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Retrospective evaluation of factors affecting long-term clinical performance of CAD-CAM laminate veneers

ABSTRACT

Purpose. The purpose of the study was to assess the clinical performance of CAD-CAM laminate veneers placed by a single operator and systematically evaluated for up to 10 years.

Material and methods. A total of 197 laminate veneers fabricated using either feldspathic ceramic (VMII) or lithium disilicate ceramic (EmaxCAD) were followed up to 10 years in 32 patients. Technical, esthetical, and biological findings of each restoration were evaluated using modified United States Public Health Service criteria. The survival and complication rates were assessed using Kaplan–Meier survival analysis and compared using the Log Rank test. Statistical significance was set at $p < 0.05$.

Results. The estimated Kaplan-Meier survival rate was 91.9% after the mean observation period. According to ceramic system used, the estimated Kaplan-Meier survival rate amounted to 92.7% for EmaxCAD and to 89.1% for VMII. Survival rates were significantly affected by the location of veneer according to Log Rank test ($p < 0.05$). A range of survival rates between 83.3% and 98.6% were observed based on the location of veneer.

Conclusions. CAD-CAM laminate veneers milled of feldspathic or lithium disilicate ceramics have comparable long-term survival rates. Oral positioning affects the survival of veneer. Veneers of incisors have higher survival rates than the veneers of maxillary canines and premolars.

INTRODUCTION

Increasing expectations of patients and clinicians for ideal dental esthetics have led the use of all-ceramic restorations more routinely for several clinical situations.¹⁻³ With their minimal invasive preparation design, sufficient esthetics and long-term survival rates; laminate veneers have been reliable alternatives to conventional all ceramic crowns.^{2,4,5} Ceramic laminate veneers are indicated for teeth with discoloration, malformation, rotation or diastemas when the other restorative options like bleaching or bonding are not possible or easy to provide sufficient esthetics in the long-term.³⁻⁵ Furthermore, there have been extensive research and development in the field of CAD-CAM systems and materials.⁵⁻⁷ Monolithic CAD-CAM restorative materials with different chemical compositions, microstructural features and crystalline contents have been introduced to provide clinicians a wide range of options.⁶⁻⁸ Due to their esthetics, biocompatibility and chemical stability; CAD-CAM restorative materials such as feldspathic ceramic, lithium disilicate, high-translucency zirconia and hybrid ceramics are indicated for the fabrication of laminate veneers.^{3,5-8} CAD-CAM technology is widely used for the production of veneers, as it reduces the number of clinical appointments and when compared to the conventional production technique, reduces the manufacturing time needed to produce all ceramic restorations.^{5,7}

In order to achieve long-term clinical success, there are key factors with the same degree of importance while restoring teeth with laminate veneers.⁹⁻¹⁵ The evolution of restorative materials and bonding systems as well as the preparation design and preservation of sound enamel are reported to affect the survival of restorations.^{11,16-18} Direct or indirect composite resins have been widely used as alternatives to all ceramic systems due to their advantages of easy luting, being repairable and cost effectiveness.^{11,18} However, a higher risk of failure and

lower survival rates were reported for direct composites when compared to ceramic systems.^{18,19} According to individual clinical trials; survival rates of ceramic laminate veneers ranged between 87-100% with observation periods ranging from 1 to 10 years while those of composite veneers ranged from 80% to 88% after 1-3 years observation.^{4,11,13-18} However, these studies are differing in terms of observation period, operator, study design or inclusion criteria. Therefore, the results are not easy to directly compare and should be interpreted carefully.

Especially long-term clinical studies are necessary to assess the effect of confounding variables such as restorative material type, oral positioning and observation period on the clinical performance of laminate veneers. The present retrospective study was based on this recognition and aimed to report the clinical performance of CAD-CAM laminate veneers placed by a single operator and systematically evaluated for up to 10 years. The null hypothesis is that type of restorative material and oral positioning of laminate veneer will not affect the survival rate or quality of survival.

