of all untoward events consisted of treatments that would suggest root canal therapy before crown placement, indicating that the inclusion of this group is unlikely to have a major impact on the overall results.

Similarly, extractions were included as untoward events because of this same principle as well as the unavailability of clinical information that may provide insight as to the prognosis of a tooth. Unfortunately, there are many justifications for tooth extraction, and there is no way to distinguish teeth that are extracted because of pulpal pathology from teeth that are extracted for other reasons with the given insurance information. Standardization of providers and understanding rationale for treatment are also impossible with a retrospective insurance-based study. Although 1 provider may perform nonsurgical root canal therapy (NS-RCT) on a tooth with pulpal pathology, another may extract the same tooth in favor of an implant. Even with the inclusion of extractions and endodontic retreatments as untoward events, the overwhelming majority (72.41%) of all untoward events consisted of initial NS-RCT.

There are certain limitations of using insurance-based studies. Patient diversity is limited because only patients living in Wisconsin with Delta Dental of Wisconsin insurance were included. Individuals with private dental insurance may potentially present with contrasting outcomes compared with uninsured individuals because of differences in access to care and patient expectation. Correspondingly, providers of crowns were limited to only those who are contracted under the Delta Dental network.

This study also depends on the accuracy of coded procedures because erroneous codes would lead to a misrepresentation in data and inaccurate results. Other factors that may impact pulpal health were not available for analysis, such as remaining dentin thickness, previous restorations, type of handpiece used, amount of water spray used, marginal finish line design, and pulpal status before crown preparation. Thus, it is impossible to control for these variables. Coding for NS-RCT is the only way we are able to confirm the presence of pulpal disease within our data set. This creates another limitation because there is likely a small population of teeth

that exhibited pulpal pathology that did not undergo NS-RCT as well as teeth that underwent NS-RCT for restorative reasons instead of biologic reasons.

Regardless of these limitations, this is the first large-scale study designed to identify factors contributing to the likelihood of NS-RCT after crown placement. Of the 88,409 teeth that were crowned, 4.8% teeth underwent an untoward event. The 10-year prediction of survival reaches 90.41%. This value is comparable with past studies despite varying follow-up times and inclusion criteria11, 12, 13, 14, 15, 16, 17. Cheung et al11 similarly followed 284 single-unit PFM crowns over 6 months–14 years and found that 15.9% had endodontic involvement at the time of recall. The survival probabilities from that study were estimated to be 84.4% after 10 years and 81.2% after 15 years.

In total, 87,318 of crowns in this study were placed by general dentists, which equated to 98.77% of all treatments. The remaining providers included categories of prosthodontists and "other," which accounted for just 0.84% and 0.39% of the total treatments, respectively. Results from the log-rank test indicate that there are no significant differences between the survival rates of teeth between these 3 groups (Figs. 2 and 3).

The majority of teeth receiving crowns were molars, constituting 75.39% of the teeth examined. This was followed by premolars (20.52% of teeth examined) and anterior teeth (4.09% of teeth examined). This variable did not satisfy the proportional hazard assumption for the Cox regression analysis, which states that the ratio of the hazards for 2 individuals is constant over time. This suggests that the variable of tooth location does not make a linear contribution to the survival model. Therefore, no results comparing the survival rates of teeth with respect to tooth location could be determined. Further analysis was stratified based on tooth location.

The analysis of crown material was divided into 3 categories: complete metal, PFM, and all ceramic. This was a natural division because the CDT codes for crowns fall into these 3 classifications. Furthermore, these 3 classes of full-coverage restorations display unique properties that are specific to each group, such as depth of crown preparation and production technique. Stainless steel crowns were not included in this study because there are few indications for the use of prefabricated stainless-steel crowns as definitive restorations on permanent teeth.

Complete metal crowns represented just 8.86% of all crowns placed. PFM crowns represented 41.5% of crowns, and all-ceramic crowns represented the remaining 49.64% of crowns. This is likely because of increasing demands for esthetic dentistry. Cox regression analysis showed a significant difference in the hazard rates of these materials. PFM crowns have approximately a 27% higher hazard rate than complete metal crowns, and all-ceramic crowns have approximately a 9% higher hazard rate than PFM crowns. Interestingly, these hazard ratios increase with the amount of tooth structure removal indicated for each crown material. This is in contrast with a previous systematic review by Goodacre et al13, which reported lower rates of failure associated with all-ceramic crowns.

The age of the patient at the time of crown delivery was also analyzed. Over 65% of patients had crowns delivered when they were between the ages of 51–70 years old, whereas very few patients had crowns placed who were under the age of 30 and over the age of 71 years. A higher percentage of patients aged 71 and older who had crowns placed experienced extraction as an untoward event. This is likely because of the increased likelihood of fracture, the increased number of restorations, and the higher caries rate in elderly populations, leading to an increased possibility of nonrestorable teeth18.

Although patients aged 30 years and younger were least likely to have a crown placed, they also had the highest rates of failure after crown placement than any other age group. In general, the Cox regression results showed that younger individuals were at an increased risk for an untoward event after crown placement than older individuals. There could be multiple explanations for this pattern. Younger individuals generally have larger pulp spaces because of less deposition of secondary dentin, making pulpal tissues closer to the heat and desiccation

at the cavosurface margin during crown preparation19. It may also indicate a correlation between crowns at a young age and pulpal pathology; crowns placed in individuals of younger ages may be necessary because of poor oral hygiene, high caries risk, or unfavorable oral conditions that may also cause a predilection for pulpal pathology.

