An *in vitro* comparison of the marginal adaptation and discrepancy of Stainless Steel Crowns

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A mini-thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Dental Sciences in Paediatric Dentistry at the Faculty of Dentistry University of the Western Cape

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KEYWORDS

Stainless steel crowns

Marginal adaptation

Marginal discrepancy

ABSTRACT

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Background: The benefits of restorative treatment are to remove cavities or defects, to restore function, maintain the arch integrity and to eliminate the progression of dental caries. The complexity of restorative treatment increases when the dental caries involves more than one surface of the tooth. Stainless steel crowns are considered to be the gold standard for multi-surface carious lesions in primary teeth. Despite the high success rate and cost-effectiveness of stainless steel crowns compared to other restorations, failure of stainless steel crowns were reported in some cases. The major causes of failure of stainless steel crowns are poor marginal adaptation and marginal discrepancy.

Aim: The aim of this study was to compare the marginal adaptation and discrepancy of stainless steel crowns (SSC's) around the tooth surfaces.

Method: An *in vitro* study was conducted using 15 stainless steel crowns from the same lot. A standard stainless steel crown preparation was prepared in the master typodont tooth. Fifteen standardized duplicated teeth were then prepared using this master typodont tooth. The cemento-enamel junction was prepared and demarcated with a 1 mm wide line, which would represent the contour of the CEJ. This was used as a reference line for the measurement of marginal adaptation and discrepancy. Stainless steel crowns were then placed over the duplicated teeth at equigingival extension, crimped and cemented with Ketac Cem Easymix *(3M ESPE).* The samples were then examined under a stereomicroscope at 100x magnification in order to measure the marginal adaptation and discrepancy. A total of forty-eight measurements per sample were taken every 2µm for marginal adaptation as well as for the marginal discrepancy. The digital camera attached to the stereomicroscope transferred the image to the computer software. A Vernier caliper was used to measure the marginal adaptation and discrepancy from the computer screen.

Results: The best marginal adaptation was reported on the lingual surface and it was statistically significant compared to other surfaces. Marginal discrepancy was reported on all surfaces. The buccal surface showed the least discrepancy and it was statistically significant compared to other surfaces.

Conclusion: The crown morphology of the primary tooth plays an important role in the marginal adaptation of the crown. To improve the adaptation of the crown, crimping of the crown margin is standard protocol for SSC placement to approximate the crown margin to the tooth surface. However, this study showed that a significant marginal gap still exists between the SSC and the tooth structure even after crimping. Additionally, the marginal discrepancies occur purely due to technical errors during the trimming procedure.

November 2017

DECLARATION

I hereby declare that *an in vitro comparison of the marginal adaptation and discrepancy of Stainless Steel Crowns* is my own work, that it has not been submitted before for any degree or examination at any university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Rasha Mahmood Abdelrahman Medhat

November 2017

ACKNOWLEDGEMENTS

I wish to acknowledge my gratitude to the following people for the assistance given to me in this research project.

Dr. R. Mulder, my supervisor, for his guidance, encouragement and support every day during the course of this study and for the great knowledge, time, and energy spent throughout my study. It was a great honour to be supervised by a supervisor like him.

Dr. N. Mohamed for the continuous guidance and support throughout my study.

May grateful thanks are also extended to **Mrs. R. Basson**.

Many thanks go to **Mr. M. Eldud** for his invaluable input and assistance in the statistical analysis.

DEDICATION

To my father who supported me to reach this level of education and couldn`t see this special day. May your soul rest in peace.

To my Mother who taught me to trust in Allah, believe in hard work and that so much could be done with little. She has shown me that if I want to succeed in anything, then I will have to give it my all.

To my lovely husband who has been a constant source of support during this project (I love you).

To my sister and brothers who gave me love and support.

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AAPD: American Academy of Pediatric Dentistry

CEJ: Cemento-enamel junction

RM-GIC: Resin modified glass ionomer cement

SSC: Stainless steel crown

CHAPTER 1: INTRODUCTION

Dental caries is one of the major oral health problems affecting children (Featherstone, 2000). Its management is because caries is a progressive disease that destroys tooth structure. If left untreated, its consequences, which include pain and infection, will negatively influence the child's health and family (Gift *et al*., 1992). Therefore, surgical and restorative measures are crucial to avoid these consequences (Tinanoff and Douglass, 2001).

The benefits of restorative treatment are to remove cavities or defects, to restore function, maintain the arch integrity and to eliminate the progression of dental caries (Innes *et al*., 2015). The complexity of the restorative treatment increases when the dental caries involves more than one surface of the tooth. As the extent of the tooth preparation increases due to the removal of dental caries, the susceptibility of the tooth to fracture increases. The greater the extent of tooth destruction, the more difficult it becomes to re-establish a functional crown morphology (Lenters *et al.*, 2006).

Failure of restorative treatment is more common in primary teeth compared to permanent teeth (Hickel *et al.*, 2005). This is due to several factors such as patient cooperation, primary tooth morphology, differences in tooth structure and the type of restorative material used. For primary teeth, it has been reported that full coronal coverage increases the structural integrity of the tooth and durability of the restoration (Innes *et al*., 2015). Accordingly, the American Academy of Pediatric Dentistry (AAPD) recommends the use of stainless steel crowns (SSC's) in primary teeth, especially where caries involves multiple surfaces (AAPD, 2016/17). In the field of paediatric dentistry, SSC's have gained popularity due to their successful performance as a restorative material (Seale, 2002).

CHAPTER 2: LITERATURE REVIEW

Primary teeth with carious lesions can be restored using different types of materials in the form of direct and indirect restorations. Direct restorations include amalgam, composite, compomer, resin modified glass ionomer and glass ionomer restorative materials (AAPD, 2016/17). Indirect restorations that provide full coronal coverage for primary teeth include stainless steel-, zirconia- and composite crowns (Attari and Roberts, 2006). Full crown coverage for primary teeth is an important requisite in certain cases, such as teeth with multi-surface carious lesions, which can be particularly challenging to treat (Innes *et al*., 2015). In these cases, full coverage with SSC's are recommended, since the uneven distribution of the occlusal force can lead to failure of amalgam restorations (Seale and Randall, 2015). Full crown coverage decreases the susceptibility of further tooth damage, replicates normal crown function and maintains the occlusion and space in the dental arch.

In 1950, Engel introduced SSC's (Humphrey, 1950). Thereafter Humphrey recommended it as a definitive restoration of primary molars (Humphrey, 1950; Ramazani and Ranjbar, 2015). Since then, different designs of SSC's have been developed in an attempt to achieve greater adaptation and replication of the morphological features of the teeth. Crowns that were neither trimmed nor contoured were initially introduced but their use is limited (Sajjanshetty *et al*., 2013). This has led to the development of pre-trimmed and pre-contoured SSC's, which have straight proximal sides (Croll *et al*., 2003). These SSC's are the most commonly used and have an advantage over untrimmed SSC's in that the design follows the gingival contour and tooth anatomy (Croll *et al*., 2003; Randall, 2002).

It would however seem that general dental practitioners seldom use SSC's. In a study by Threlfall *et al*. (2005), 93 dentists were interviewed. Of these 3% were using SSC's routinely, 15% used them frequently and 82% never used SSC's in their dental practices at all. Reasons for this included the belief that SSC placement was difficult, unaesthetic and expensive (Threlfall *et al*., 2005). In another study, clinicians indicated that the placement of SSC's was a time-consuming procedure and the regular use of local anesthesia negatively affected the cooperation of children (Kindelan *et al*., 2008). However, the literature has shown that it is not a time-consuming or difficult procedure. This was attributed to the fact that the preparation for the SSC is simple with minimal tooth preparation, resulting in decreased technique sensitivity (Kindelan *et al*., 2008).

2.1 Indications for stainless steel crowns

The use of SSC's following pulp therapy remain the gold standard (AAPD, 2016/17). The high success rate of the procedure; attributed mainly to the good coronal seal provided by the SSC (Hutcheson *et al*., 2012) and the reduction of bacterial ingress into the pulp chamber (Moskowitz *et al.*, 2005). Several studies have re-affirmed the superiority of SSC's following pulp therapy in primary teeth compared to other restorative materials (Guelmann *et al*., 2005; Moskowitz *et al*., 2005; Hutcheson *et al*., 2012).

Other indications for SSC's include cervical decalcification, crown fractures and extensive occlusal wear (Tinanoff *et al*., 2015). SSC's are considered the treatment of choice for teeth with developmental defects such as hypocalcification and hypoplasia as the hypomineralized nature of the tooth structure compromises the adhesive properties of bonding agents (Fayle, 1999). SSC coverage is effective as it prevents the rapid loss of tooth structure, which commonly occurs in teeth with developmental defects (Jones, 1990). With SSC's, occlusal wear and a decrease in the occlusal height is prevented (Randall, 2002).

SSC’s can be modified to serve as space maintainers (SSC band-and-loop) when placed on abutment teeth (Randall, 2002). SSC’s have been used in patients with infra-occluded primary molars where it was necessary to maintain the mesio-distal space and occlusal height for the opposing teeth (Arhakis and Boutiou, 2016).

Due to the highly polished surface of SSC’s which limits bacterial adhesion and biofilm formation (Bin Alshaibah *et al.*, 2012), it is effective in patients with special needs where routine oral hygiene is impaired (Kindelan *et al.*, 2008). For the same reason, SSC’s are recommended for children with high caries risk (AAPD, 2016/17).

The main indication for SSC’s is the restoration of posterior teeth with extensive cavities where more than one surface is affected by dental caries (Tinanoff *et al*., 2015: AAPD, 2016/17). Several studies were conducted to compare the success of the SSC’s with other direct restorative materials such as amalgam and composite in teeth with multi-surface carious lesions (Messer and Levering, 1988; Roberts and Sherriff, 1990; Einwag and Dünninger, 1996). During cavity preparation for an amalgam restoration, additional removal of tooth structure is sometimes required to establish the adequate resistance and retention form (Eberting, 1999). This may further weaken the tooth and increase the difficulty in re-establishing the functional anatomy of the primary tooth.

2.2 Advantages of stainless steel crowns

2.2.1 Longevity

Einwag and Dünninger (1996) compared the longevity of SSC's to multi-surface amalgam restorations over an eight-year period. The failure rate of SSC's was 8% after 3 years, 10% after 4.5 years and 17% after 8 years. The amalgam restorations showed 34% failure after 3 years and 64% after 4.5 years. After 4.5 years, they reported a total of 60% failure for amalgam restorations compared to a 10% failure rate for SSC's (Einwag and Dünninger, 1996).

In 2004, a retrospective study conducted in young children treated under general anesthesia evaluated the longevity of SSC's (Drummond *et al*., 2004). The longevity compared to that of amalgam, composite and compomer restorative materials. Over a four-year period, the failure rate for SSC's was 7% compared to amalgam (43%), composite (27%) and compomer (15%) (Drummond *et al*., 2004). Roberts *et al* (2005) found that SSC's have a higher success rate in primary teeth with multi-surface carious lesions compared to resin modified glass ionomer cement (RMGIC) restorations (Roberts *et al*., 2005).

Resin modified glass ionomers (RMGIC's) have performed well as a restorative material due to a favorable flexural and compressive strength (Croll and Nicholson, 2002). There is also the advantage of ion elution and the restoration serves as a fluoride reservoir. Hutcheson and colleagues (2012) compared the success of the SSC's with RMGIC open sandwich restorations. They reported 3% marginal failure for the RMGIC open sandwich restoration after 6 months and 5% after 12 months compared to intact margins in the SSC group (Hutcheson *et al*., 2012). Atieh (2008) compared the success of SSC's with the RMGIC open sandwich technique over a two-year-period. The failure rate was not significant between the two groups with 5% reported for

SSC’s compared to 7.5% for the RMGIC open sandwich restoration (Atieh, 2008). **Table 1** summarizes the results of the aforementioned studies.

