



ORIGINAL ARTICLE

Fracture resistance of different primary anterior esthetic crowns



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KEYWORDS

Preveneered;
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Abstract *Purpose:* Investigate and compare fracture resistance of four commercially available esthetic crowns.

Methods: Sixty-four anterior crowns were used: NuSmile Primary crowns (NuSmile, Houston, Tex. USA) (16); Preveneered Cheng Crowns, (Orthodontic Technologies Inc., Houston, TX) (16); NuSmile ZR (NuSmile, Houston, Tex. USA); and Cheng Crowns zirconia (Orthodontic Technologies Inc., Houston, TX). Crowns were mounted and cemented on a negative replica and placed under servo hydraulic mechanical universal testing machine. Force was applied at 90° with cross-head speed of 1 mm/min until they fractured. Maximum breaking loads were recorded. Data was then analyzed using software that measured the fracture resistance of the crowns. One-way Analysis of Variance (ANOVA) was used to find the differences between the groups and Scheffe post hoc test was used for intergroup comparisons. The level of significance was set as $p \leq 0.05$.

Results: Mean maximum loads were as follows: NuSmile ZR crowns (937.36 + 131.68 N), Cheng Zirconia Crowns (751.43 + 102.103 N), NuSmile Primary crowns (482.37 + 76.92), and Preveneered Cheng Crowns (415.57 + 12.28). Zirconia crowns the had highest fracture resistance compared to veneered crowns ($p < 0.05$). No significant difference between NuSmile ZR Zirconia and Cheng Crowns zirconia nor between NuSmile primary Preveneered and Preveneered Cheng Crowns.

Conclusion: Zirconia crowns showed the highest fracture resistance with NuSmile zirconia crowns to being able to resist fracture even under intense pressure of load compared to Cheng Crowns zirconia.

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1. Introduction

Historically, full coverage restorations have been in the form of stainless steel crowns (SSCs). Yet it often fails to meet the esthetic demands of patients (Beattie et al., 2011). Various options are available having its advantages and disadvantages that provides full coverage restoration for anterior primary dentition (Shah et al., 2004). Crowns for restoring primary

incisors falls into two categories: (1) those that are preformed and held onto the tooth by luting cement, and (2) those that are bonded to the tooth (Waggoner, 2015).

In the mid-1990s, preveneered stainless steel crowns (PVSSCs) were developed and marketed for primary anterior teeth restorations such as Cheng Crowns, Kinder Krowns, NuSmile Primary Crown, Whiter Biter II Crown (Baker et al., 1996; Yilmaz and Yilmaz, 2004). Each company has its own secrets that could not be revealed such as the materials used and the process of manufacturing the preveneered crowns (Waggoner and Cohen, 1995). However, Croll (1998) reported that the crowns are bonded to a welded meshwork in the crown. Beattie et al. (2011) reported that NuSmile crowns had a chemical union between the composite resin and the stainless steel metal. The stainless steel crowns are pre-bonded with resin veneer facings extending to all cosmetically prominent areas. A trade-off between their respective strengths and weaknesses is the combination of the two materials. Stainless steel is strong, resilient and malleable.

Waggoner and Cohen (1995) conducted a study testing the amount of shear force required to fracture or dislodge four primary esthetic preveneered stainless steel crowns and identify the veneer failures. Crowns included were: Cheng Crowns (CC), (Peter Cheng Orthodontic Laboratory); Kinder Krowns (KK) (Mayclin Dental Studio, Inc); NuSmile™ Primary Crowns (NC), (Orthodontic Technologies, Inc.); and Whiter Biter Crown® II (WB), (White Bite Inc.). Results indicated that The Whiter Biter Crown veneered primary stainless able to resist the highest force compared to other crowns tested WB (686.5 + 181.4), whereas NuSmile reported (447.2 + 78.5), Cheng Crwons was reported to be (511.9 + 83.4). Beattie et al. (2011) conducted a similar study testing the following crowns: EC crowns, (Dental Innovators, Austin, TX); Kinder Krowns, (St. Louis Park, MN); NuSmile Primary Crowns, (Houston, TX), and the results indicated no significant difference in force between the three crowns.

Waggoner and Cohen (1995) defined adhesive failure as a result in the entire facing being dislodged without breakage. A cohesive failure would result in the veneer remaining bonded to the metal but demonstrating breakage within the resin itself. A mixed failure would result when part, but not all, of the veneer was chipped from the metal-resin interface, leaving other resin still present and bonded.