MATERIAL AND METHODS

The study was designed to be retrospective and performed under the approval of institutional ethical committee (Reference number 2020/29-115131). The requirements of the Declaration of Helsinki were observed, and the informed patient consent forms were obtained to allow data evaluation of follow-up records. A total of 43 patients were assessed for eligibility. The study included 32 patients (24 females, 8 males, mean age of 30 ± 6.1 years) treated with a total of 197 laminate veneers and traced up to 10 years. Patients under 18 and over 70 years old with parafunctional habits, periodontal disease, systemic pathological conditions, smoking, non-vital teeth and poor oral hygiene were excluded. Vital anterior and posterior teeth (up to the second

premolar) without mobility, extensive enamel loss and malocclusion were included. The veneers were placed by the same operator following a standardized prosthodontic procedure at the Graduate Prosthodontic Clinic of Istanbul University Dental School.

The treatment was initiated with a diagnostic wax-up which was then used to perform a direct mock-up (Luxatemp; DMG) for esthetic, functional and phonetic evaluation. The esthetic analysis was also performed on the initial photographs and articulated plaster casts by taking into account each patient's esthetic expectations. Minimally invasive tooth preparation was planned individually after completing a full diagnostic evaluation including smile analysis, lip profiles, angle class, tooth proportions, inclinations, occlusal contact positions, overjet, overbite and anterior canine guidance.

The reduction of tooth substance was guided by a directly placed intraoral mock-up on which the preparation depths were marked. Design of preparation involved the incisal edge (Fig. 1). Teeth were prepared with an average tooth reduction amount of 0.4 to 0.7 mm on the labial surface with equigingival chamfer margins. Following the tooth preparation, temporary restorations were prepared (Luxatemp; DMG) and bonded after the teeth were spot-etched. All the laminate veneers were designed virtually and milled out via CAM system (Cerec InLab System; Sirona) using two different CAD-CAM restorative materials. Veneers were fabricated using either lithium disilicate (EmaxCAD, IPS emax CAD; Ivoclar Vivadent) or feldspathic ceramic (VMII, Vita Mark II; Vita Zahnfabrik). Finished restorations were checked for accuracy using try-in pastes. Marginal adaptation, esthetics, occlusion and proximal contacts were evaluated before adhesive cementation.

Prior to adhesive cementation, internal surfaces of veneers were etched with 5% hydrofluoric acid gel for 20 seconds (lithium disilicate ceramic) or 60 seconds (feldspathic

ceramic). Subsequently, the restorations were cemented under isolation using light cured resin cement (Variolink Veneer, Esthetic; Ivoclar Vivadent AG) following the manufacturer's instructions. After removing excess cement from the margins, both the palatal and buccal surfaces were light-polymerized for 40 seconds (Bluephase; Ivoclar Vivadent).

Following the cementation of veneers, post-treatment recalls were scheduled at 6 months for the first year and then annually for up to 10 years. The most recent recall visit was conducted in November 2021. At these sessions; technical, esthetical, and biological findings of each restoration were evaluated using modified United States Public Health Service (modUSPHS) criteria.²⁰ Management of any complications and professional dental prophylaxis were performed. Moreover, photographic records of each follow-up visit collected and then used for comparison with the initial photographs. Eleven patients dropped out the study due to lack of recent photographs during follow-up period. Data regarding the following assessments were recorded at the clinical examinations:

- Biological complications such as periodontal disease, tooth wear, postoperative sensitivity, caries, mobility, pain and loss of vitality.
- Technical complications such as fracture, debonding, chipping or changes in marginal integrity, proximal contacts or in the form of restoration.
- Esthetic complications such as marginal discoloration, uneven surface texture and color mismatch with the existing dentition.

