Comparative Evaluation of Commercially Available Stainless Steel Crowns: An In- Vitro Study.

Abstract:

Purpose : The purpose of this study was to evaluate the tensile strength, compressive strength,adaptability,retention,resistance and dimensions of different commercially available stainless steel crown (SSC) and a new crown (rainbow) coming in the market.

Materials & method : Sixty extracted primary molars were used.Crown preparation was done.They were divided into four groups of 15 samples each. Each group was assigned a commercially available crown and group II was assigned the new rainbow crown. They were all subjected to universal mechanical testing machine.

Results : Group I has maximum value for tensile and compressive strength. The post hoc tukey analysis confirmed that there was no statistical difference between other variables for all the groups.

Conclusion : All the four brands of SSC had similar fracture resistance. Further study with big sample size is needed to evaluate their performance under cyclical and multiaxial force loads.

Key words : stainless steel crown,tensile strength, compressive strength,

Introduction:

Rocky Mountain Company introduced Chrome steel crowns in 1947 [1] and in 1950 it was popularized by Humphrey[2]. Over the years, SSCs have found a wide range of use in the world of clinical pediatric dentistry. Since 1950 several modifications were recommended for SSC techniques in which each author seemed to have individual minor preferences and modifications; however, the basic preparation appears to remain the same.[2,3] The SSC is the standard for restoration of compromised pediatric dentition.[4,5]. It is superior, in terms of better retention and less recurrent decay, relative to posterior composite resin and amalgam Class II restorations as reported by previous authors.[6,7]

SSCs do not require complete isolation for bonding, as do crowns made of composite resin, nor do they require a preparation incorporating mechanical retention into the design, as do amalgam restorations. A properly trained dentist can quickly prepare and place an SSC. Advantages of steel crowns include their high ductility, which is important for the clinical adaptation of the crowns, and their reasonable hardness and strength. Other factors such as good durability and low cost have led this type of crown to be widely used for provisional restorations.

The first primary molars are the primary teeth that most commonly receive full-coverage restorations(8). The maximum bite force in the area of the first primary molar and the first permanent premolar was measured by Braun and colleagues. Linear regression generated values of maximum bite force ranging from 78 Newton's (N) for 6 year-olds to 106 N for 10 year-olds(9). Various studies have considered the bite force of both pediatric and adolescent patients,(10.11) but in most studies, the sensor was placed in the posterior-most tooth

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area. Braun and colleagues(9) measured maximum bite force in the area of the first primary molar and the first permanent premolar, as this region could be used for testing in younger children, and measurement in this area was comfortable for participants. The study setting and age group for that earlier study were similar to those of the current study, which was designed to measure the force required to fracture primary molars in the pediatric setting, so the data published by Braun and colleagues(9) were suitable as control values for the current study.

Therefore the aim of the present study was to sub-critically load different primary molar crowns and to evaluate tensile strength, compressive strength, adaptability, retention and resistance and dimension of different commercially available crowns.

Materials and Method:

Sixty extracted human primary molars (30 upper, 30 lower) with deep caries were used. Directly after extraction, teeth were stored in 0.5% chloramine-T for a maximum of four weeks. Teeth were randomly assigned to four groups (n=15). Teeth were cleaned and caries was removed. In the case of pulp exposure, pulp remnants were removed and the pulp chamber was filled with a glass ionomer cement (Ketac Molar Aplicap A3, 3M ESPE, Seefeld, Germany) (Figure 1). The original shape of the molar tooth was restored to its original form with composite build-ups of Filtek Z 250 (3M ESPE) which was bonded with Prime & Bond NT (Dentsply, Konstanz, Germany) after 7 s etch-and-rinse technique to dentine (Scotchbond Etchant, 3M ESPE). Polymerisation steps were 20 s for the adhesive and 40 s for each layer of resin composite using a bluephase® G2 LED lamp (Ivoclar Vivadent, Schaan, Principality of Liechtenstein). The power of the polymerisation lamp (1200 mW/cm²) was repeatedly controlled (bluephase® meter, Ivoclar Vivadent). Crown preparations were cut according to the recommendations of the manufacturers with torpedo shaped diamond burs (868, Hager & Meisinger GmbH) under profuse water cooling (minimum of 50mL/min) with margins in sound dentine. A circular step preparation of 1.0 mm was cut with a cylindrical diamond bur (837, Hager & Meisinger GmbH), preparations for steel crowns were made tangentially leaving the cingulum intact.