Results of their study showed Whiter Biter II exhibited adhesive failures while the other three crowns experienced a mixed adhesive/cohesive failure that resulted in pieces, this study confirms that the type of fracture was also a mixed failure.

Various biomedical applications have been developed with the use of Zirconia as a biomedical resource, the latest being crowns for adult teeth. Further, it is currently used as a core material in full-ceramic crowns and bridges, implants, orthodontic brackets and in endodontic root posts (Kosmac et al., 2007). The physical characteristics of zirconia has been its preference allowing perfect suitability in the dental system with minimum challenges and complications (Kosmac et al., 2008). Its ability to resist fractures, high flexural strength, biocompatibility and the ability to withstand chemicals are some of the natural and physical characteristics that make it suitable. Apart from that numerous tests that have been conducted on zirconia, it was qualified as one of the best materials to be used for developing dental crowns. Manufac-

turers of the crowns took advantage of these qualities in opting to employ the use of zirconia in manufacturing the pediatric crowns.

For many years, zirconia crowns have been used in the field of dentistry (Townsend et al., 2014). Zirconia is one of the most promising ceramics due to its favorable mechanical properties and esthetics (Kosmac et al., 2008). In a study done by Townsend et al. (2014) zirconia crowns from three manufacturers as follows: EZ Pedo (EZP; EZ-Pedo, Loomis, Calif, USA); NuSmile ZR (NSZ; NuSmile, Houston, Tex. USA); and Zirconia Kinder Krowns (KKZ; Kinder Crown, St. Lewis Park, Minn., USA), with Preveneered NuSmile (NSW) SSCs being the controlled group. Thickness of the crowns at six different locations (mesial, distal, buccal, lingual, mesio-occlusal, and disto-occlusal) of all crowns was measured. Uniaxial compressive force was applied to the central groove until crown fractured. Results indicated that the force required to fracture the EZP crown was significantly higher than that required for NSZ and KK. The reason is because EZP crowns were significantly thicker in three of the six measured locations. In comparison to the control group, the forces required to fracture the preveneered stainless steel crowns were greater than the forces required to fracture all manufacturers' zirconia crowns.

Preveneered stainless steel crowns (PVSSCs) and zirconia crowns are new materials used in pediatric dentistry. Their use in the field of pediatric dentistry has been embraced due to its efficiency. The materials have different properties therefore they have different impacts when used. One of these properties is their ability to withstand external forces and resist fractures.

The aim of this study was to investigate and compare the fracture resistance of four commercially available primary anterior esthetic crowns.

2. Materials and methods

Sixty-four anterior crowns from two manufacturers were used in this study namely: NuSmile primary crowns (NuSmile, Houston, Tex. USA) (n = 16); Preveneered Cheng Crowns, (Orthodontic Technologies Inc., Houston, TX) (n = 16); NuSmile ZR Zirconia (NuSmile, Houston, Tex. USA) (n = 16); and Cheng Crowns zirconia (Orthodontic Technologies Inc., Houston, TX) (n = 16). Each replica was placed under servo hydraulic mechanical universal testing machine.

In the first step, all crowns were filled with Interacrylic Ortho Resin (Interacrylic Ortho, Interdent, Celje, Slovenia) and was allowed to set for 24 h (Fig. 1). The crowns and dies were tried on to ensure a passive fit (Fig. 2). Any visible undercuts in the dies were removed with a composite finishing bur. Each Crown replica was then embedded in PVC (polyvinyl chloride) filled with Interacrylic Ortho Resin (Interacrylic Ortho, Interdent, Celje, Slovenia) and allowed to set for 24 h (Fig. 3). A negative replica of each company's crown was duplicated with Deguform® Plus (Dentsply International, Germany) and was allowed to set for 24 h (Fig. 4). With four negative master impressions, they were used to fabricate an ideal ortho resin die for each crown and were set for 24 h. The esthetic crowns were cemented on the acrylic with glass ionomer cement (G-Cem, GC Corporation, Alsip, IL) according to manufacturer's instructions. The die-crown units were then allowed to set for 24 h. Each die with cemented crown