The GIC and RMGIC open sandwich restorations have the advantage of fluoride release and aesthetics due to the composite placed on the occlusal level. This technique is however sensitive to moisture contamination (Seale and Randall, 2015). SSC’s are characterised by the relative lack of technique sensitivity during placement of the crown without affecting the longevity of the crown (Seale, 2002). Other restorative materials such as amalgam, compomers, composites, GIC’s and RMGIC’s are technique sensitive materials posing a risk of oral fluid contamination during placement, which may compromise the longevity of the restoration (Randall, 2002). The recommendation of SSC’s in cases with inadequate moisture control where the failure of other modalities is likely (AAPD, 2016/17) has become a viable restorative technique.

Table 1: Longevity of different restorative materials

Author	Failure rate of restoration				Study design	Duration of study	Restored surfaces
	Amalgam	Composite	Compomer	SSC's			
Einwag and Dünninger (1996)	34%			8%	Retrospective study	4.5 years	Multi-surface
	64%			10%		3 years	
Drummond *et al*., 2004	52%	33%	15%	7%	Retrospective study	4 years	Multi-surface
Hutcheson *et al*., 2012		5%		0%	RCT	6 months	Class II
		3%		0%		12 months	
Atieh, 2008		7.5%		5%	RCT	2 years	Class II

*RCT: Randomized controlled trial

2.2.2 Cost-effectiveness

SSC's are cost-effective (Moskowitz *et al.*, 2005) compared to other conventional restorative materials, due to their superiority in restoring multi-surface cavities in primary molars (Innes *et al.*, 2015, Tonmukayakul *et al.*, 2015). When compared to SSC's, the dentist may spend multiple visits replacing these conventional restorations due to a higher failure rate (Wilson *et al.*, 1997). This increased treatment cost to the practitioner and longer clinical chair time may negatively affect the compliance of the child and parent (Randall, 2002). Eriksson *et al.* (1988) evaluated the cost-effectiveness of SSC's compared to amalgam restorations. A 35% cost reduction was reported for teeth restored with SSC's compared to the repeated cost for replacement of amalgam restorations (Eriksson *et al.*, 1988). Due to the durability and longevity of SSC's, most recommendations concur that placement of SSC's remains a cost-effective procedure (Randall, 2002; Seale, 2002; AAPD, 2016/17).

2.3 Disadvantages of stainless steel crowns

The main disadvantage is the perception of the patient that SSC's have poor aesthetics. The aesthetic demand has grown significantly in recent decades for adults and children (Guelmann *et al.*, 2011). In 2009, a study conducted in the United States to evaluate the main concerns of parents regarding the dental restorative materials used to treat their children's teeth. The study concluded that about 57% of parents were concerned about aesthetics and 23% were concerned about the initial cost of the treatment. The remaining 20% were concerned about the risk of toxicity (17%) from the SSC's. Parents were least concerned about the longevity of the treatment (3%) (Zimmerman *et al.*, 2009).

Due to these aesthetic concerns, pre-veneered SSC's, which are covered by a layer of porcelain, were introduced in the 1990's (Croll and Helpin, 1996). The literature has shown that pre-veneered stainless steel crowns cannot withstand the occlusal forces causing various degrees of occlusal chipping which in turn affects the aesthetics (Seale and Randall, 2015). Another study by Gupta *et al.* (2008) showed that an additional drawback of using pre-veneered SSC's appeared to be a decrease in the shear bond strength of the veneer facing when crown crimping was performed on the palatal/ lingual areas during the fitting procedure, leading to a loss of the veneer surface (Gupta *et al.*, 2008).

Ionic release of metallic restorations is one of the major concerns when metallic restorations need to be placed intraorally. SSC's contain 17-19% chromium, 9-12% nickel and 0.08-0.1% carbon (Menek *et al*, 2012). This raised concern regarding the use of SSCs due to their ability to corrode intra-orally and could lead to the release of metallic ions such as nickel, which may contribute to the development of allergic reactions, dermatitis and asthma (Ramazani *et al.*, 2014). In 2012, Yilmaz *et al*. reported a case with delayed hypersensitivity reaction as a result of SSC placement in a first molar (Yilmaz *et al*., 2012). Some studies showed that the amount of nickel released from SSC's is below the critical value for inducing allergic reactions and did not exceed the daily dietary intake (Menek *et al.*, 2012; Ramazani *et al.*, 2014). Contrary to these findings, Zinelis and colleagues (2008) evaluated the alteration in the components of SSC's after long-term intraoral use. No alteration in the components of the SSC's was reported which indicated that no ionic release occurred (Zinelis *et al*., 2008).

2.4 Failure of stainless steel crowns

2.4.1 Crown wear

The literature reported different reasons for SSC failure. Zinelis *et al*. (2008) evaluated the morphological alteration of SSC's that were placed intra-orally for a period of 3 to 101 months. Their study comprised of two parts i.e. the clinical part, which involved the placement of SSC's in seventeen primary molars intra-orally, and the laboratory part that was conducted after the teeth were exfoliated. The SSC's examined under high vacuum scanning electron microscopy. Minor occlusal deterioration reported in 47% of cases while 11.7% showed extensive deterioration, occlusal wear and perforation (Zinelis *et al*., 2008).

In 2011, Yilmaz *et al.* conducted a similar study to evaluate the occlusal wear of SSC's that were placed in thirty-one primary molars. The mean intra-oral time of these SSC's was 19.6 ± 5.8 months. They reported significant reduction in the occlusal and contact surfaces of the SSC's (Yilmaz *et al*., 2011). The occlusal deformity and wear were attributed to the long-term intra-oral use of SSC's (Zinelis *et al*., 2008; Yilmaz *et al*., 2011). Occlusal wear of SSC's may also be seen in children with excessive masticatory force or bruxism (Croll, 1983). However, compared to other direct restorative materials such as amalgam, composite, compomer, and RMGIC, the SSC's had a higher degree of wear resistance (Seale and Randall, 2015). In addition, Krämer and colleagues (2012) compared the wear resistance of SSC's to other indirect restorations in primary teeth such as pre-veneered SSC's, Protemp crowns and resin composite crowns. It was found that SSC's exhibited higher wear resistance compared to the other crowns as well (Krämer *et al*., 2012).

In 2016, Aly and colleagues conducted a study to assess the effect of zirconia crowns, SSC's and pre-veneered SSC's on the enamel surface of opposing teeth. They reported a significant difference between the three groups, the most aggressive wear patterns reported in the zirconia group, followed by the pre-veneered crowns, and lastly, the SSC's. Additionally, they showed that, the tooth wear was influenced by the surface smoothness, ductility and flexure of the crowns (Aly *et al*., 2016).

2.4.2 De-bonding

Debonding of SSC's is considered to be a failure, which occurs due to the lack of the retentive properties of the luting cement (Randall, 2002), or incorrect crimping of the SSC. Non-adhesive cements (zinc oxide eugenol-, zinc phosphate- and polycarboxylate cements) and adhesive cements (GIC-, RMGIC- and resin cements) are used for cementation of SSC's (Yilmaz *et al*., 2004). It has been found that adhesive cement possesses a higher retention force when used as cementing agent for SSC's (Dahl and Øilo, 1986; Karatoprak and Kırzıoğlu, 1997). Two studies compared the retention using GIC and RMGIC luting cements. No statistical difference was reported between the two luting cements (Yilmaz *et al*., 2004; Yilmaz *et al*. 2006). In another study, RMGIC luting cement showed a high retentive force, which was statistically significant, compared to the conventional GIC (Subramaniam *et al*., 2010).

Furthermore, Rector and colleagues (1984) conducted a study to evaluate the influence of marginal adaptation and SSC retention. They reported a significant correlation between adequate marginal adaptation and proper crown retention (Rector *et al*., 1984). Poor marginal adaptation also results in the creation of a marginal gap between the SSC and the tooth. Consequently, dissolution of the cement results in secondary caries and crown failure (Memarpour *et al*., 2016).

Inadequate marginal adaptation of the SSC, particularly at the distal surface of second primary molars, may impede the eruption of the first permanent molar (Croll *et al*., 1981; Croll, 1999).

2.4.3 Effect on periodontal tissue

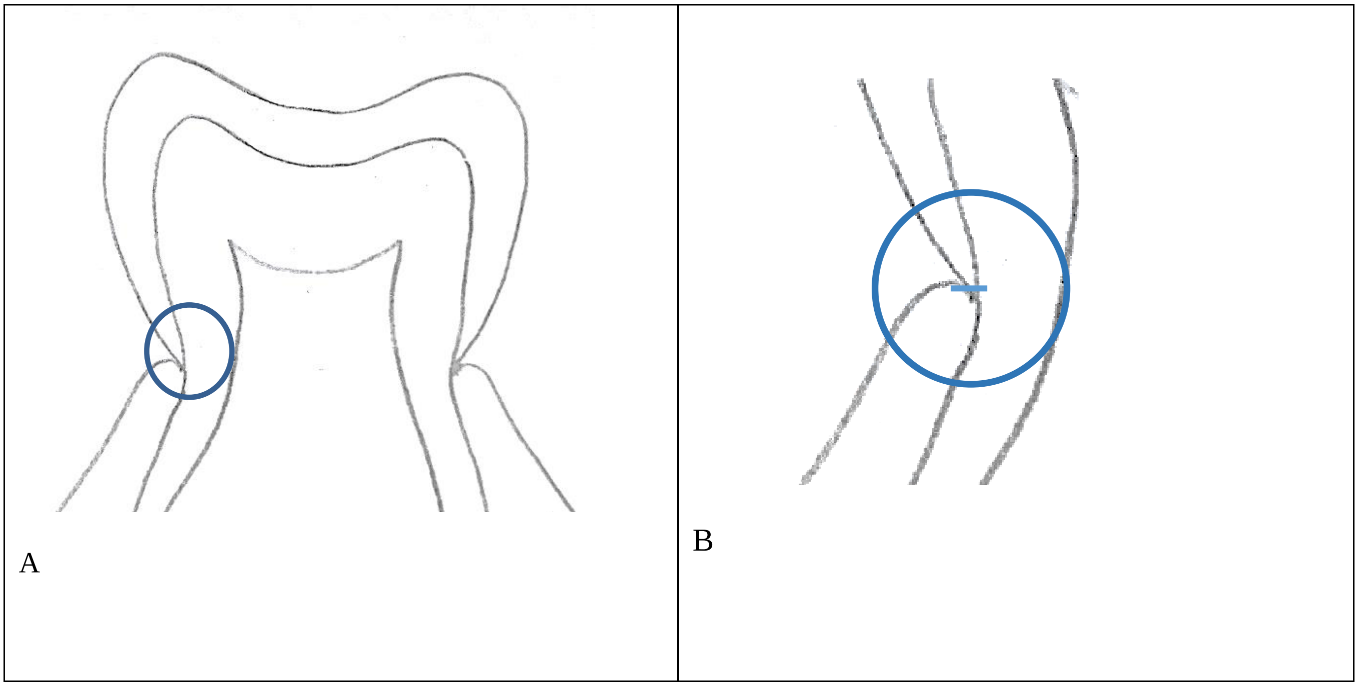
The periodontium of a child has a normal pocket depth range between 0.2 – 1.2 mm (Pathak and Nandlal, 2016). Over-extension of the crown's margin will therefore result in invasion of the biological width of the primary tooth periodontium (Sharma *et al.*, 2012). Gingival bleeding, discomfort, secondary caries and alveolar bone resorption were reported in some studies where SSC's were placed. These signs of failure occurred due to several predisposing factors, such as poor marginal adaptation, marginal discrepancy and encroachment of the biological width (Sharaf and Farsi, 2004; Atieh, 2008; Madrigal López *et al*., 2014).