Laminate veneers without any complications and no need for retreatment rather than maintenance were rated as successful. Veneers with minor required repairs, but no need for further intervention were rated as surviving. Veneers with major complications that are not

clinically acceptable and affecting the survival of restoration were rated as failure. Figure 2 shows clinical situation that is recorded as failure during clinical examination.

Statistical analysis was performed using a statistical software program (IBMSPSS Statistics, v21.0; IBM Corp). Descriptive statistics were performed on data to summarize sample characteristics. Continuous variables were expressed as mean values and standard deviations. The survival and complication rates were assessed using Kaplan–Meier survival analysis and compared using the Log Rank test. Survival rate was calculated from the cementation date of the veneer to the end of follow-up period. Hazard curves were generated to analyze different independent factors on the probability of failure over time ($\alpha=.05$).

RESULTS

A total of 197 laminate veneers were placed between 2011 and 2019 and followed up to 10 years in 32 patients. Thirty patients received more than 1 veneer. Distribution of laminate veneers according to location and placement year is presented in Tables 1 and 2. The mean observation period of surviving laminate veneers was 5.6 years (min: 2 years; max: 10 years). Overall survival probability of laminate veneers is presented in Figure 3. Of these, 9 failed because of debonding, 4 because of fracture, and 3 because of chipping. The estimated Kaplan-Meier survival rate for all the laminate veneers was 91.9% after the mean observation period.

According to material type used for the fabrication of laminate veneer, the estimated Kaplan-Meier survival rate amounted to 92.7% for EmaxCAD and to 89.1% for VMII (Fig. 4). In all, 16 veneers in 11 patients were considered as failure, 11 milled of EmaxCAD and 5 milled of VMII. There was, however, no significant difference in the survival rates between the material types ($p=.145$).

According to location, a range of survival rates between 83.3% and 98.6% were estimated (Fig. 4). Complication rates were significantly affected by the location of veneer according to Log Rank test ($p < .05$). Furthermore, the cumulative hazard curve shows the complication rate increased substantially between 4 and 8 years (Fig. 5).

DISCUSSION

Long-term clinical performance of CAD-CAM laminate veneers was evaluated in this retrospective study. Moreover, the effect of confounding variables such as restorative material type and location of veneer on the survival of restoration was investigated. The null hypothesis was partly rejected based on the results revealing significant correlation between the location of veneer and survival rate, while there was no significant difference in the survival rates between material types.

In spite of the frequent use of laminate veneers, there is a lack of studies regarding the long-term clinical performance of restorations. Providing complete standardization in the long-term clinical studies with ideal indications, treatment protocols, patient compliance and detailed evaluation criteria make this type of investigations complicated.^{3,5,9,13,21} In the present study, veneers were placed by the same operator, specialized in prosthetic dentistry and systematically followed up to 10 years using modified USPHS criteria which enables standardization and detailed evaluation of veneers overtime.^{13,14,20} Furthermore, the USPHS criteria is often used in clinical studies and reported to be practical for the comparisons.^{20,21}

Comparable survival rates for both of the CAD-CAM restorative materials were observed. Technical problems such as debonding and fracture were the main reasons of failure. The Kaplan-Meier survival analysis revealed an overall survival probability of 91.9%. According

to material type; the estimated Kaplan-Meier survival rate was 92.7% for EmaxCAD and 89.1% for VMII. These results are in agreement with the survival rates reported by the other long term clinical studies with observation periods ranging from 5 to 8 years and survival rates ranged between 76% and 98%.^{5,9-11,13-18,22} There are also studies reported comparatively higher survival rates of veneers in contrast with the present study.^{5,9,14,23} Especially, in the short-term clinical studies with an observation period less than 2 years, the obtained survival rates were higher and ranged between 98% and 100%.^{9,14,23} Differences in survival rates among the studies could be attributed to the differences in study design, inclusion criteria, material type and statistical methodology.^{2,21}

