ORIGINAL RESEARCH

Three-dimensional Evaluation of Wear of Primary Teeth Opposing Various Posterior Pediatric Crowns after Aging Procedures: An *In Vitro* Study

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Abstract

Aims and background: Neglecting to replace diseased or decayed teeth results in different dental illnesses, some of which may require extensive and expensive treatment. Stainless steel crowns (SSCs) still remain optimal for primary molar rehabilitation, yet some disadvantages prompted the introduction of esthetic alternatives: zirconia (ZC) and Bioflx (BF) crowns. Comparing their wear effects on opposing natural teeth is crucial for clinical decision-making. Hence, the aim of this study is to evaluate and compare the wear of primary teeth opposing various pediatric crowns after aging procedures, using a three-dimensional surface scanner.

Materials and methods: Ten natural primary maxillary second molars (control group A) and ten primary molar crowns in each group—SSCs (group B), ZC (group C), and BF (group D)—were antagonized against primary second mandibular molars. Aging procedures included artificial saliva immersion, thermocycling, and two-body wear testing. Prescan and postscan images were obtained and superimposed using a 3D scanner. Statistical analysis was done using one-way ANOVA and *post hoc* tests with a statistically significant level of $p < 0.05$.

Results: Mean volumetric loss of antagonist teeth in group C (ZC) was 3.37 ± 0.198, followed by similar results in group D (BF), which was 2.21 ± 0.33; group B (SSC) was 2.03 ± 0.36, where all values were statistically significant with the *p*-value of < 0.05.

Conclusion: Bioflx crowns express similar antagonistic tooth wear compared to SSCs, while ZC were distinguished with higher values.

Clinical significance: These insights help clinicians choose materials that effectively restore both function and esthetics while considering differences in tooth structure and occlusion, which are termed to be essential aspects of pediatric dentistry.

Keywords: Antagonist tooth wear, Bioflx, Pediatric crowns, Three-dimensional scan.

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Introduction

In pediatric dentistry, deciduous teeth rehabilitation is essential for preserving space, assuring healthy chewing, and directing the emergence of permanent teeth. Malocclusion, early tooth loss, and complicated orthodontic problems that may later require extensive, costly treatment arising due to failure in the replacement of damaged or decayed primary teeth.[1] The AAPD states that crowns should be luted to teeth treated by pulpotomy, pulpectomy, and teeth affected by developmental abnormalities or severe tissue loss.[2]

Stainless steel crowns (SSCs) have been regarded as the pinnacle of quality for about 70 years because of their affordability, longevity, and comparatively easy placement. Thin crown margins allow for good adaptation while maintaining acceptable marginal quality. Macroscopic mechanical retention is consistently attainable due to the morphological features of primary molars. However, parents are concerned about the nickel levels and the unattractive metal appearance.[3] Numerous esthetic crowns, including ZC, BF, and Edelweiss, have been introduced to the market over the last decade. Zirconia crowns are polycrystalline ceramic-based material, are highly esthetic, durable, and biocompatible. They are resistant to high temperatures but expensive. To restore primary teeth, they need a drastic, aggressive strategy with subgingival preparation margins, which can frequently result in exposed pulp chambers along with occasional gingival hemorrhaging or chipping/fracture concerns, as well as a substantial amount of antagonist wear, which can jeopardize ZC retention.[4–7]

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Bioflx crowns are high-strength hybrid resin polymers with enhanced durability, flexibility, and a snug fit. The sand-blasted intaglio surface for enhanced retention shows capacity for self-adaptation. Recent studies suggest them as an alternative for full coverage restoration.[8]

A complicated and multifaceted phenomenon as promptly occurring as tooth wear is brought on by the interplay of mechanical, chemical, and biological forces. Teeth wear may vary according to individual factors such as the chewing force, dietary habits, and type of dental restoration. Prevalence of tooth wear into the dentin of deciduous teeth in children increases linearly with age.[9]