2.5 Marginal adaptation and discrepancy

2.5.1 Marginal adaptation

Marginal adaptation is defined as "the perpendicular marginal distance from the internal surface of the restoration to the finishing line of the preparation" (

Figure 1) (Holmes *et al.*, 1989). This is clinically significant, as any increase in the marginal gap between the tooth surface and the crown may result in dissolution of the cement, which in turn increases the risk of microleakage, recurrent/ secondary caries and periodontal disease (Mously *et al.*, 2014). This significantly affects the longevity, retention and the success of SSC's (Rector *et al*., 1984).



Key

A: The blue circle marked the area of the marginal adaptation.

B: Zoom in for the area marked in pint A

Figure 1: Marginal adapatation

To approximate the SSC margin to the tooth surfaces, crimping of the crown is recommended by the manufacturers. This involves first curving the gingival third of the crown inwards, by using a crimping plier (**Figure 2**). The margin is then bent slightly towards the tooth to improve the marginal adaptation, resulting in a SSC margin with a decreased overhang (**Figure 3**) (Croll *et al.*, 2003).

Durr *et al.* (1982) claimed that errors in the crimping procedure of the SSC margins result in inadequate marginal adaptation (Durr *et al.*, 1981). In 2006, Afshar conducted a study to evaluate the efficiency of crimping on the marginal adaptation of SSC's. They concluded that proper marginal adaptation could be achieved by adequate crimping of the crown margins (for the pre-crimped SSC's as well) because it reduces the crown circumference at the marginal area (**Figure 3**) (Afshar, 2006).

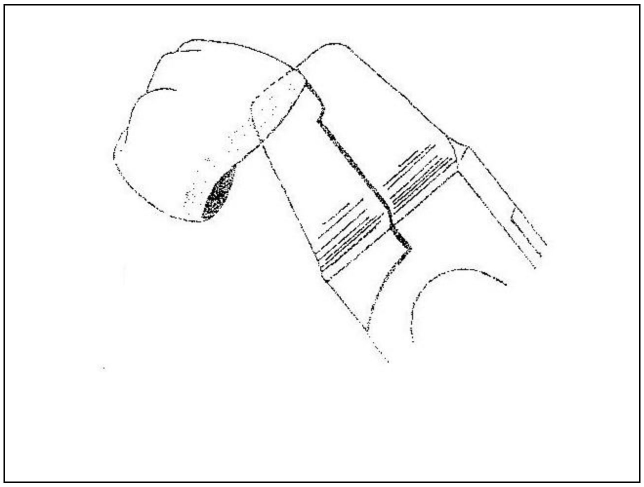


Figure 2: Crimping of SSC

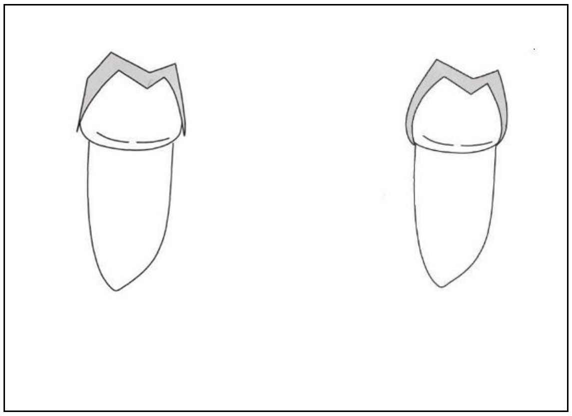


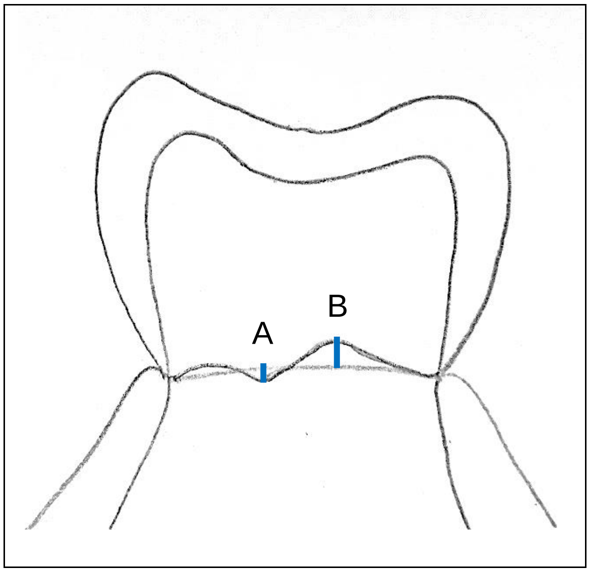
Figure 3: SSC margin modification after crimping

Several trials have been conducted in the literature where the correlational relationship between marginal adaptation and SSC success was assessed (Rector *et al*., 1984; Krämer *et al*., 2012; Erdemci *et al*., 2014; Memarpour *et al*., 2016). Studies evaluating the periodontal health in association with SSC placement found a positive correlation between plaque index and gingivitis in SSC's where poor marginal adaptation was reported (Webber *et al*., 1974; Durr *et al.*, 1981; Ramazani *et al*., 2010; Hutcheson *et al*., 2012). Proper marginal adaptation and fit are therefore crucial for the long-term success of SSC's.

Achieving optimal marginal adaptation is a crucial step to provide excellent durability and predictable success for the crowns (Memarpour *et al.*, 2016) and to allow normal eruption of the adjacent permanent molar (Kindelan *et al*., 2008). Croll and colleagues (2003) found that by achieving adequate marginal adaptation, the longevity of the SSC's could be extended from 5 to 15 years (Croll *et al*., 2003).

2.5.2 Marginal discrepancy

The term marginal discrepancy is used to describe the vertical misfit between the crown margin at various points and the abutment (**Figure 4**) (Amin *et al.*, 2015). Maintaining accurate marginal fit between the tooth and the crown is essential for protecting the tooth from chemical, physical, bacterial and thermal injuries (Erdemci *et al*., 2014. Yasangi *et al.*, 2015).



Key

A: Point A shows the overextended margin of the SSC.

B: Point B shows the under extended margin of the SSC.

Figure 4: Marginal discrepancy

The ideal extension of the SSC margin to the anatomic location of cemento-enamel junction (CEJ) or slightly occlusal to it is recommended to achieve proper retention (Croll *et al*., 2003). Accordingly, unequal extension in the margin may result either in an open margin or in over-extension of the SSC margin (Croll *et al*., 2003).

The extension of the crown margin can be assessed clinically by passing a periodontal probe around the margin (Bader *et al*., 1991) and ensuring that no blanching of the gingiva is present clinically (Croll *et al*., 2003).

2.6 Rationale for the study

Despite the high success rate of stainless steel crowns, several factors have been discussed that contribute to their failure. From the reviewed literature, the marginal adaptation and discrepancy of SSC's have been identified as the most important factors. From the literature, clinical failure was evident in the presence of microleakage, secondary caries and periodontal disease, which occurred due to poor crown adaptation and marginal discrepancies. In addition, marginal adaptation and fit was partly attributed to the operator skill set and tooth morphology (Erdemic *et al*., 2014).

The rationale of the study was based on the paucity of studies that simultaneously focused on marginal adaptation and discrepancy. Additionally, no studies were performed on a standardized "ideal SSC preparation" with the same SSC model number to ensure comparability of the SSC's adaptation and discrepancy. The purpose of this study was to compare the marginal adaptation and fit of SSC's between the four surfaces (mesial, lingual, distal and buccal) and to predict the factors that may contribute to the variation in adaptation and fit of SSC's.

CHAPTER 3: AIMS AND OBJECTIVES

3.1 Aim

The aim of this study was to compare the marginal adaptation and discrepancy of stainless steel crowns around the typodont tooth surfaces.

3.2 Objectives

a. To compare the degree of marginal adaptation of SSC's in the buccal and lingual surfaces to the proximal surfaces.

b. To compare the degree of marginal discrepancy of SSC's in the buccal and lingual surfaces to the proximal surfaces.

3.3 Null hypothesis

a. SSC's have adequate marginal adaptation and no marginal discrepancy.

b. There is no difference in the marginal adaptation of SSC's between the buccal and lingual surfaces compared to the proximal surfaces.

c. There is no difference in the marginal discrepancy of SSC's between the buccal and lingual surfaces compared to the proximal surfaces.

CHAPTER 4: MATERIALS AND METHODS

4.1 Study design

An *in vitro* experimental study was conducted.

4.2 Sample size

A total of 15 stainless steel crowns from the same lot and 15 standardized teeth were used.

4.3 Number of measurements

It has been found that using a small sample size may lead to a large standard deviation compared to the mean value as opposed to a large sample size, which produces data that is more consistent. Groten *et al.* (2000) found that a large number of measurements for each sample (Groten et al., 2000) could compensate for the small sample size. According to this conclusion, Lee *et al*. (2008) and Gonzalo *et al.* (2009) conducted studies using a small sample size (n = 10) and to overcome this small sample size they increased the number of measurements per sample to 50 and 60 measurements respectively (Gonzalo *et al*., 2009; Lee *et al*., 2008). This resulted in a more consistent distribution of the data with a small standard deviation compared to the mean values (Nawafleh *et al*., 2013). The sample size in the present study was fifteen and forty-eight measurements per sample were recorded. The measurements around each specimen provided adequate prediction for the adaptation and discrepancy for all tooth surfaces.

4.4 Materials

Stainless steel crowns *(3M ESPE, Seefelt, Germany).* Size E3 was chosen for quadrant four.

Ketac Cem Easymix *(3M ESPE, Seefelt, Germany).*

FB polyester resin for tooth duplication.

Rhodamine B isothiocyanate used as cement colouring agent *(Sigma Aldricht, USA).*

Additional silicon impression material *(FUTURA AD, Brazil).*

President silicon impression material *(Coltene, Switzerland).*

4.5 Methodology

This laboratory study was performed on a phantom head with an occluding maxillary and mandibular jaw in order to simulate the intra-oral clinical procedure. One polymethylmethacrylate second mandibular primary molar (Tooth 85) *(Ivorine teeth, Colombia Dentoform Corp., South Africa)* of a paediatric phantom head was selected. A polymethylmethacrylate phantom head tooth (typodont tooth) was used to standardize the crown morphology between the samples. In this study, the typodont tooth was used as a master tooth.

4.5.1. Master tooth selection rationale

The correlation between the remaining tooth structure and marginal adaptation is lacking in the literature. Myers and colleagues (1981) evaluated the influence of the residual tooth structure on the retention and adaptation of the SSC. They reported that the cervical part of the tooth is the most important area for crown retention and adaptation (Myers *et al*., 1981).