Type of failures varied between materials. All the fracture type failures occurred within VMII group revealing a higher risk of fracture than the EmaxCAD group of veneers. This finding could be explained by the structural differences between materials and denser crystals that are present in lithium disilicate ceramic which make the material more resistant against fractures.²⁴ The majority of failures observed in the present study was debonding (56.2%), followed by fractures (25%). Debonding and fractures are reportedly the most frequent reasons of failure for laminate veneers in scientific literature.^{3,5,10,14,22} In line with previous results; 9 laminate veneers failed because of debonding which were milled of EmaxCAD revealing higher susceptibility to debonding type failures than the veneers milled of VMII. Several studies have emphasized that the most frequent type of failure in veneers made of lithium disilicate ceramics is debonding.^{6,10,23} The bonding success might be affected by the differences in chemical composition and microstructure of the materials. Since the glassy phase is more dominant in the microstructure of VMII, bonding success could be expected to be higher.^{6,10,23,24} Similar to our findings, researchers concluded that the bonding strength is highly dependent on the chemical

composition and microstructure of the material.^{23,24} However, it is difficult to make direct comparisons among studies due to the differences in terms of study protocols, luting agents and follow-up periods.

In the present study, the location of laminate veneer significantly had an impact on the survival of restoration ($p < .05$). Lower survival rates that were observed for maxillary canines and premolars are revealing the importance of anterior canine guidance, occlusal contact points and elimination of excessive occlusal loads to provide successful restorations in the long-term.^{4,10,16} Studies regarding the effect of location on the survival of laminate veneers are limited and the obtained results are differing.^{22,23,25} Recently, Raif et al reported no significant effect of location in comparing maxillary and mandibular arches on the survival of veneers.²⁵ Although the effect was not statistically significant, higher failure rate for molar teeth was reported in their long-term retrospective study.²⁵ The sample size is critical and need to be large enough to have power to estimate projected longevity based on the location of veneer.²¹

Limitations of the present study include that there was not a large number of patients treated but had a large number of veneers. Also, the number of veneers applied in each patient differed, both singular veneers and close to full-arch veneers were applied limiting the evaluation of patient-related factors on the final outcome. The use of log rank test and Kaplan–Meier method seems reasonable for the patient cohort but limited for the statistical analysis of failure types. All the veneers were placed by the same experienced prosthodontist, making extrapolation to other clinicians with different skill levels or clinical settings difficult. Further clinical studies are necessary with a larger sample size and longer observation to clarify how the different parameters such as preparation design, bonding protocol and novel CAD-CAM material alternatives might influence the survival of restorations.

CONCLUSIONS

Within the limitations of this clinical study, the following conclusions were drawn:

1. CAD-CAM laminate veneers fabricated using feldspathic or lithium disilicate ceramics have comparable long-term survival rates.
2. Oral positioning affect the survival of veneer. Veneers of maxillary canines and premolars have higher complication rates than the veneers of incisors.

REFERENCES

1. Spitznagel FA, Boldt J, Gierthmuehlen PC. CAD/CAM Ceramic Restorative Materials for Natural Teeth. *J Dent Res* 2018;97:1082–91
2. Layton DM, Walton TR. The up to 21-year clinical outcome and survival of feldspathic porcelain veneers: accounting for clustering. *Int J Prosthodont* 2012;25:604–12.
3. Beier US, Kapferer I, Burtscher D, Dumfahrt H. Clinical performance of porcelain laminate veneers for up to 20 years. *Int J Prosthodont* 2012;25:79–85.
4. Edelhoff D, Liebermann A, Beuer F, Stimmelmayer M, Güth JF. Minimally invasive treatment options in fixed prosthodontics. *Quintessence Int* 2016;47:207–16.
5. Nejatidanesh F, Savabi G, Amjadi M, Abbasi M, Savabi O. Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers - a retrospective study. *J Prosthodont Res* 2018;62:462–7.