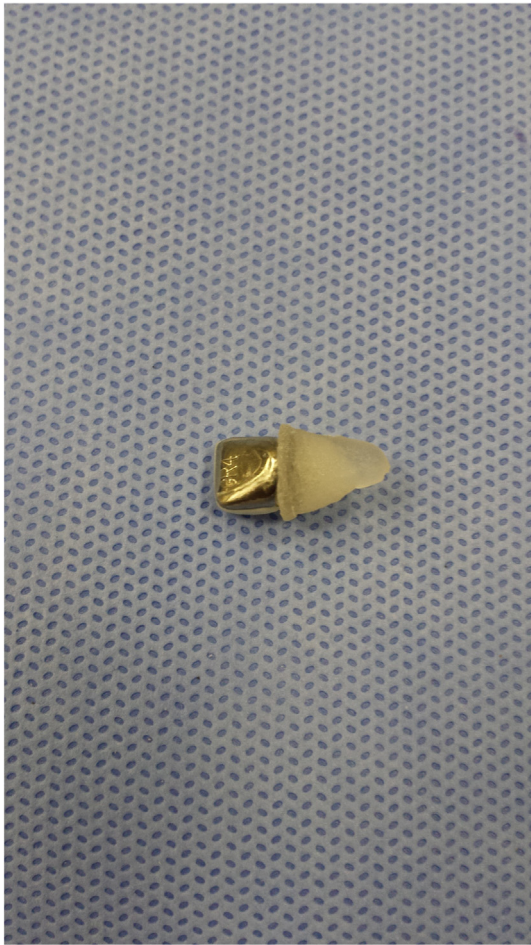


Fig. 1 Crowns were filled with InteracrylicOthro Resin.

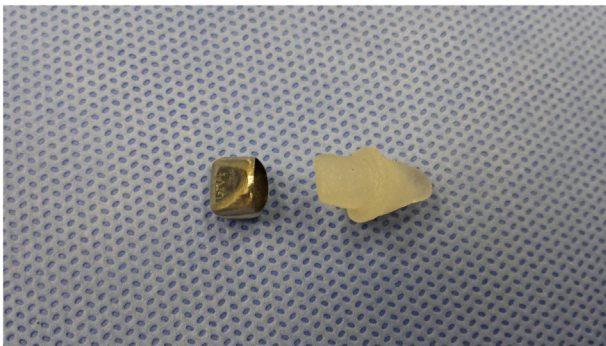


Fig. 2 Passive fit was insured to all crowns.

was placed into a custom holder on a servo hydraulic mechanical universal testing machine (Instron, Model 5965, Norwood, MA), where force was applied to the crowns at an angle of 90° with a crosshead speed of 1 mm/min. on the mid incisal tip till they fractured. Maximum breaking loads were recorded in Newtons (N). As for veneered stainless steel crowns, the force was recorded when the veneer facing fractured off the steel crown.

Data was entered into the computer and analyzed using Statistical Package for Social Sciences (IBM, SPSS) version

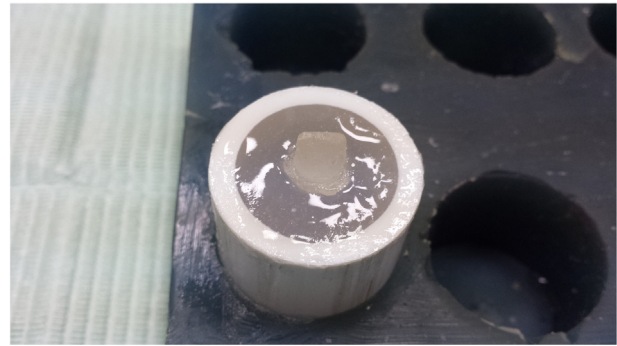


Fig. 3 Crown replica placed in cone filled with InteracrylicOthro Resin.



Fig. 4 Deguform® Plus (Dentsply International, Germany) duplicating material poured over the replica.

20. Microsoft Excel Spreadsheet was also used in sorting and preparation of the data for analysis. Descriptive analysis was undertaken to present an overview of the findings and frequency tables were generated. One-way Analysis of Variance (ANOVA) was used to find the differences between the groups and Scheffe post hoc test, for intergroup comparisons. The level of significance was set as $p \leq 0.05$.

3. Results

A total of sixty-four crowns, sixteen crowns in each group, were all placed randomly under the servo hydraulic mechanical universal testing machine. No visible failures in any of the crowns were seen, therefore, no samples were excluded.