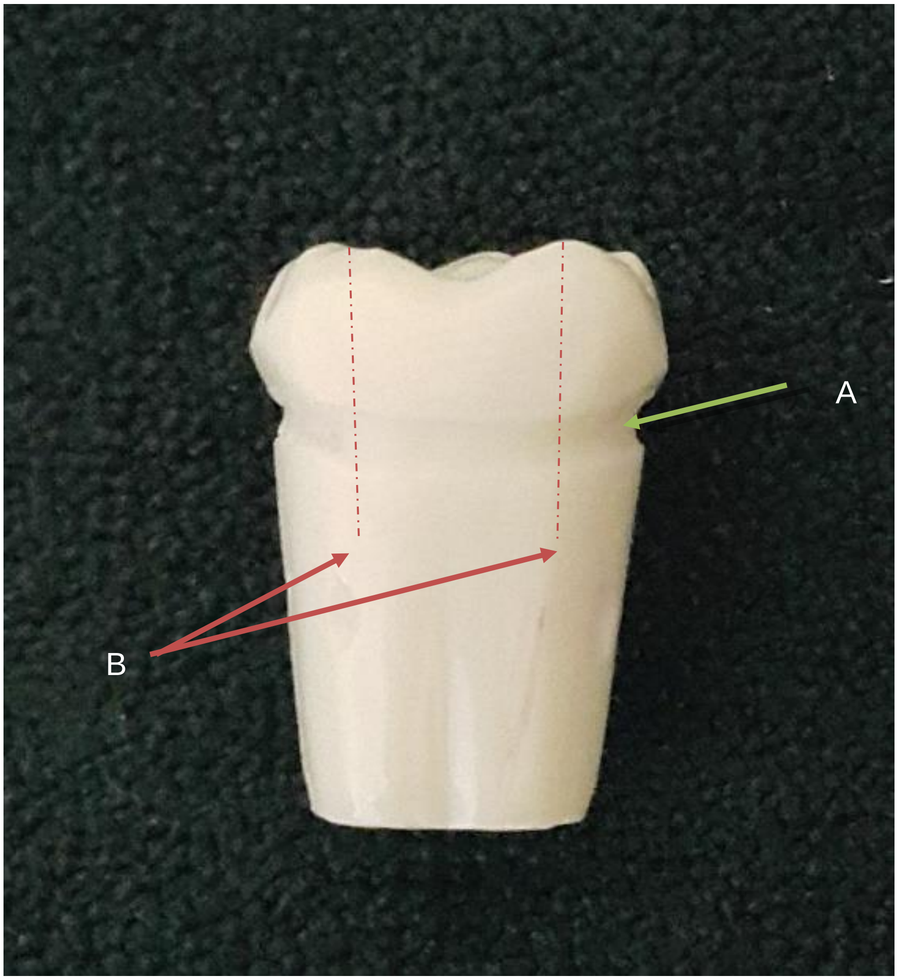
4.5.2 Master tooth preparation

A standard SSC tooth preparation was done on the polymethylmethacrylate second mandibular primary molar (Tooth 85) (Erdemic *et al*., 2014). The occlusal surface of the second mandibular primary molar tooth was reduced by 1 mm using a 836R bur *(Modified end cylinder bur, Diatech Dental, Heerbrugg, Switzerland).* The proximal surfaces were prepared using a diamond feather edge bur *(Diatech)* to remove all mesial and distal undercuts without leaving any ledges (**Figure *5***).

Figure 5 : Master tooth preparation

The cemento-enamel junction (CEJ) was marked in the master tooth using a 836R bur to a depth and thickness of 1 mm (**Figure *6***). The marked (CEJ) was used as a reference line for the measurement of marginal adaptation and discrepancy.

In order to differentiate between the buccal, lingual, mesial and distal surfaces of the tooth during the measuring of the marginal adaptation and discrepancy, a line was drawn from each cusp on the long axis of the tooth toward the apical part of the root surface, thereby separating the four surfaces. Four grooves were prepared using an 836R bur (**Figure 6**).



Key:

A: CEJ line

B: surface demarcation

Figure 6: Master tooth

4.5.3 Duplication of master tooth

In order to standardize the preparation for all teeth used in this experiment, a silicone mould was made from the master typodont tooth using additional silicon *(FUTURA AD) (3M ESPE, South Africa).* The use of additional silicone increased the efficiency and accuracy of the mould. This mould was used to duplicate 15 teeth by pouring FB polyester resin into the mould (**Figure** *7*).

Any excess resin material was removed to prevent inadequate fitting of the duplicated tooth in the mandibular phantom head and the duplicated teeth were labelled with numbers 1 to 15.

In the present study, the use of duplicated teeth with the same crown size for all 15 specimens provided standardization for the tooth circumference and preparation in order to reduce any variation in the measurement between all teeth.

Figure 7: Mould for duplication of teeth

4.5.4 Demarcation of the cemento-enamel junction in the duplicated teeth

The prepared CEJ in the master tooth was re-demarcated in the duplicated teeth by filling the prepared groove with a blue gingival barrier light curing resin *(SDI, Australia)* to facilitate clearer visual identification of the CEJ margin (**Figure 8**). The gingival barrier resin was applied according to the manufacturer's instructions. Any excess material was removed before curing, ensuring the surface was flush. A plastic instrument was used to remove the excess material, which could negatively affect marginal adaptation and discrepancy measurements. The resin was light cured for 30 seconds using a Demetron LC curing light.

If reference lines are not used on extracted teeth to make the CEJ line clearly visible and provide a reference point for SSC over- or under extension and ensure clear identification, the researcher could over- or underestimate the SSC marginal adaptation/ discrepancy. Clinically, this error does not readily occur, since insufficient marginal trimming results in blanching until the crown has been trimmed, resulting in the ideal SSC margin level. For this reason, an incorrect finishing line, which does not simulate the clinically relevant tooth-SSC interface, could result in altered performance of the SSC crown with *in-vitro* studies (Seraj *et al*., 2011; Krämer *et al*., 2012).

Figure 8: Demarcation of the CEJ (gingival barrier resin)

4.5.5 Seating of the duplicated teeth

An occlusal stamp was made using president silicone impression material (vinyl polysiloxane) to record the position of the master tooth in the phantom head jaw prior to being replaced with the duplicated tooth (**Figure *9***). This would facilitate accurate positioning of each duplicated tooth in the phantom head jaw.

A

B

C

D

Figure 9: Occlusal stamp

KEY
A/B: Master tooth
C: Duplicated tooth
D: Occlusal view

4.5.6 Selection and adjustment of Stainless Steel Crowns

Clinically, the selection of the appropriate crown size can be done by using a divider to measure the mesio-distal dimension of the tooth itself or using the contralateral tooth if the crown is destroyed, making appropriate crown measurement difficult (Fayle, 1999).

In the present study the mesio-distal width of the typodont tooth, number 85, was measured in order to record the size before tooth preparation (to create the master tooth). Based on the measurement, 15 SSC's, (size E3) were selected. The crowns were trimmed and shaped according to the manufacturer's instructions and placed on the duplicated teeth in the mandibular jaw of the phantom head. Performing the placement and adaptation of the SSC on the phantom head in this *in-vitro* study, simulated the actual clinical procedure. It was important to adjust the crown margin in relation to the primary tooth gingiva. The marginal extension and fit were then assessed **(Figure 10)**.

The ideal extension of the crown margin either one millimeter subgingivally or equigingivally, prevents invasion of the periodontal pocket (biological width) and the subsequent damage to the gingiva and alveolar bone. In the present study, the desired occlusal height and equi-gingival extension of the crowns were achieved by adjusting and trimming the gingival area of a crown using a crown and bridge scissor.

Figure 10: Clinical appearance of the SSC fit and margin

The crown curvature was shaped with a Johnson Contouring Pliers #114 (**Figure 11**) and the margin was crimped around the crown circumference to allow maximum marginal adaptation (**Figure 12**) using 3M ESPE crimping pliers (800-421). Finishing and polishing of the crown margin was completed using a large heatless stone and rubber wheel, respectively. The fit and extension of the crown were re-assessed before cementation. Clinically, the correct SSC placement is determined by an audible clicking sound produced during lingual-buccal placement of the crown at the try-in stage, prior to cementation (Goldberg, 1969).

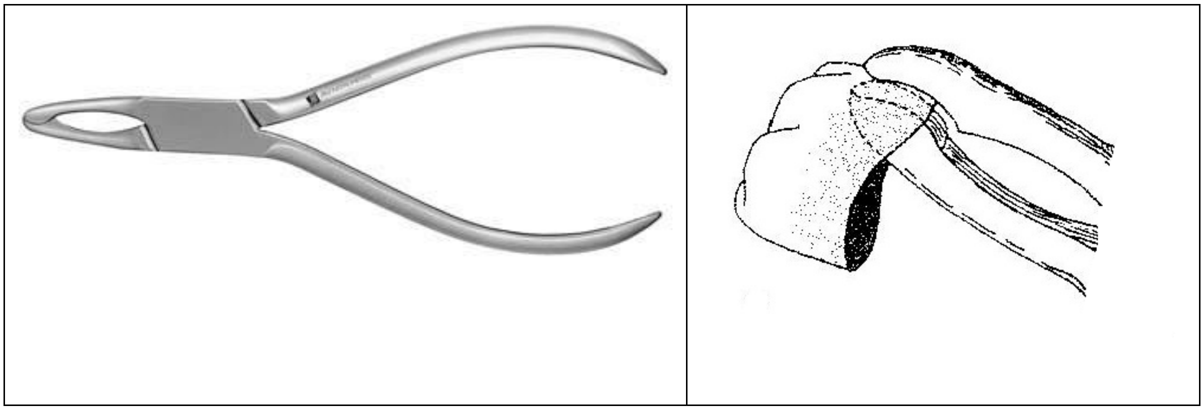


Figure 11: Johnson Contouring Plier #114 for crown curvature

Figure 12: 3M ESPE crimping pliers (800-421)

4.5.7 Cementation of the Stainless Steel Crown

Although adhesion was obtained between the cement material and the FB polyester resin used for manufacturing the duplicated teeth, it does not have the same adhesion as the cement material would have to natural teeth. However, the adhesion strength is irrelevant in the present study, as adhesion was not investigated. The rationale for using the cement was to secure the crown in a fixed position to allow accurate assessment of the margins. The adjusted stainless steel crowns were cemented onto the duplicated teeth using *Ketac Cem (3M ESPE)* cement according to the manufacturer's instructions, while the teeth were in the mandibular phantom head. One spoon of the powder was mixed with two drops of the liquid. Rhodamine B isothiocyanate dye at a 0.066% concentration was incorporated into the cement (**Figure 13**). This served as a contrast medium to enable easier viewing of the marginal adaptation. The material was applied to the inner surface of SSC's and the crowns were seated over the duplicated teeth by occluding the upper jaw of the phantom head with the lower. After complete setting of the cement, the excess material was removed using a probe and the teeth were cleaned using a pumice and brush. All the teeth were then stored for 48 hours at 35^0C and 95% humidity.

Figure 13: Rhodamine B isothiocyanate dye incorporated into Ketac Easy Mix cement

4.5.8 Measurement of marginal adaptation and discrepancy with the stereomicroscope and digital camera

In the present study, a stereomicroscope with digital camera was used. De Santi Alvarenga *et al.* (2015) proved that measurements obtained using the stereomicroscope in conjunction with the digital camera, were accurate. The advantage of working with a digital camera is that the image can be easily manipulated (De Santi Alvarenga *et al*., 2015). Amin *et al.* (2015) showed the high accuracy of the stereomicroscope with camera for measuring the marginal accuracy of four different crowns (Amin *et al*., 2015).

Each specimen was placed under a stereomicroscope *(Nikon SMZ-10 stereophoto, Japan)* at 100x magnification. The measurements of the adaptation and discrepancy were recorded around the circumference of each specimen every 2µm (micrometers) by using a micrometer screw gauge. Each specimen was attached to the head of the micrometer screw gauge by double-sided adhesive tape (**Figure 14**).