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When compared to natural teeth, dental restorations have differential wear characteristics that influence the deterioration rates occurring in opposed natural teeth. Because of the flexibility of the stomatognathic framework, severe occlusal wear in the primary teeth might be sustainable with good oral health; however, rapid wear exposing the pulp or causing a significant vertical height loss can lead to pulpal inflammation, TMJ issues, or impaired function.[10]

Unfortunately, clinical verification of enamel wear as compared to restorative materials is difficult to obtain. On the other hand, *in vitro* research can provide this data. Replicating the complexity of the masticatory system by means of wear simulation can predict the longevity of dental materials. Therefore, a two-body wear test can replicate the attrition, friction, and fatigue wear brought on by intimate occlusal interaction between materials and teeth, hence quantifying the amount of wear resistance while swallowing and nonfunctional kinetic occlusal motions.[11]

In contrast to stereo microscopical examination, which necessitates sectioning specimens, 3D wear assessment is a nondestructive technique. It has been shown to be an extremely accurate test that gives quantitative readings over the entirety of the natural teeth/restoration surface.[12]

Little data exists comparing primary tooth wear to different posterior pediatric crowns following aging procedures. Therefore, the purpose of this study is to use a 3D surface scanner in order to evaluate and contrast the wear of primary teeth against different posterior pediatric crowns following aging procedures. Given that natural teeth opposing different crowns do not significantly vary in terms of wear, the null hypothesis was proposed.

Materials and Methods

The nature and purpose of the study were explained, and authorization from the Institutional Review Board was attained (VDCW/IEC/464/2024). An *in vitro* trial was done with a total sample size of 40, as mentioned below:

- Group A (10)—Primary 2nd maxillary molars against primary 2nd mandibular molars
- Group B (10)—Stainless steel crowns against primary 2nd mandibular molars
- Group C (10)—Zirconia crowns against primary 2nd mandibular molars
- Group D (10)—Bioflx crowns against primary 2nd mandibular molars

Natural Teeth Preparation

Forty primary mandibular 2nd molars naturally exfoliating, caries-free, without any visual wear loss, were included. Fractured and severely worn teeth were excluded from the study. The selected samples were embedded in self-cured acrylic resin using uniform molds.

Crown Preparation

Ten primary maxillary 2nd molars (A) control; 30 primary maxillary 2nd molars crowns were selected from three available brands—(B) stainless steel–E7 (Kids-E crown), (C) zirconia–size 7, (D) Bioflx–size 4. Metal dies were formulated by creating a negative replica of the crowns, which were later mounted on resin blocks.[10] Then crowns were cemented conferring to the producer's directions, followed by a setting time of 24 hours.

Prescan Imaging

Primary mandibular 2nd molars antagonizing each group of crowns were evaluated as baseline values before aging procedures using a 3D scanner.

Artificial aging by placing in artificial saliva for 30 days at 37°C. Thermocycling was done with alternate cold bath at 5°C and hot bath at 55°C; ascending and descending speed of 30 mm/s, vertical and horizontal movement of 3 mm and 2 mm, respectively, with dwell time of 60 seconds. Two-body wear operation was performed under a CE of 50 N for 1,20,000 cycles with a cycle frequency of 1.6 Hz by a dual-axis chewing simulator (Fig. 1) with natural teeth specimens opposing preformed cemented crowns.

Postscan Imaging

Prescanned samples were assessed after aging procedures by a 3D scanner, and they were compared by superimposing images.

IBM SPSS Statistics for Windows, Version 26.0, Armonk, NY: IBM Corp., Released 2019, was used for evaluating the data. The values of the standard deviation and mean were employed to express the descriptive statistics. The Shapiro–Wilk and Kolmogorov–Smirnov normality examinations were performed. The data were found to be normally distributed. Inferential statistics were done by using one-way ANOVA followed by *post hoc* analysis to assess maximum volumetric loss among groups. Significance level was fixed as 5% ($\alpha = 0.05$). A p-value < 0.05 is considered to be statistically significant.