Table 1. shows the mean force required to fracture primary anterior esthetic crown. NuSmile Zirconia crowns showed the highest load to fracture ($937.36 + 131.68$), while Preveneered Cheng Crowns showed the lowest ($415.57 + 12.28$).

Table 1 The mean force required to fracture primary anterior esthetic crown.

Group	N	Mean	Standard deviation
Cheng Crowns Preveneered	16	415.58	12.28
Cheng Crowns Zirconia	16	751.43	102.1
NuSmile primary crowns	16	482.37	76.94
NuSmile Zirconia crowns	16	937.36	131.69
Total	64	646.68	229.62

Table 2 Scheffe post hoc test of four groups of esthetic crowns.

(I) Group	(J) Group	Mean difference (I-J)	Std. error	Sig.
Cheng Crowns Preveneered	Cheng Zirconia Crowns	-335.87*	32.52	0.000
	NuSmilePreveneered	-66.79	32.52	0.250
	NuSmile Zirconia	-521.79*	32.52	0.000
Cheng Crowns Zirconia	Cheng Preveneered Crowns	335.86*	32.52	0.000
	NuSmilePreveneered	269.07*	32.52	0.000
	NuSmile Zirconia	-185.93*	32.52	0.000
NuSmilePreveneered	Cheng Preveneered Crowns	66.79	32.52	0.250
	Cheng Zirconia Crowns	-269.06*	32.52	0.000
	NuSmile Zirconia	-454.99*	32.52	0.000
NuSmile Zirconia	Cheng Preveneered Crowns	521.79*	32.52	0.000
	Cheng Zirconia Crowns	185.93*	32.52	0.000
	NuSmilePreveneered	454.99*	32.52	0.000

* The mean difference is significant at the 0.05 level.

One-way ANOVA indicated that there was a statistically significant difference ($p = 0.000$) in load among the four groups. The Scheffe's post hoc test (Table 2.) revealed a significant difference ($p = 0.00$) between the Cheng Crowns Preveneered and Cheng Crowns Zirconia, Cheng Crowns Preveneered and NuSmile Zirconia, Cheng Crowns Zirconia and NuSmilePreveneered, Cheng Crowns Zirconia and NuSmile Zirconia, and NuSmile Preveneered and NuSmile Zirconia groups.

Both zirconia crowns showed statistically significant difference in force required to fracture the crowns it in comparison to preveneered stainless steel crowns ($p \leq 0.05$). However, there was statistically no significant difference between Cheng Crowns Preveneered and NuSmile Preveneered groups.

4. Discussion

From the results of this study, it is evident that the zirconia crowns performed better than the preveneered crowns. The significance in difference is attributed to the fortifying features of the zirconia crowns that makes them excellent for use as crowns. The results further confirm the clinical studies and evaluations done before which also concluded that zirconia crowns are excellent for use in crown restorations. More studies testing zirconia used in primary crowns are needed but Prior studies were done in permanent crowns by Kim et al. (2012), Nergård and Lægred (2014), Nakamura et al. (2015).

Vagkopoulou et al. (2009), Denry and Kelly (2008), and Manicone et al. (2007) also concluded that zirconia crowns were of high-caliber compared to the crowns made from other materials.

The ceramic of Zirconium dioxide (zirconia) which is used to fix and restore the teeth framework has favorable mechanical and optical characteristics that makes it able to withstand so much load (Sundh and Sjogren, 2006). The study by Nakamura et al. (2015) concluded that they use zirconia because of its satisfactory performance in meeting the clinical requirements of crown restoration due to its capacity to resist the pressure and forces that holds the crowns just as in the experiment. The same findings were made by Kim et al. (2012), Nergård and Lægred (2014), Nakamura et al. (2015), Vagkopoulou et al. (2009), Denry and Kelly (2008), and Manicone et al. (2007), which makes Zirconia an ideal material

to use in making crowns due to its ability to withstand fracture (Kosmac et al., 2000).

Features of the NuSmile zirconia crowns that made it as the best performer in this experiment is its additional scientific based designs that entail the use of anatomical contours as well as unique shaping and precise thickness (Al-Amleh et al., 2010). These aspects not just beautify the crown but go further to strengthening the crown while minimizing possible chances of teeth reduction or abrasion through the mouth activity that directly or indirectly involves the dental cavity (Johansson et al., 2013). The NuSmile crown is highly polished minimizing plaque accumulation and aids in protecting the dental cavity of the mouth (Beuer et al., 2012).