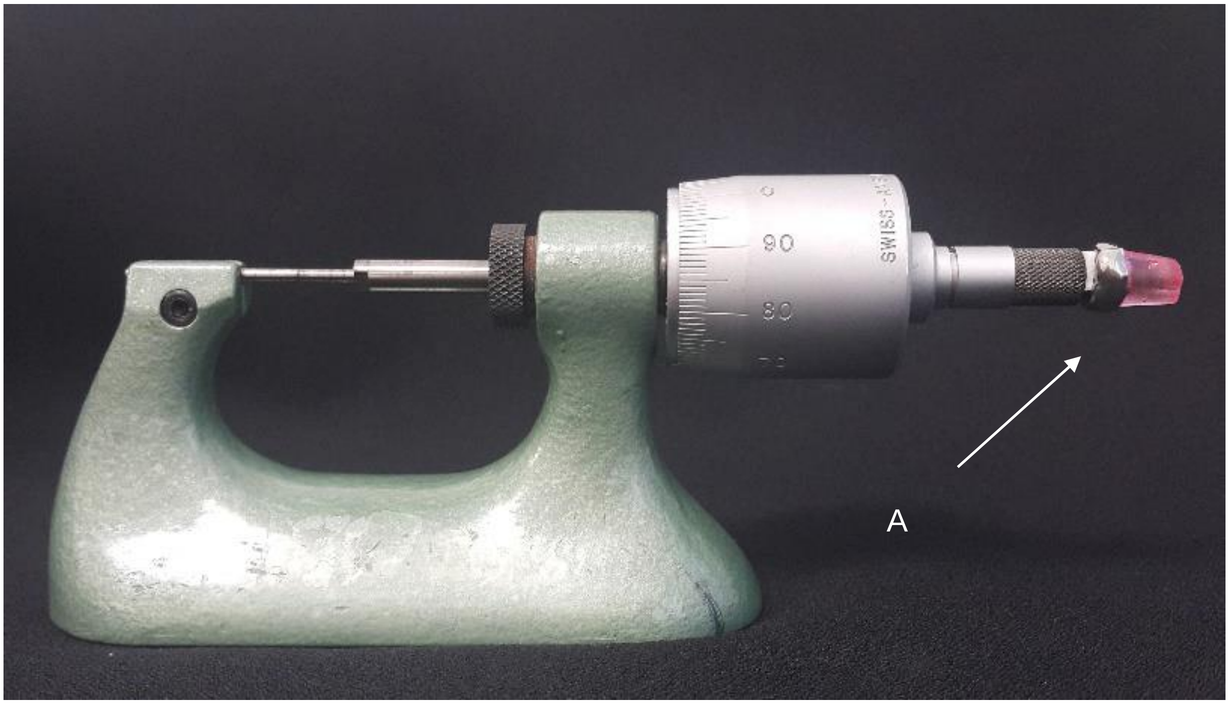


Figure 14: A micrometer screw gauge

KEY:

A: illustrates the area of the specimen attachment to the micrometer using double-sided adhesive tape.

Forty-eight measurements were taken per specimen for marginal adaptation as well as for marginal discrepancy. Thereafter, marginal adaptation measurements were taken from the inner margin of the SSC to the tooth. The micrometer screw gauge was placed in an upright position to allow measurement of the marginal adaptation. This was done by fabrication of a silicone mould as a base to stabilize the micrometer (**Figure 15**).

Figure 15: Placement of the micrometer screw gauge for the measurement of marginal adaptation

For the measurement of marginal discrepancy, the micrometer screw gauge was placed under a stereomicroscope (**Figure 16**). The marginal discrepancy was measured from the CEJ line to the SSC crown margin.

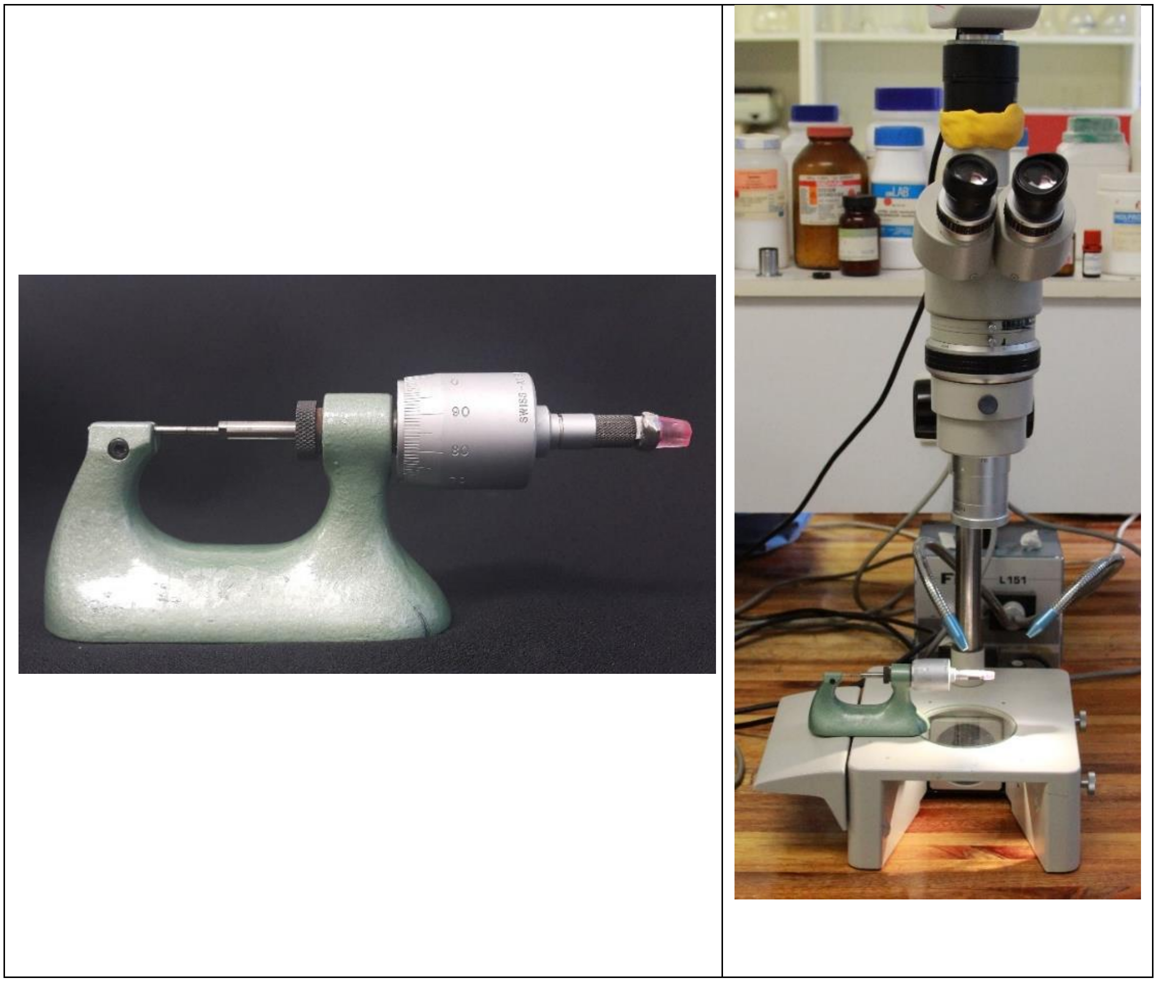


Figure 16: Placement of the micrometer screw gauge for measurement of marginal discrepancy

The marginal adaptation and discrepancy of each crown was measured in millimeters using a Vernier caliper. This was done by attaching a camera *(LEICA DFC 290, Leica Microsystems Ltd, Germany)* to the stereomicroscope to transfer the image to the computer software *(ACD See software V3.1).* A translucent paper was attached to the computer screen. A horizontal line was drawn on the translucent paper to determine the fixed measuring points for every 2µm (micrometer) rotation of the micrometer screw gauge (**Figure 17**).

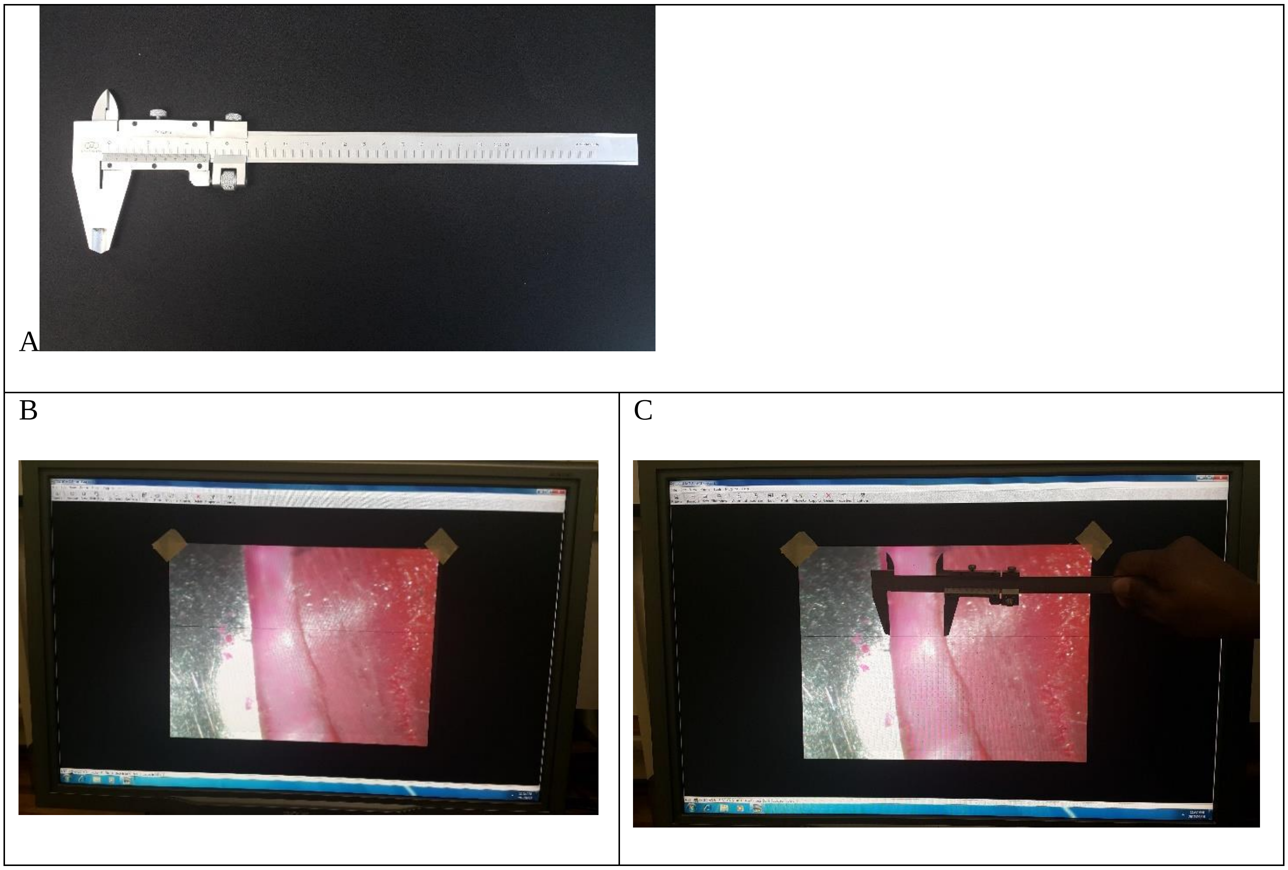


Figure 17: Measuring of the marginal discrepancy

<u>KEY:</u>

(A): Vernier caliper

(B): The computer image with a translucent paper attached to it

(C): Illustrates use of the Vernier caliper on the computer screen to measure the marginal discrepancy.

4.6 Validity and Reliability

The researcher examined the specimens. The researcher and the supervisors of the project performed consensus measurements in order to ensure no variation. Additionally, thirteen percent of the sample was re-examined after 2 weeks for intra-observer reliability using the Paired Sample test.

4.7 Measuring parameters of the specimen measurements

The ideal measurement in this study was defined by the smallest marginal discrepancy and the best marginal adaptation. The larger the discrepancy found between the tooth and crown, the poorer the fit.

4.8 Data analysis

All the readings recorded from each surface were transferred to an Excel spreadsheet (Microsoft Corporation, USA) for further analysis. Descriptive statistics were calculated for the quantitative variables as mean, standard deviation and upper and lower 95% confidence intervals (CI).

CHAPTER 5: RESULTS

In the present study, the differences in the marginal adaptation on different aspects of the tooth were evaluated. Additionally, the difference in the marginal discrepancy between the different tooth surfaces was also evaluated.