6. Imburgia M, Cortellini D, Valenti M. Minimally invasive vertical preparation design for ceramic veneers: a multicenter retrospective follow-up clinical study of 265 lithium disilicate veneers. *Int J Esthet Dent* 2019;14:286–98.
7. Sen N, Us YO. Mechanical and optical properties of monolithic CAD-CAM restorative materials. *J Prosthet Dent* 2018;119:593–9.
8. Li RW, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: state of the art. *J Prosthodont Res* 2014;58:208–16.
9. Morimoto S, Albanesi RB, Sesma N, Agra CM, Braga MM. Main Clinical Outcomes of Feldspathic Porcelain and Glass-Ceramic Laminate Veneers: A Systematic Review and Meta-Analysis of Survival and Complication Rates. *Int J Prosthodont* 2016;29:38–49.
10. Gurel G, Sesma N, Calamita MA, Coachman C, Morimoto S. Influence of enamel preservation on failure rates of porcelain laminate veneers. *Int J Periodontics Restorative Dent* 2013;33:31–9.
11. Gresnigt MMM, Cune MS, Jansen K, van der Made SAM, Özcan M. Randomized clinical trial on indirect resin composite and ceramic laminate veneers: Up to 10-year findings. *J Dent* 2019;86:102–9.
12. Olley RC, Andiappan M, Frost PM. An up to 50-year follow-up of crown and veneer survival in a dental practice. *J Prosthet Dent* 2018;119:935–41.
13. Layton D, Walton T. An up to 16-year prospective study of 304 porcelain veneers. *Int J Prosthodont* 2007;20:389–96.

14. Layton DM, Clarke M, Walton TR. A systematic review and meta-analysis of the survival of feldspathic porcelain veneers over 5 and 10 years. *Int J Prosthodont* 2012;25:590–603.
15. D'Arcangelo C, De Angelis F, Vadini M, D'Amario M. Clinical evaluation on porcelain laminate veneers bonded with light-cured composite: results up to 7 years. *Clin Oral Investig* 2012;16:1071–9.
16. Hong N, Yang H, Li J, Wu S, Li Y. Effect of Preparation Designs on the Prognosis of Porcelain Laminate Veneers: A Systematic Review and Meta-Analysis. *Oper Dent* 2017;42:197–213.
17. Alenezi A, Alsweed M, Alsidrani S, Chrcanovic BR. Long-Term Survival and Complication Rates of Porcelain Laminate Veneers in Clinical Studies: A Systematic Review. *J Clin Med* 2021;10:1074.
18. Coelho-de-Souza FH, Gonçalves DS, Sales MP, Erhardt MC, Corrêa MB, Opdam NJ, Demarco FF. Direct anterior composite veneers in vital and non-vital teeth: a retrospective clinical evaluation. *J Dent* 2015;43:1330–6.
19. Heintze SD, Rousson V, Hickel R. Clinical effectiveness of direct anterior restorations--a meta-analysis. *Dent Mater* 2015;31:481–95.
20. Bayne SC, Schmalz G. Reprinting the classic article on USPHS evaluation methods for measuring the clinical research performance of restorative materials. *Clin Oral Investig* 2005;9:209–14.

21. Schwendicke F, Opdam N. Clinical studies in restorative dentistry: Design, conduct, analysis. *Dent Mater* 2018;34:29–39.
22. Faus-Matoses V, Ruiz-Bell E, Faus-Matoses I, Özcan M, Salvatore S, Faus-Llácer VJ. An 8-year prospective clinical investigation on the survival rate of feldspathic veneers: Influence of occlusal splint in patients with bruxism. *J Dent* 2020;99:103352.
23. Aslan YU, Uludamar A, Özkan Y. Clinical performance of pressable glass-ceramic veneers after 5, 10, 15, and 20 years: A retrospective case series study. *J Esthet Restor Dent* 2019;31:415–22.
24. Bakir M, Bakir S, Bahsi E. Bond strength of ceramic or resin CAD-CAM laminate veneers. *Am J Dent* 2020;33:287–90.
25. Arif R, Dennison JB, Garcia D, Yaman P. Retrospective evaluation of the clinical performance and longevity of porcelain laminate veneers 7 to 14 years after cementation. *J Prosthet Dent* 2019;122:31–37.