Kirakozova and Caplan17 previously found that younger age and greater extent of tooth destruction were significant predictors of root canal treatment after delivery of full-coverage restorations. The results of the current study confirmed these findings; however, without access to radiographs in the current study, tooth destruction was unable to be measured. However, assuming proper preparations were produced for each crown type, the present results indicate that crown materials that require more structure reduction are significantly more likely to undergo an untoward event.

The primary focus of this study was to identify variables that impact pulpal health after crown placement. Because hazard rates increase with lower age and with crown materials that necessitate deeper preparations, these results, in whole, suggest that remaining dentin thickness likely plays a large factor in the development of pulpal pathology after crown procedures. Additional research is needed to further understand the relationship between the variables discussed in this study as well as variables that are unable to be followed in an insurance database. Specifically, a large-scale, prospective study that accounts for pulpal diagnosis before crown placement, remaining tooth structure, and status of current restorations would allow a more thorough and accurate investigation of the factors contributing to this pathologic process.

Conclusion

Within the constraints and limitations of this study, the rate of untoward events after crown placement was low, with a 90.41% predicted survival rate after 9 years. Survival rate decreases as age at the time of crown placement decreases and with the placement of PFM and all-ceramic crowns. These findings suggest remaining dentin thickness at the time of crown preparation has a significant impact on the likelihood of untoward events after the crown has been delivered. Future research in this area should be focused on prospective studies to standardize procedure protocol and obtain results based on preoperative and postoperative pulpal diagnosis.

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The authors deny any conflicts of interest related to this study.

References

1 J.D. Bader, D.A. Shugars. **Summary review of the survival of single crowns.** *Gen Dent*, 57 (2009), pp. 74-81

2 D.H. Pashley. **Dentin-predentin complex and its permeability: physiologic overview.** *J Dent Res*, 64 (1985), pp. 613-620

3 K. Langeland, L.K. Langeland. **Pulp reactions to cavity and crown preparation.** *Aust Dent J*, 15 (1970), pp. 261-276

4 L. Zach. **Pulp lability and repair; effect of restorative procedures.** *Oral Surg Oral Med Oral Pathol*, 33 (1972), pp. 111-121

5 B.N. Cavalcanti, C. Otani, S.M. Rode. **High-speed cavity preparation techniques with different water flows.** *J Prosthet Dent,* 87 (2002), pp. 158-161

6 A.I. Hamilton, I.R. Kramer. **Cavity preparation with and without waterspray. Effects on the human dental pulp and additional effects of further dehydration of the dentine.** *Br Dent J*, 123 (1967), pp. 281-285

7 W.R. Cotton. **Pulp response to an airstream directed into human cavity preparations.** *Oral Surg Oral Med Oral Pathol,* 24 (1967), pp. 78-88
8 R.S. Tobias. **Pulpal response to a temporary crown and bridge material in ferret teeth.** *J Oral Rehabil,* 7 (1980), pp. 387-393
9 C.A. de Souza Costa, J. Hebling, R.C. Randall. **Human pulp response to resin cements used to bond inlay restorations.** *Dent Mater*, 22 (2006), pp. 954-962
10 G. Bergenholtz, C.F. Cox, W.J. Loesche, S.A. Syed. **Bacterial leakage around dental restorations: its effect on the dental pulp.** *J Oral Pathol*, 11 (1982), pp. 439-450
11 G.S. Cheung, S.C. Lai, R.P. Ng. **Fate of vital pulps beneath a metal-ceramic crown or a bridge retainer.** *Int Endod J*, 38 (2005), pp. 521-530
12 J. Valderhaug, A. Jokstad, E. Ambjørnsen, P.W. Norheim. **Assessment of the periapical and clinical status of crowned teeth over 25 years.** *J Dent*, 25 (1997), pp. 97-105
13 C.J. Goodacre, G. Bernal, K. Rungcharassaeng, J.Y. Kan. **Clinical complications in fixed prosthodontics.** *J Prosthet Dent*, 90 (2003), pp. 31-41
14 G.S. Cheung. **A preliminary investigation into the longevity and causes of failure of single unit extracoronal restorations.** *J Dent*, 19 (1991), pp. 160-163
15 S. Ericson, B. Hedegård, A. Wennström. **Roentgenographic study of vital abutment teeth.** *J Prosthet Dent*, 16 (1966), pp. 981-987
16 C.R. Jackson, A.E. Skidmore, R.T. Rice. **Pulpal evaluation of teeth restored with fixed prostheses.** *J Prosthet Dent*, 67 (1992), pp. 323-325
17 A. Kirakozova, D.J. Caplan. **Predictors of root canal treatment in teeth with full coverage restorations.** *J Endod,* 32 (2006), pp. 727-730
18 R. López, P.C. Smith, G. Göstemeyer, F. Schwendicke. **Ageing, dental caries and periodontal diseases.** *J Clin Periodontol*, 44 (Suppl 18) (2017), pp. S145-S152
19 S. Bernick, C. Nedelman. **Effect of aging on the human pulp.** *J Endod*, 1 (1975), pp. 88-94