Data was analysed statistically using the One Way Anova test to determine a statistically significant difference for marginal adaptation and discrepancy of the 15 SSC's. The Tukey HSD test was used for multi-comparison tests between the four surfaces (Mesial, Lingual, Distal, Buccal) for each marginal adaptation and discrepancy value.

Only p-values less than 0.05 were regarded as statistically significant. All statistical analysis was carried out using SPSS 14.0 for Windows (SPSS©, Inc. Chicago, IL, USA) and Microsoft Excel 2010 (Microsoft Corporation, USA).

5.1 Marginal adaptation for Stainless Steel Crowns

The distance from the internal surface of the SSC to the finishing line of the preparation, (marginal adaption) was measured in (mm) for all surfaces (Figure 1). The mean value for the marginal adaptation on the buccal surface was 0.583. However, the mean values of the other surfaces (mesial, distal and lingual respectively) were lower (**Table 2**).

Table 2: Marginal adaptation per surfaces

	Mean	Std. Deviation
Mesial	0.515	±0.031
Lingual	0.260	±0.020
Distal	0.508	±0.024
Buccal	0.583	±0.024

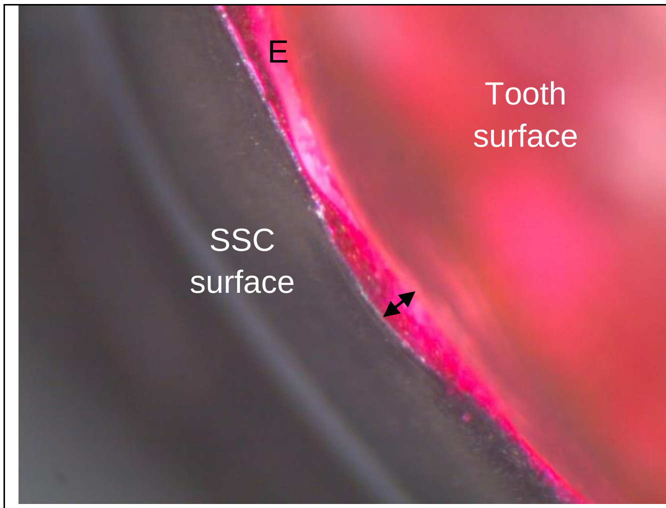
The results showed that there are statistical differences between mesial, lingual, distal and buccal surfaces (**Table 3**).

Table 3: One Way Anova test for comparison of marginal adaptation

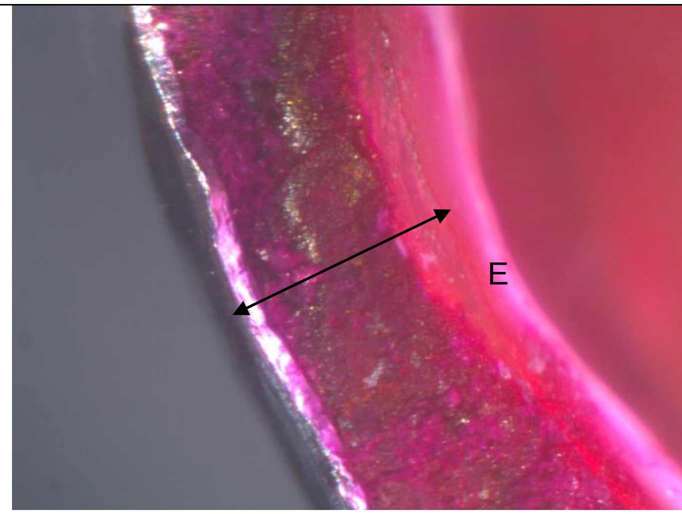
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.901	3	0.300	31.489	0.000
Within Groups	0.534	56	0.010		
Total	1.435	59			

To determine which surface presented with the most optimal adaptation, multiple comparisons between all surfaces was done using the Tukey HSD test. Each surface was compared with the others to determine where the significant differences were. The lingual surface was found to have the best adaptation compared to all the other surfaces (mesial, distal and buccal surfaces) (**Figure 18**). A p-value of 0.000 indicates that this difference between the lingual and other surfaces is statistically significant (**Table 4**).

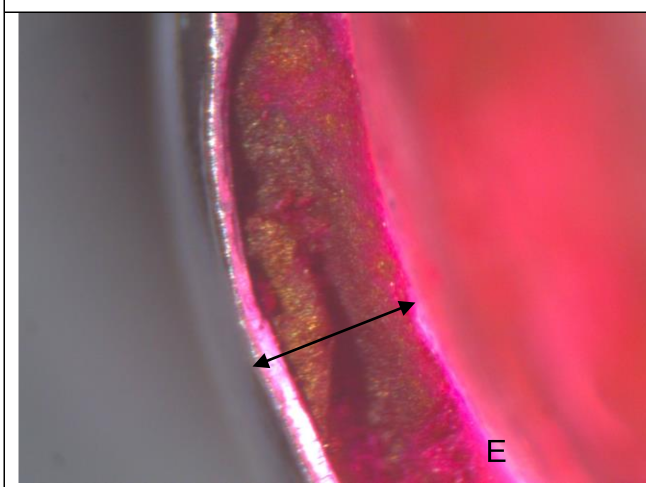
Although there is no statistically significant difference between the mesial, distal and buccal surfaces, the buccal surface showed poor adaptation compared to the other surfaces (**Figure 18**). The distribution of the mean values clearly showed the poorer adaptation of the surfaces compared to the lingual aspect (**Figure 19**).



A



B



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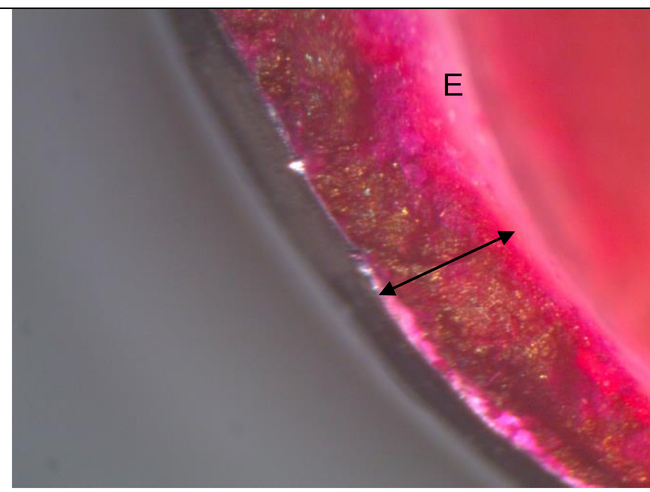

D

Figure 18: Marginal adaptation under stereomicroscope

KEY:

A: Lingual surface

B: Buccal surface

C: Mesial surface

D: Distal surface

E: CEJ

Table 4: Multiple comparisons for marginal adaptation

(I) Surface on tooth		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Mesial	**Lingual**	0.254	0.035	0.000	0.160	0.349
	Distal	0.007	0.035	0.997	-0.087	0.101
	Buccal	-0.067	0.035	0.241	-0.162	0.026
Lingual	**Mesial**	-0.254	0.035	0.000	-0.349	-0.160
	Distal	-0.247	0.035	0.000	-0.342	-0.153
	Buccal	-0.322	0.035	0.000	-0.416	-0.227
Distal	**Mesial**	-0.007	0.035	0.997	-0.101	0.087
	Lingual	0.247	0.035	0.000	0.153	0.342
	Buccal	-0.074	0.035	0.168	-0.169	0.019
Buccal	**Mesial**	0.067	0.035	0.241	-0.026	0.162
	Lingual	0.322	0.035	0.000	0.227	0.416
	Distal	0.074	0.035	0.168	-0.019	0.169

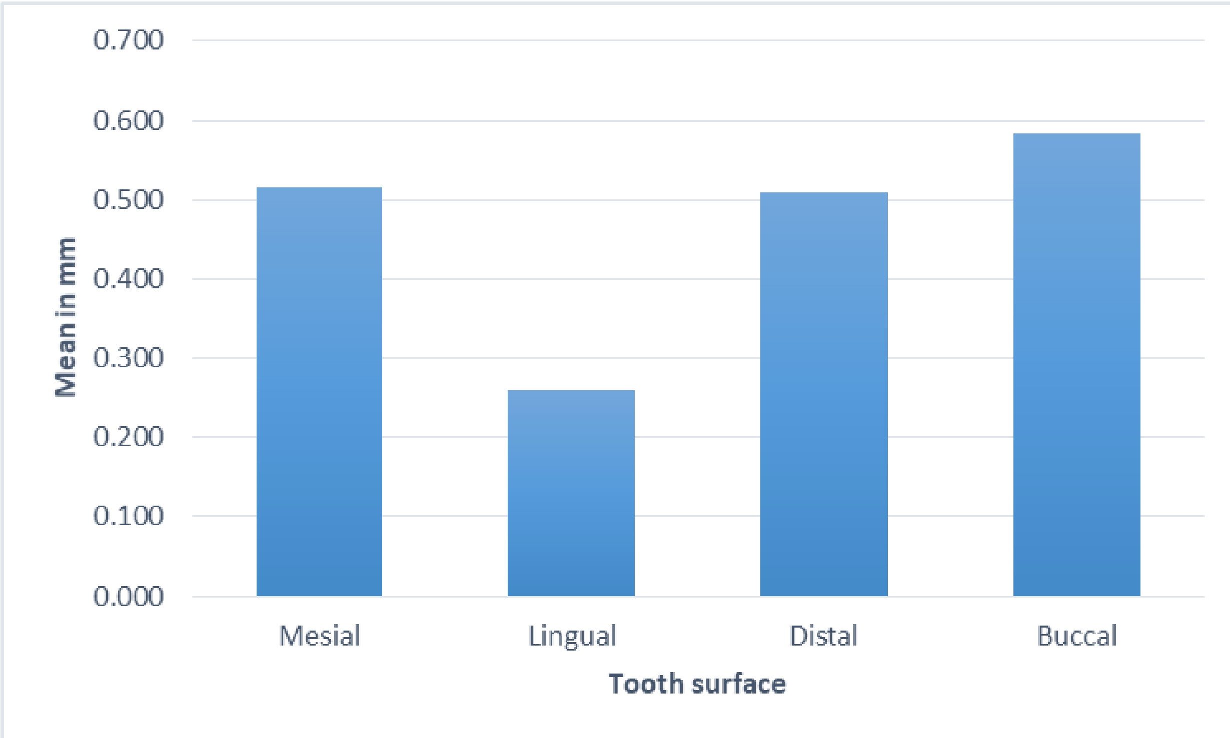

Figure 19: Mean values for marginal adaptation

SSC 7 and 14 were randomly selected and the measurements repeated after 2 weeks. The paired sample test was used to evaluate the intra-observer reliability for the measurement obtained for marginal adaptation. The mean of SSC 7 was 0.461 and 0.426 in the first and second round of readings, respectively. The mean of SSC 13 at the first round was 0.517 and 0.528 at the second round (**Table 5**).

Table 5: Paired sample test for marginal adaptation (SSC 7 and 13)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**SSC7 1st round observation**	0.461	48.000	±0.157	0.022
	SSC7 2nd round observation	0.426	48.000	±0.186	0.026
Pair 2	**SSC13 1st round observation**	0.517	48.000	±0.160	0.023
	SSC13 2nd round observation	0.528	48.000	±0.144	0.020

The correlation of the two measurements was evaluated using the paired sample correlation test. This test showed that there was no statistically significant difference between the measurements in the first and second round measurements taken of SSC 7 and 13 (**Table 6**). The mean values and the standard error for the first and second measurements for marginal adaptation of SSC 7 and 13 are illustrated in (**Figure 20**).