Selection of appropriate crown sizes was performed by assessing the diameter of the individual prepared tooth in order to avoid forming by bending. Luting was performed with RelyX Unicem (shade A3; 3M ESPE) according to the manufacturer's instructions. Overhangs of luting resin were spot cured for 2 s and then removed with a scaler. Final polymerisation was performed for 20 s per aspect. Prior to thermo-mechanical loading, roots of the teeth were cut 3 mm apically from the margins (Accutom 50, Struers, Willich, Germany) in order to get them adhesively fixed in the specimen holders of the chewing simulator (8 pairs of specimens per group). After storage at 37°C in aqua dest for 21 days, specimens were subjected to 2,500 thermal cycles between 5-55°C (15 s dwelling time, 15 s stop between the baths, THE1000, SD Mechatronik, Feldkirchen, Germany).

The force required to fracture the SSCs for primary mandibular first molars was measured. The crowns and dies were tried on to ensure a passive fit. Any visible undercuts in the dies were removed with a composite finishing bur. The SSCs were cemented onto the epoxy dies according to each manufacturer's instructions with resin-modified glass ionomer cement (G-Cem, GC Corporation). The die–crown units were then allowed to set for 4 hours. Each die–crown unit was placed into a custom made holder on a universal mechanical testing machine (MTS, Eden Prairie, MN), and loading was increased until the crown fractured (figure 2). The force was delivered through a stainless steel ball fixture, set in a uniaxial lever intended to replicate a cusp contact. Testing was performed in a single cycle, with the speed of the crosshead maintained at 1 mm/min, until the crown component fractured. The 4 types of crowns were compared, in terms of the force required to fracture, by means of 1-way analysis of variance.

Statistical Analysis:

After completing the study, the obtained data were subjected to statistical analysis by using statistical software SPSS version 16.0 (SPSS INC., CHICAGO, IL, USA). ANOVA and post hoc Tukey test were applied for comparing the tensile strength of each group. All the test were performed at 95% confidence level with the level of significance set 0.05 (5%), $p = 0.05$. $p < 0.05$ was significant and $p > 0.05$ was non-significant.

Results:

In the present study, total numbers of 60 extracted primary molars were used. They were divided into four groups with 15 samples in each group (figure 1). When we compared the dimensions of all 4 types of crowns, no significant difference was recorded as shown in table [1].

On comparing the compressive strength, Group I has maximum value, followed by Group II (Rainbow), group III and group IV as shown in table [2].

An intergroup comparison of tensile strength was done by using ANOVA test. The mean value of Groups I was highest (282.67±135.46) as compared to Group II (226.87±113.93), Group III (223.4±211.5), and Group IV (220±98.65) and a statistically non-significant difference were noted between the four groups [Table 3]. The Post hoc Tukey analysis confirmed that there was no statistically significantly difference was recorded between all the four groups regarding the compressive strength and tensile strength [Table 4 and Table 5].

Table 1: Comparative Evaluation of Dimensions Between all the Groups

	Group I	Group II	Group III	Group IV
Buccal Surface	0.16	0.17	0.17	0.18
Lingual Surface.	0.15	0.17	0.15	0.20
Distal Surface	0.15	0.16	0.16	0.20
Mesial Surface	0.14	0.15	0.15	0.20
Occlusal Surface	0.17	0.19	0.18	0.21

Table 2: Comparison of Compressive Strength between all the Groups

Variable	Groups	N	Mean	Std. Deviation	Std. Error Mean	p- value
Compressive Strength	Group I	15	312.4	202.28	52.23	0.533
	Group II	15	306.6	191.03	49.32	
	Group III	15	251.53	172.03	44.42	
	Group IV	15	224.73	202.61	52.31	

$p>0.05$ = Non- significant

Table 3: Comparison of Tensile Strength between all the groups

Variable	Groups	N	Mean	Std. Deviation	Std. Error Mean	p- value
Tensile Strength	Group I	15	282.67	135.46	34.98	0.606
	Group II	15	226.87	113.93	29.42	
	Group III	15	223.4	211.5	54.61	
	Group IV	15	220	98.65	25.47	