TABLES

Table 1. Distribution of laminate veneers according to location.

NLV	8	10	15	15	18	18	14	16	10	8
Tooth	15	14	13	12	11	21	22	23	24	25
	45	44	43	42	41	31	32	33	34	35
NLV	4	6	7	7	7	7	7	7	6	4

NLV: number of restored teeth by laminate veneers.

Table 2. Distribution of laminate veneers by year.

Year placed	2011	2012	2013	2014	2015	2016	2017	2018	2019
NLV	6	16	9	41	18	32	53	12	10

NLV: number of restored teeth by laminate veneers.

FIGURES

Figure 1. Incisal view of teeth preparation.



Figure 2. Clinical situation recorded as failure



Figure 3. Kaplan-Meier survival curve for survival of Laminate veneers.

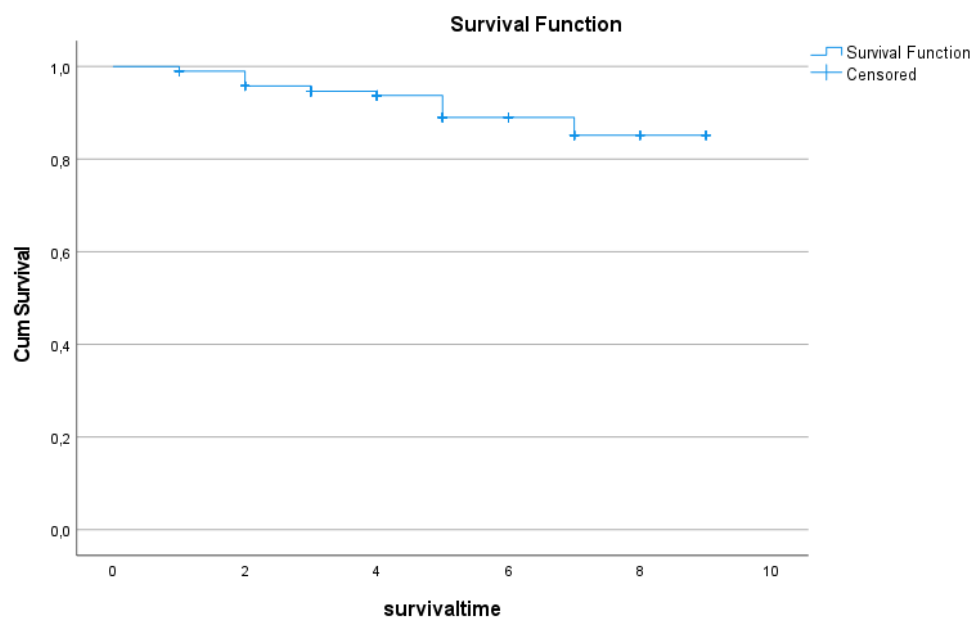


Figure 4. Kaplan-Meier survival curve of laminate veneers. A, based on material type; B, based on location. Emax CAD, IPS e.max CAD and VMII, Vitablocs Mark II. ManAnt, mandibular incisors; Mancanin, mandibular canines; Manpre, mandibular premolars; MaxAnt, maxillary incisors; MaxCanin, maxillary canines and MaxPre, maxillary premolars.