Results

Table 1 and Figure 2 illustrate volumetric loss of natural teeth, antagonizing various crowns after wear analysis. Significant differences emerged among groups, with ZC (group C) showing the highest wear, averaging 3.37 ± 0.198, followed by BF (group D) at 2.21 ± 0.33, and SSC crowns (group B) at 2.03 ± 0.36, all possessing significant statistical values with $p < 0.05$. Table 2 demonstrates intergroup comparisons, revealing SSC to cause minimal wear compared to the others. Figures 3A to D displays superimposed pre- and postwear images of natural teeth antagonizing various crown groups from oral simulation, and Figure 3E highlights stress areas in green that correspond to increased tooth material wear levels across the samples. Findings highlight the impact of crown material and design on wear outcomes.



Fig. 1: Chewing simulator

Table 1: Wear of natural teeth on comparison of pre- and postwear analysis

Groups	*Prewear*	*Postwear*	*Volumetric loss*	*F*	*Sig*
A	133.9010 ± 1.05640	132.1620 ±1.21846	1.73900 ± 0.48864	39.321	0.00
B	99.8920 ± 0.40353	97.8540 ± 0.64741	2.03800 ± 0.36104		
C	181.61410 ± 0.626182	178.24040 ± 0.660963	3.373700 ± 0.198789		
D	134.6310 ± 0.73804	132.42040 ± 0.842826	2.210600 ± 0.336178		

Table 2: Intergroup comparison of volumetric loss in natural teeth against crowns

(I) category	*(J) category*	*Mean difference (I-J)*	*p-value*
NT	SSC	–0.30	0.01
	ZC	–1.10	0.000
	BF	–0.70	0.001
SSC	NT	0.30	0.01
	ZC	–0.80	0.000
	BF	–0.40	0.344
ZC	NT	1.10	0.000
	SSC	0.80	0.000
	BF	0.40	0.045
BF	NT	0.70	0.001
	SSC	0.40	0.344
	ZC	–0.40	0.045

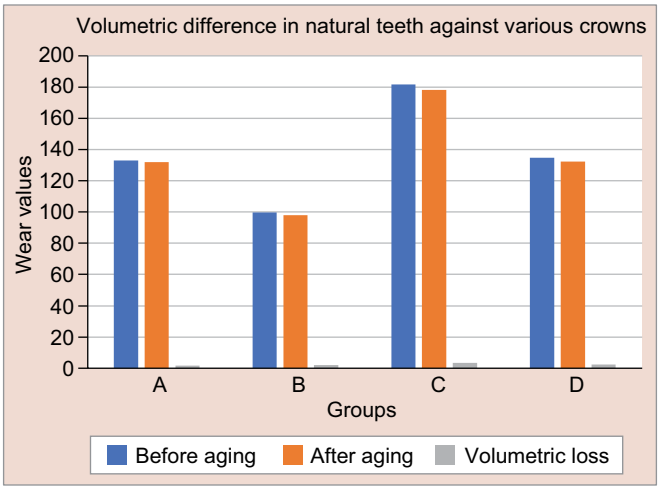


Fig. 2: Volumetric difference in natural teeth against various crowns

Discussion

Primary tooth prosthetic rehabilitation restores function and occlusion, while multifactorial wear gradually deteriorates tooth surfaces. Clinicians must balance mastication, esthetics, and preservation using SSCs or BF crowns, each with distinct benefits and limitations.[13]