A study by Townsend et al. (2014) was done to measure the fracture resistance of primary mandibular first molar zirconia crowns from three different manufacturers - EZ Pedo (Ezp), NuSmile (NSZ), and Kinder Krowns (KK) – and compared it with the thickness of the zirconia crowns and the measured fracture resistance of PVSSCs. In his study, he found that EZP crowns were significantly thicker in three of the six measured locations. The force required to fracture the EZP crown (1091 N) was significantly higher than that required for NSZ (691 N) and KKZ (576 N). There was a positive correlation between fracture resistance and crown thickness in the mesial, distal, mesioocclusal, and distoocclusal dimensions. None of the zirconia crowns proved to be as resistant to fracture as the PVSSCs (Townsend et al., 2014). The results of our study indicate the opposite that zirconia crowns were able to stand the highest force to fracture compared to the preveneered crowns.

Aside from the numerous tests that have qualified NuSmile crowns as the closest to natural enamel of the teeth, its immediate chemistry is evident in resisting fractures (Denry and Kelly, 2008). NuSmile zirconia pediatric crowns ensures health of the gingiva and perfect fitting due to its ability to naturally replicate its translucency (Wegner and Kern, 2000).

Preveneered crowns were meant for primary anterior tooth restorations (Baker et al., 1996; Yilmaz and Yilmaz, 2004). They were designed and composed of composite resins attached to a metal coping either chemically or mechanically. As a strategy to maintain a competing edge in the market, materials used to process and manufacture the Preveneered crowns were withheld by the respective producing companies

initially (Waggoner and Cohen, 1995). Croll (1998), however, reported that the crowns were made by being bonded to a welded meshwork in the crown. It was reported for instance that NuSmile crowns were designed by a chemical uniting the composite resin and the stainless steel metal. Such design was achieved by ensuring that the Stainless steel crowns were pre-bonded together with resin veneer that were made to face and extend to all cosmetically prominent areas (Beattie et al., 2011). This, as a strategy explains, why the veneered teeth are seemingly weak and unable to resist against external forces applied on them. The combination of the two materials created room for the potential strengths and weaknesses of the crowns.

Stainless steel is characterized as strong, resilient and malleable with thickness of 0.2 mm and is considered as clinically acceptable (Beattie et al., 2011), while the composite or porcelain restorations ensures the esthetic tooth shades as well as hide the metallic appearance of the base structure. It was these esthetic materials which were placed at a thickness of 1.5–2 mm that were meant to aid the crowns in withstanding the occlusal forces experienced by a patient. Combined, the two materials formed a crown consisting of stainless steel which is thin yet the foundation of strength for the composite or porcelain that is supposed to present the restoration with a tooth-like appearance (Beattie et al., 2011). Aboushelib's et al. (2006) study of veneered crowns concluded that the challenges of using the veneered crowns include the fact that they are relatively inflexible yet brittle which means that when the resin is overloaded excessive compression or other forces, they tend to break.

Veneered crowns are also unable to withstand a lot of force and pressure because of crimping especially the lingual surface due to the fact that the crowns are forced on the teeth. In getting the veneered crowns fixed, the teeth often have to be subjected to significant removal of tooth structure in an effort to ensure that the crown is a passive fit and this affect the strength of the crown and teeth to withstand the external force (Croll, 1998; MacLean et al., 2007). Preference for the veneered especially in comparison to the other crowns such as the SSCs is because they are easily inserted in one single appointment, and furthermore, their esthetics are unaffected by saliva or hemorrhage (Croll, 1998). The caution in using them however is because they are relatively inflexible and brittle due to the fact that their resin facing material breaks easily when exposed to heavy forces.

The study done by Baker et al. (1996) on veneered crowns is another reservation in using veneered crown due to the limited shades available and the difficulty in inserting multiple approximating crowns in patients who have problems of crowding or loss of space due to bulk. Also veneered crowns begin to develop fractures with time because of their brittle nature. Some of the strategies to counter the problems of facing teeth are the heat sterilization that effecting the resin facing. Types of veneered crowns in the market varies depending on method of facing attachment, the availability of the shades, the length of the crowns and the ability of the clinician to crimp the crown (Waggoner, 2015).

5. Conclusions

In conclusion, Zirconia crowns showed the highest fracture resistance and the NuSmile zirconia crowns were proven to

resist fracture even under intense pressure of load compared to Cheng Crowns zirconia.

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