$p>0.05$ = Non- significant

Table 4 Intergroup comparison of compressive strength between all the groups

	Groups (J)	Mean Differences (I-J)	Standard Error	p- value
Group I	Group II	5.80000	70.25165	1.000
	Group III	60.86667	70.25165	.822
	Group IV	26.80000	70.25165	.981
Group II	Group I	-5.80000	70.25165	1.000
	Group III	55.06667	70.25165	.861
	Group IV	81.86667	70.25165	.651
Group III	Group I	-60.86667	70.25165	.822
	Group II	-55.06667	70.25165	.861
	Group IV	81.86667	70.25165	.651
Group IV	Group I	-87.66667	70.25165	.599
	Group II	81.86667	70.25165	.651
	Group III	-26.80000	70.25165	.981

Table 5 Intergroup comparison of Tensile strength between all the groups

	Groups (J)	Mean Differences (I-J)	Standard Error	p- value
Group I	Group II	55.80000	53.47765	.725
	Group III	59.26667	53.47765	.686
	Group IV	3.40000	53.47765	1.000
Group II	Group I	-55.80000	53.47765	.725
	Group III	3.46667	53.47765	1.000
	Group IV	6.86667	53.47765	.999
Group III	Group I	-59.26667	53.47765	.686
	Group II	-3.46667	53.47765	1.000
	Group IV	6.86667	53.47765	.999
Group IV	Group I	-62.66667	53.47765	.647
	Group II	-6.86667	53.47765	.999
	Group III	-3.40000	53.47765	1.000

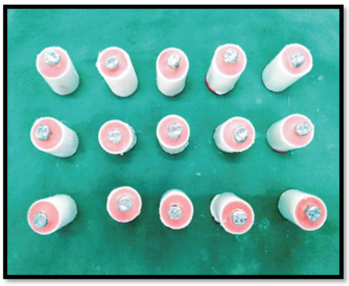

Figure 1: Extracted Teeth in Acrylic Block

Figure 2: Stainless Steel Crown Tooth Specimen under Compressive Load

Discussion:

This study was undertaken to determine the force required to fracture 4 types of SSCs in the first primary molar area and to statistically compare these values with the average occlusal load generated by 6- to 10-year-old patients, as reported previously. SSCs represent an attempt to meet parents' desires for a restoration while addressing dentists' desires for a durable restoration that can withstand the occlusal forces of mastication. In this study, all crowns tested through a single cycle were able to withstand occlusal forces equivalent to the previously documented bite force of young children in the first mandibular primary molar area. If SSCs are exposed to uniaxial force loads equivalent to those generated by children 6 to 10 years old, the crown should not fracture. Occlusal function is not uniaxial. Also, in clinical practice, the crown preparation is rarely a perfect match for the selected preformed crown. In addition, the chemical characteristics and the temperature of the oral environment cannot be strictly controlled.

As such, it is likely that fractures of the crown observed in clinical situations could be attributable to certain variables that are typically well controlled in experimental settings, including the multiaxial (rather than uniaxial) application of force, improper placement of crowns (with consequent development of stress or mechanical retention), cyclical application of occlusal forces by the patient, and variations in temperature or chemical characteristics within the oral environment. Any of these factors could lead to the discrepancy between the results of this study and the clinical failures that Ram and colleagues (12) observed in their in vivo study. The minimum and maximum values of force required to fracture the SSCs differed substantially among the 4 types of crowns. This disparity may be attributable to the mode of bonding between core and surface material in each crown and the ways in which the crowns failed.

Adhesion is defined as the interaction at the interface between 2 materials(13),whereas cohesion is the interaction between molecules within one material.(13) Because of differences in manufacturing processes and resulting differences in the use of mechanical and chemical adhesion for each type of crown, .(14) These crowns entail additional preparation time, because more tooth structure must be removed. In turn, the greater loss of tooth structure increases the risk of noncarious exposure of the pulp. However, SSCs do not offer pleasing solution to severe breakdown of a primary molar when composite resin or glass ionomer is contraindicated because insufficient tooth structure remains after removal of the caries. The option exists to place a laboratory-fabricated or milled crown, but because of the greater time required for scanning or fabrication of the impression, as well as enormous increase in cost, few parents would make this choice.

Conclusion:

In this study, the 4 brands of SSCs tested had similar fracture resistance to the application of uniaxial force. Further study is needed to evaluate their performance under cyclical and multiaxial force loads and thus to determine their potential for clinical success.

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