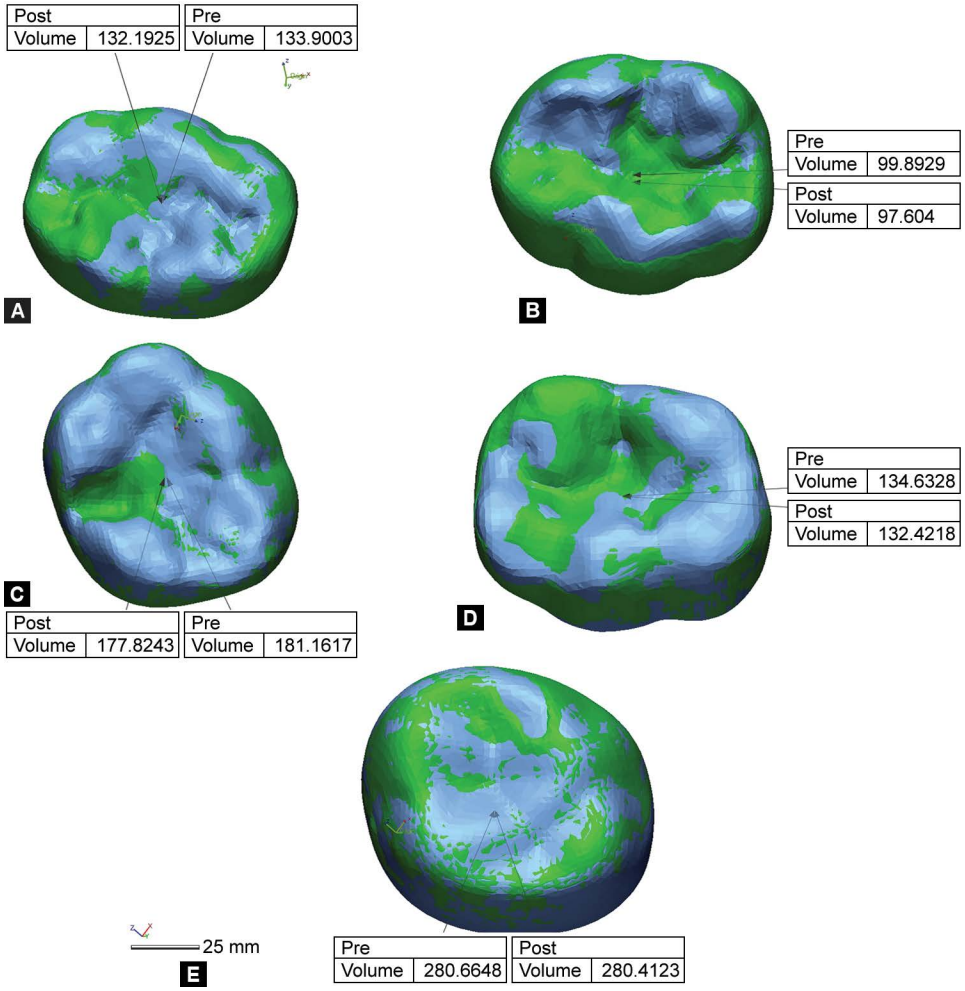
Dental wear is a challenging process that is impacted by both chemical and mechanical variables, leading to progressive breakdown of tooth structure.[14] Regarding this evaluation, pivotal aspects that come to forefront are inherent resistance of material to wear, and its effect on the opposing dentition making it two distinct yet interrelated phenomena.[15] Tooth wear may lead to pulpal irritation with hypersensitivity or pulpitis, esthetic compromise, and functional disturbances affecting occlusal and proximal relationships.[16] So, in this study, we evaluated and compared wear of primary teeth against three commercially available crowns.

Although *in vitro* studies cannot perfectly capture complexities of an *in vivo* environment, they provide valuable preliminary insights into properties of restorative materials. By simulating a close to oral environment, various aging procedures were employed in this study.[17] Incorporating thermal cycling replicates fluctuations in oral temperature, thus mimicking the aging process. Loading force is an essential part of an *in vitro* wear test study. 49–50 N is the mean value of physiological occlusal forces, and the experimental setup employed 50 N for 120,000 chewing cycles.[18] To replicate intraoral chewing mechanisms as nearly as feasible, thermocycling and two-body wear simulation were used in this investigation.

Wear distribution seen in primary dentition is asymmetric; Warren et al.[19] have indicated that anterior teeth tend to exhibit more wear than the posterior molars, with maxillary teeth enduring more pronounced wear compared to their mandibular counterparts. These differences are largely a result of variations in tooth morphology and occlusal relationships, which markedly influence wear patterns. In our work, strict standardization of tooth samples was maintained to ensure that these intrinsic variabilities were accounted for, thereby mirroring clinical realities as closely as feasible.