Table 6: Correlation of the two measurements (marginal adaptation)

		N	Correlation	Sig.
Pair 1	**SSC7 1st round observation & SSC7 2nd round observation**	48.000	0.408	0.003
Pair 2	**SSC13 1st round observation & SSC13 2nd round observation**	48.000	0.824	0.000

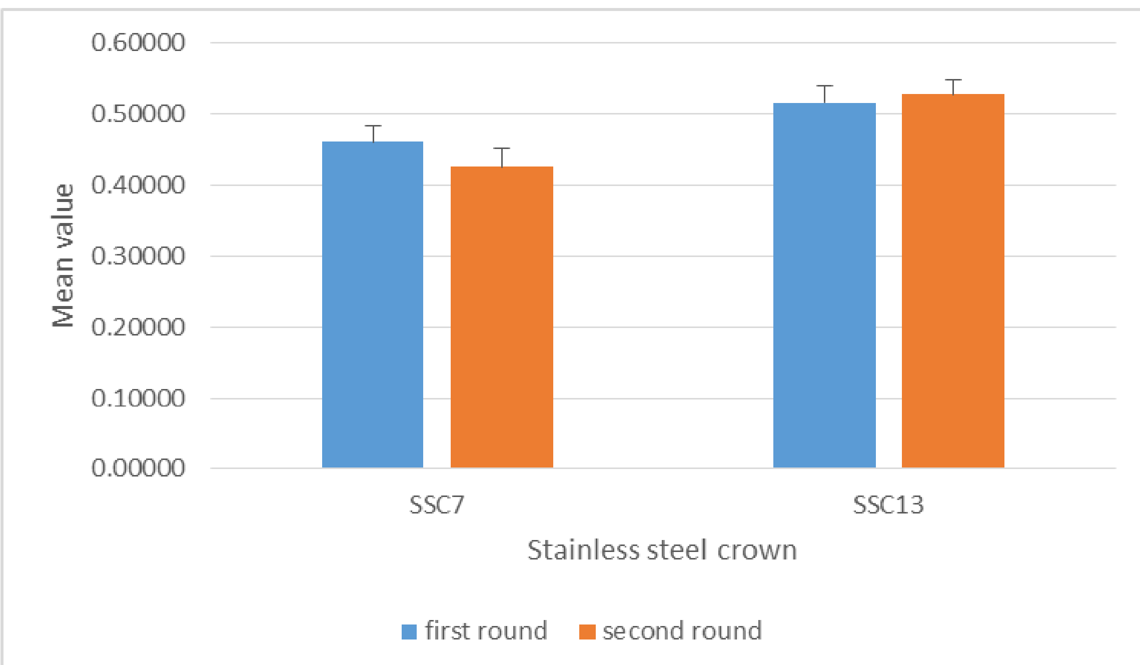

Figure 20: Mean and standard error for marginal adaptation (first and second measurements)

5.2 Marginal discrepancy for Stainless Steel Crowns

The vertical distance between the crown margin at various points and the CEJ line (marginal discrepancy) was measured using the One Way Anova test. The average reading for the marginal discrepancy on the buccal surface was 0.164. However, this value was lower in the mesial, distal and lingual aspects respectively (**Table 7**).

Table 7: Mean values for marginal discrepancy

	Mean	**Std. Deviation**	**Std. Error**
Mesial	-0.163	±0.224	0.057
Lingual	-0.408	±0.204	0.052
Distal	-0.339	±0.219	0.056
Buccal	0.164	±0.199	0.051
Total	-0.186	±0.304	0.039

The results showed that there is a statistical difference between the mesial, lingual, distal, and buccal surfaces with a p-value of 0.000 (**Table 8**).

Table 8: One Way Anova comparison for marginal discrepancy

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2.941	3.000	0.980	21.767	0.000
Within Groups	2.522	56.000	0.045		
Total	5.464	59.000			

The variation in the marginal fit of the SSC's was determined by the Tukey HSD test. The mean of each surface was compared to the mean of the other surfaces to determine the statistical significance between the surfaces. The marginal discrepancy on the buccal surfaces was statistically significant compared with all other surfaces. In addition, there was a significant difference between the marginal discrepancy of the mesial surface and the lingual surface. However, there was no significant difference between the lingual and distal surfaces and between the distal and mesial surfaces (**Table 9**).

Additionally, the mean of each group was displayed in a homogenous subset using the Tukey HSD test. In this test, the distal and lingual surfaces were grouped together. The distal and mesial surfaces were also grouped together while the buccal surface was reflected separately as the mean value is different (**Table 10**).

The marginal discrepancy on the buccal surfaces had a positive value which indicates that the crown margin was located above the CEJ line (**Figure 21**). The mesial, distal and lingual surfaces had negative values, which indicate that the location of the crown margin is below the margin of the CEJ. The distribution of the values of each surface is graphically illustrated in (**Figure 22**).

Table 9: Mean marginal discrepancy between surfaces

(I) Surface on tooth		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Mesial	Lingual	0.244	0.077	0.013	0.039	0.449
	Distal	0.175	0.077	0.119	-0.029	0.380
	Buccal	-0.328	0.077	0.000	-0.533	-0.122
Lingual	Mesial	-0.244	0.077	0.013	-0.449	-0.039
	Distal	-0.069	0.077	0.806	-0.274	0.135
	Buccal	-0.572	0.077	0.000	-0.778	-0.367
Distal	Mesial	-0.175	0.077	0.119	-0.380	0.029
	Lingual	0.069	0.077	0.806	-0.135	0.274
	Buccal	-0.503	0.077	0.000	-0.708	-0.298
Buccal	Mesial	0.328	0.077	0.000	0.122	0.533
	Lingual	0.572	0.077	0.000	0.367	0.778
	Distal	0.503	0.077	0.000	0.298	0.708

Table 10: The mean values (marginal discrepancy) for each group in homogenous subset

Surface on tooth	N	Subset for alpha = 0.05		
		1	2	3
Lingual	15.00000	-0.40866		
Distal	15.00000	-0.33909	-0.33909	
Mesial	15.00000		-0.16388	
Buccal	15.00000			0.16415
Sig.		0.80606	0.11975	1.00000

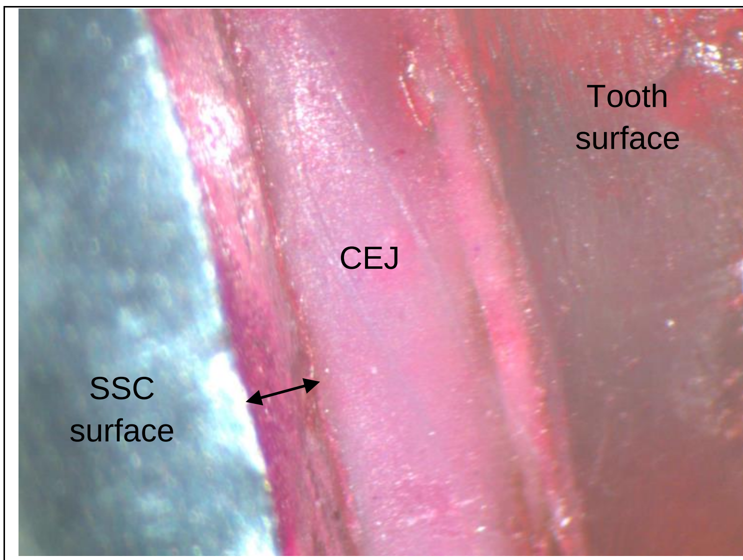

Figure 21: Marginal discrepancy on the buccal surface

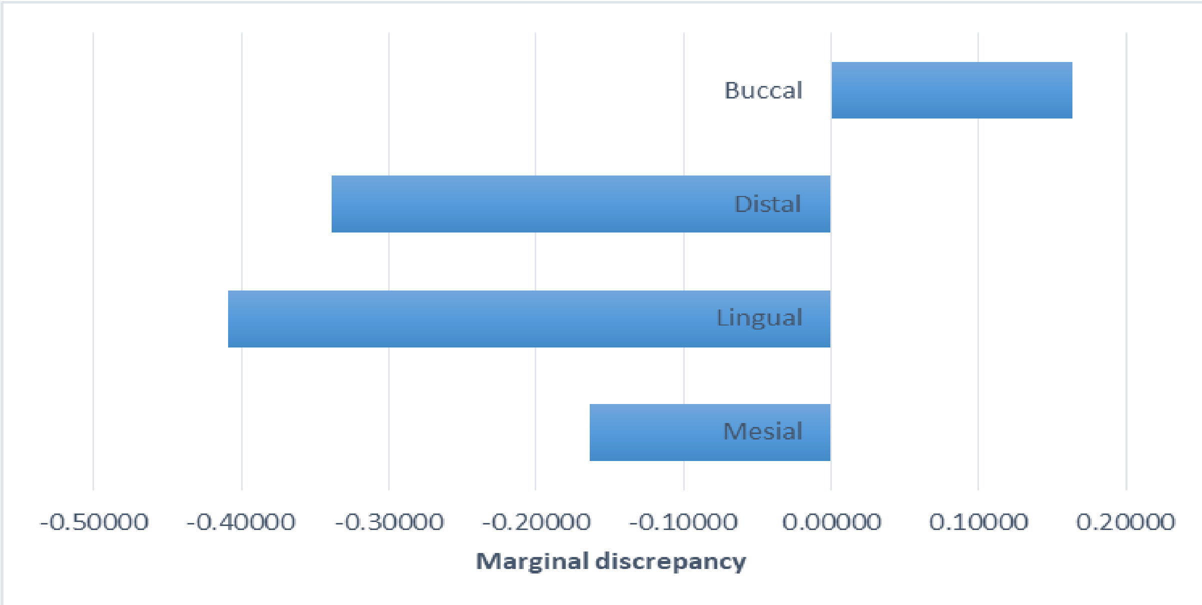

Figure 22: Mean values (marginal discrepancy) for each surface

SSC 7 and 13 were randomly selected and the measurements repeated after 2 weeks. The paired sample test was used to evaluate the intra-observer reliability for the measurement of marginal discrepancy. The mean of SSC 7 at the first round was -0.077 and -0.044 in the second round of readings. The mean of SSC 13 was -0.207 and -0.210 at the first and second round reading respectively (**Table 11**).

Table 11: Mean of measurements for marginal discrepancy (SSC 7 and 13)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**SSC7 1st round observation**	-0.077	48.000	±0.220	0.031
	SSC7 2nd round observation	-0.044	48.000	±0.274	0.039
Pair 2	**SSC13 1st round observation**	-0.207	48.000	±0.322	0.046
	SSC13 2nd round observation	-0.210	48.000	±0.335	0.048

The correlation of the two measurements was evaluated using the paired sample correlation test. This test showed that there was no statistically significant difference between the measurements in the first and second rounds for SSC 7 and 13 (**Table 12**). The mean values and the standard error for the first and second measurements of marginal discrepancy for SSC 7 and 13 are illustrated in (**Figure 23**).