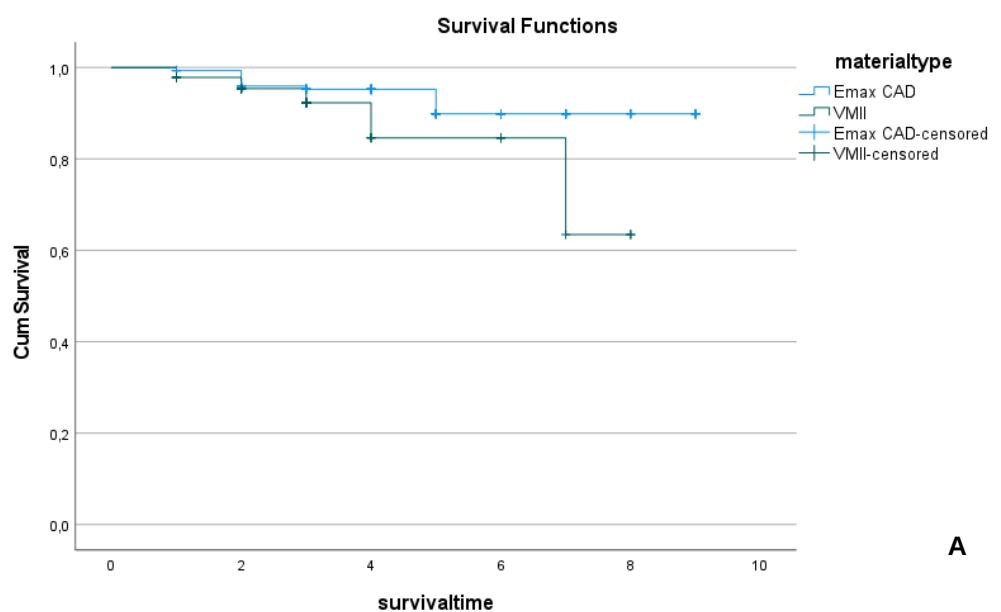
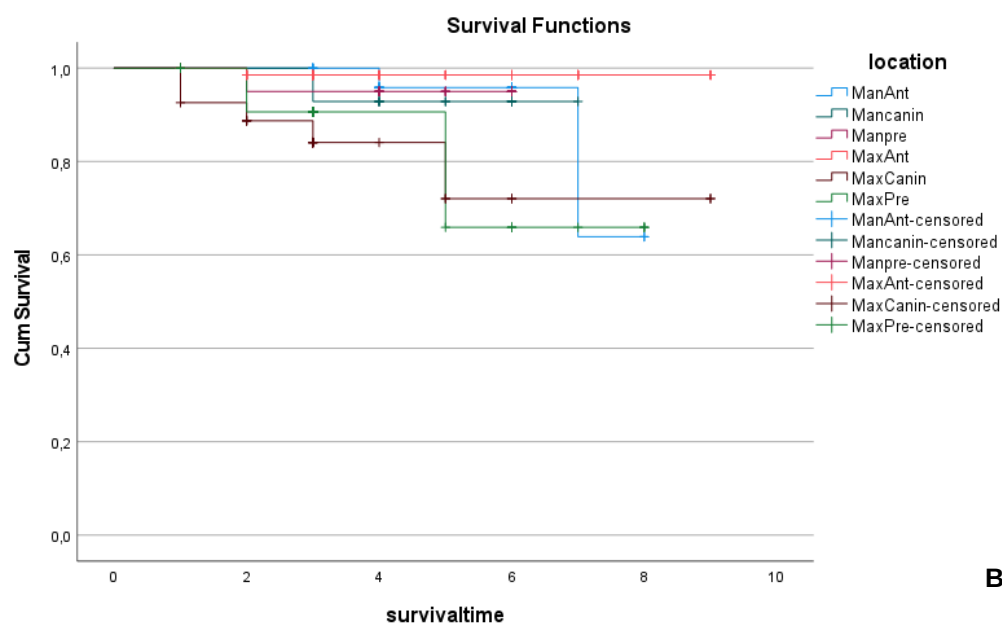
**A****B**

Figure 5. Hazard function for Laminate veneers.