Overall results established a statistically significant difference among all the groups, while BF has similar antagonistic wear rates as SSC, and still, SSCs prove to be the gold standard. This aligned with Amer et al.,[20] Choi et al.,[14] where the SSC group had the least wear rate, as occlusal pressures were absorbed by the ductility of steel.

In our study, natural teeth antagonizing ZC showed a lower level of wear resistance. This result supports the findings of Möhn et al.,[21] using a similar protocol of thermocycling and chewing simulation, who revealed ZC caused high antagonistic wear when compared to other groups. Talekar et al.,[22] reported that glass-fiber-reinforced composite discs (GFRC) producing greater wear loss compared to zirconia. When zirconia and GFRC came into contact, antagonistic tooth wear was more noticeable. Additionally, zirconia has a microhardness that is roughly ten times greater in comparison with natural teeth.



Figs 3A to E: Superimposed images of natural teeth from top left (A) group A; (B) group B; (C) group C; (D) group D; (E) Bioflx

According to Kinay Taran et al.,[23] opposing primary teeth experienced more wear as a result of prefabricated crowns of monolithic zirconia type. Sripetchdanond et al.[24] reported zirconia and composite resins generating far less enamel wear than natural teeth.

Amer et al.[20] found that esthetic crowns produce greater wear in the antagonistic enamel of primary molar SSC and that CAD/CAM hybrid crowns, an appealing tooth-colored alternative, caused less wear of the opposing enamel than ZC. In this study, the subtly increased wear trend in antagonistic teeth of zirconia aligns with existing literature.

On the contrary, Bolaca et al.,[25] suggested zirconia to be the preferred material for complete coronal restoration in deciduous teeth, because it causes less oppositional tooth wear than lithium disilicate, resin nanoceramic, and nanohybrid composite resin. Also, Murali et al.,[26] documented that both SSCs and ZC maintained stable proximal contact and resulted in negligible wear on opposing teeth over a 1-year observation period.

In recent years, BF crowns have gained favor in the realm of pediatric dentistry. Their rising popularity can be attributed to their exceptional combination of durability, superior esthetics, and enhanced flexibility. Studies such as those conducted by Goswami et al.,[27] have identified these crowns as a promising substitute for conventional SSCs and ZC for over a 6-month period, in terms of good retention and esthetic results. On the contrary, Patil et al.,[28] have indicated that primary molars fitted with either BF or SSCs did not exhibit any signs of opposing tooth wear over a period of 12 months.

Our investigation further incorporated scanning methodologies to evaluate the wear behavior of BF. It implies that the stress generation undergone by restorative crown material gets dissipated, such that the overall surface area of the crown experiences some amount of wear, or in the worst case, it forms occlusal dimples as reported by the manufacturer. Hence, the crown compiles in maintaining the harmony of the oral cavity. Assessments reveal minimal material loss and confirm Deolikar et al.'s[29] findings as BF generating lower internal stress than zirconia, combining mechanical resilience, esthetic superiority, and reduced antagonist wear. Their enhanced elasticity limits stress transfer and resultant wear on opposing dentition.

Future studies should aim to extend the monitoring period by employing *in vivo* experiments to accurately capture wear progression under everyday oral conditions. Moreover, a detailed biomechanical analysis of stress distribution across various crown designs could provide further insight into how these restorative solutions interact with natural primary dentition.

Conclusion

Notably, the promising performance of BF crowns, which exhibit enhanced flexibility and reduced antagonist wear as well as restorative material wear, supports their potential use when

compared to ZC when high-end esthetics are not of prime concern. Thus, ensuring a viable option in long-term, evidence-based treatment strategies, as well as further clinical validation, is to be highlighted.

Clinical Significance

These findings guide clinicians in selecting materials that optimize function, esthetics, and occlusion. Advancing prosthetic care in pediatric dentistry depends on identifying materials that minimize wear-related complications, ensuring a holistic, evidence-based approach to treatment.

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