Table 12: The correlation of the two measurements (marginal discrepancy)

		N	Correlation	Sig.
Pair 1	SSC7 1st round observation & SSC7 2nd round observation	48.000	0.891	0.000
Pair 2	SSC13 1st round observation & SSC13 2nd round observation	48.000	0.981	0.000

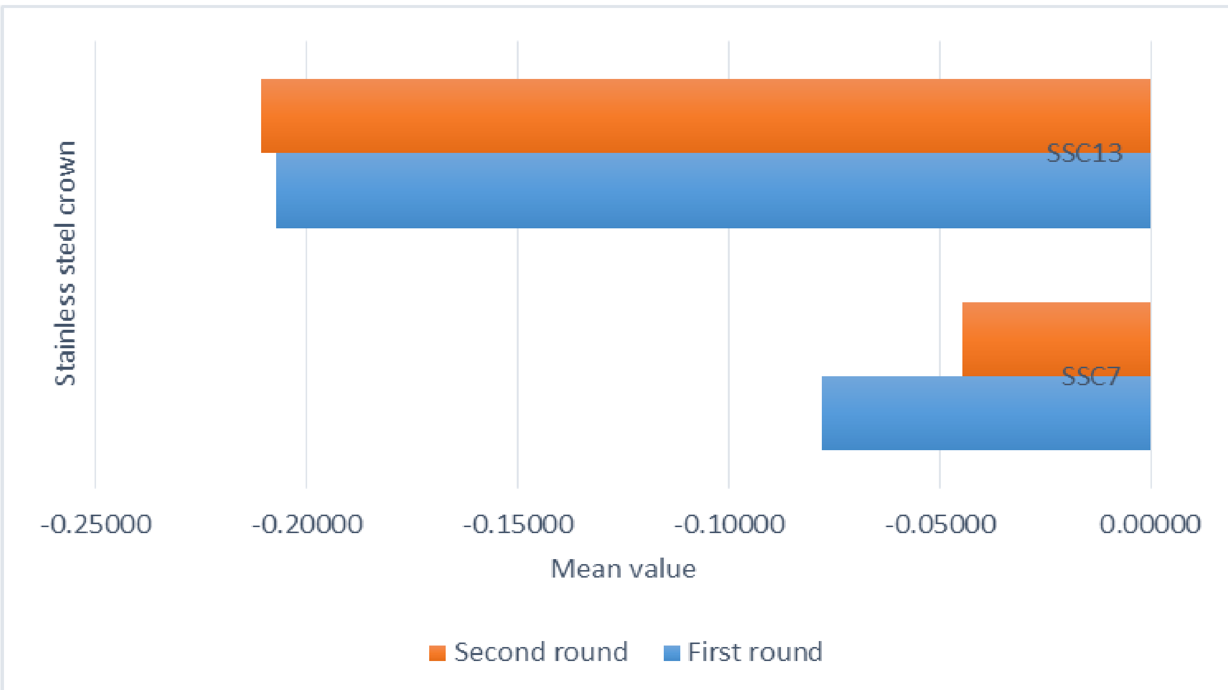

Figure 23: Illustrating chart for the mean and standard error of the first and second marginal discrepancy measurements

CHAPTER 6: DISCUSSION

Inadequate marginal adaptation and marginal discrepancy have a negative effect on the longevity and success of SSC's (Croll *et al*., 2003). It is therefore important to assess the factors that influence the adaptation and fit of the crown.

6.1 Marginal adaptation

The null hypothesis stated that SSC's have adequate marginal adaptation and there is no difference in the marginal adaptation of SSC's between the buccal and lingual surfaces compared to the proximal surfaces was rejected. In the present study, the best marginal adaptation of the SSC's was found on the lingual surface and was statistically significant compared to the other surfaces. Anatomically, the lingual margin is straighter compared to the buccal aspect allowing for better adaptation (McDonald and Avery, 2004).

Although there was no statistically significant difference between the mesial, distal and buccal surfaces, the poorest marginal adaptation was reported on the buccal surface. This finding was confirmed by other studies where the mesial and lingual surfaces showed inadequate marginal adaptation and the most common surface with poor marginal fit was the buccal surface (Woo *et al*., 2007; Erdemci *et al*., 2014; Ramazani and Ranjbar, 2015). This is likely due to the presence of the mesio-buccal bulge present on the second mandibular primary molar. This mesio-buccal bulge creates under cuts, which hamper crown adaptation during the crimping procedure. Woo *et al*. (2007) reported similar results for marginal adaptation of the second mandibular primary molar (Woo *et al*., 2007). Ramazani and Ranjbar (2015) reported similar results where a conventional SSC preparation was utilized. They found that when the buccal surface was prepared, in their second group, a significant reduction in the microleakage was reported due to better adaptation of the crown margin after reduction of the buccal bulge (Ramazani and

Ranjbar, 2015). The authors postulated that this significant difference in the buccal surface might be due to the crown morphology, which plays a crucial role in achieving this result. Accordingly, they advocated modification of the conventional preparation by recommending additional tooth preparation of the buccal surface (Ramazani and Ranjbar, 2015). Similarly, in the present study, the presence of mesio-buccal bulge contributed to the poor marginal adaptation on the buccal surface.

Accurate crown adaptation at the margin around the tooth circumference can be achieved by crimping and curving the margin of the SSC. This procedure is clinically challenging. More and Pink (1973) suggested a technique to evaluate the marginal adaptation and extension of the SSC at the interproximal areas by performing a bitewing radiograph before crown cementation (More and Pink, 1973). Accurate crown marginal adaptation at the mesial and distal surfaces can be detected by radiographic assessment while assessment of the buccal and lingual surfaces radiographically is difficult due to the radiopacity of the SSC on the radiographs. However, the use of this technique is not always feasible and clinically limited as it exposes the child to unnecessary ionizing radiation (Randall, 2002).

All efforts should therefore be focused on finding an appropriate method to improve crown adaptation. As SSC's have been found to have higher success and longevity for multi-surface carious primary teeth compared to all other restorations, it is worth the effort to increase the success and improve performance of the SSC, thereby minimizing unwanted consequences such as microleakage and periodontal problems.

The luting cement has a crucial role in closing the gap between the crown and tooth by forming a tight seal that prevents microleakage. Memarpour *et al*. (2010) compared the degree of microleakage using various adhesive and non-adhesive luting cements. They reported a significant reduction in microleakage when RM-GIC together with adhesive agent was used as luting cement as opposed to a RM-GIC alone (Menarpour *et al*., 2010). This may improve the marginal seal and compensate for the marginal defects associated with SSC's. RM-GIC's are biocompatible cements and they have been found to have high physical strength and bond chemically to the tooth structure (Li *et al*., 2015). In addition, RM-GIC's are insoluble in the mouth (Croll *et al*., 2003).

6.2. Marginal discrepancy

The null hypothesis stated that SSC's have no marginal discrepancy and there is no difference in the marginal discrepancy of SSC's between the buccal and lingual surfaces compared to the proximal surfaces was rejected. In the present study, a uniform extension of the SSC margin around the circumference of the tooth was measured. Marginal discrepancies of all SSC's were reported with two different values (negative and positive) in relation to the cemento-enamel junction (CEJ). Croll *et al*. (2003) concluded that the ideal crown extension should approximate the location of CEJ or slightly occlusal to it (Croll *et al.*, 2003). Clinically, this is ensured by using gingival blanching as an indicator as to the position of the margin which can be detected using a probe. Although there is insufficient evidence to support the relation between gingival blanching and post-operative complications, some authors interpret blanching of the gingival following crown placement as an over-extension of the crown (Kindelan *et al.*, 2008).

Negative values obtained indicate that the crowns were extended below the CEJ, which means that the crowns were placed more subgingival. Positive values indicated that the crowns extended above the CEJ.

The negative values indicated that the lingual, mesial, and distal surfaces were the areas where more encroachment of the soft tissue and the biological width occurred. This may be attributed to the difficulty in assessing and detecting the crown extension at these surfaces. In this study, blanching could not be used as an indicator but an explorer and periodontal probe were used to detect the crown extension. This was found to be inaccurate and is indicated by the negative values obtained on the lingual, mesial and distal surfaces.

On the other hand, the buccal surface produced positive values, indicating that the crowns were located at the ideal position. The extension of the crown margin buccally can be detected by visual inspection and can be assessed more appropriately than other surfaces.

The method of marginal trimming using crown and bridge scissors to place the crown on the appropriate height have a negative effect on the crown fit around the tooth circumference as it may lead to under and over extended margins and resultant marginal discrepancy. To achieve good marginal fit with more precise marginal trimming, the use of large rotary abrasive stone is suggested (Croll *et al*., 2003).

The contour of the gingival margin is difficult to follow during the trimming procedure. Clinically, a probe is used to carve a faint line that follows the contour of the gingival margin. This faint line gives an indication of where the crown should be trimmed. However, during the trimming procedure it is very difficult to follow the curved line accurately. How accurate the crown is cut does not depend only on the trimming instrument but also on the ability of the clinician to trim the crown exactly to the line that has been carved into the crown. All of these factors influence the accuracy of the crown extension around the tooth circumference and may contribute to the marginal discrepancy.

All SSC's require further manipulation prior to placement (Croll *et al*., 2003). Accurate marginal adaptation and fit can be achieved by: 1) selecting the appropriate size of the crown, 2) trimming the crown margin accurately for appropriate length, 3) crimping the crown edges to approximate the prepared area, 4) finishing, and polishing the margins of the crown (Afshar *et al*., 2015). This is where the learning curve is essential and dependent on the operator's skill.

CHAPTER 7: CONCLUSION

The crown morphology of the primary tooth plays an important role in the marginal adaptation of the crown. Crown bulges create an area of undercuts, which may compromise the adaptation of SSC adaptation. Although, crimping of the crown margin is used in all dental practices as a standard protocol for SSC placement and approximation of the crown margin to the tooth surface, this study showed that a significant marginal gap exists between the SSC and the tooth structure when using this technique. Marginal discrepancies of the SSC's occur due to technical errors during trimming procedure.

Knowledge and skill level of the operator contribute to the success of SSC's. Educating clinicians regarding adequate marginal adaptation and proper crown fit are likely to result in greater SSC success.

Limitations of the study:

Although this study was conducted to simulate the intra-oral procedure for SSC placement, some shortcomings were detected. Due to the presence of the thick plastic gingiva in the phantom head, marginal extension of the crown could not be detected as in the clinical setting, which is indicated by gingival blanching.

Additionally, this study did not evaluate the significance of this marginal gap in the presence of luting cements in relation to microleakage.

Recommendations for clinical application:

Crimping and adaptation procedures have been used extensively for pre-formed crowns. However, based on the results of this study, marginal adaptation and discrepancy remains an issue. Certain clinical recommendations for adaptation and cementation can be made to guide clinicians and increase the chances of success of SSC placement.

1. Based on the results of this study, modification of the conventional SSC tooth preparation technique could be considered by reducing the buccal bulge (Ramazani and Ranjbar, 2015) somewhat and ensuring adequate crimping to improve the marginal adaptation of the SSC.
2. Considering the adaptation and discrepancy illustrated in the present study, RM-GIC is preferred to GIC cements, which are prone to hydrolytic degradation, thereby compromising the marginal integrity. RM-GIC together with the use of an adhesive is therefore highly recommended to seal the gap between the crown and tooth in order to prevent microleakage and improve the marginal seal (Memarpour *et al.*, 2010). As recommended by Pathak *et al*. (2016), the use of self-adhesive resin or RMGIC cements

(RelyX U200, 3M ESPE; SmartCem2, Dentsply Caulk; RelyX Luting 2, 3M ESPE) will reduce the number of steps required (Pathak *et al*., 2016).

3. To reduce the marginal discrepancy, all effort must be invested in improving the trimming technique by using a rotary abrasive stone to guard against under- or over-extended SSC margins.

Knowledge and skill level of the operator contribute to the success of SSC's. Educating clinicians regarding adequate marginal adaptation and proper crown fit are likely to result in greater SSC success.

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PUBLICATION:

https://doi.org/10.1080/23337931.2018.1444995

ACTA BIOMATERIALIA ODONTOLOGICA SCANDINAVICA

Taylor & Francis

Acta Biomaterialia Odontologica Scandinavica

ISSN: (Print) 2333-7931 (Online) Journal homepage: http://www.tandfonline.com/loi/iabo20

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To cite this article: Riaan Mulder, Rasha Medhat & Nadia Mohamed (2018) In vitro analysis of the marginal adaptation and discrepancy of stainless steel crowns, Acta Biomaterialia Odontologica Scandinavica, 4:1, 20-29, DOI: 10.1080/23337931.2018.1444995

To link to this article: https://doi.org/10.1080/23337931.2018.1444995

Published online: 27 Feb 2018.