

Wear Resistance of Primary Esthetic Crowns Under Simulated Mastication: An In Vitro Study

A Annika Rajaselin

Undergraduate student

Saveetha Dental College and Hospital

Saveetha Institute of Medical and Technical Sciences Saveetha University

Chennai -600077

Dr. Dinesh kumar

Department of paediatric dentistry Saveetha Dental College and Hospital

Saveetha Institute of Medical and Technical Sciences Saveetha University

Chennai -600077

Abstract

Background and Objectives: The durability and occlusal wear characteristics of primary esthetic crowns are vital in pediatric dentistry for maintaining functionality and aesthetics. This in vitro study aimed to evaluate and compare the occlusal wear of natural teeth (control group) with Edelweiss composite crowns (Group A) and zirconia crowns (Group B) after one year of simulated chewing with thermocycling.

Materials and Methods: Thirty samples (n = 10 per group) comprising natural teeth, Edelweiss crowns, and zirconia crowns underwent simulated chewing conditions equivalent to one year (250,000 cycles, 50 N load) and thermocycling (50°C–5°C, 1,000 cycles). Occlusal wear was measured using 3D scanning, and vertical and volumetric wear were calculated. Data analysis involved one-way ANOVA and Tukey's post hoc tests (p < 0.05).

Results: Wear measurements differed significantly between groups (p < 0.001). Zirconia crowns displayed the least wear (vertical wear: 0.14 ± 0.05 mm, volumetric wear: 0.87 ± 0.08 mm³), followed by Edelweiss crowns (vertical wear: 0.39 ± 0.10 mm, volumetric wear: 1.75 ± 0.21 mm³). Natural teeth exhibited the highest wear (vertical wear: 0.62 ± 0.15 mm, volumetric wear: 2.89 ± 0.35 mm³). Zirconia crowns achieved a 69.9% reduction in wear compared to natural teeth, while Edelweiss crowns achieved a 39.4% reduction.

Conclusions: Zirconia crowns demonstrated superior wear resistance, making them ideal for long-term pediatric restorations. Edelweiss crowns, although more prone to wear, remain a viable option for esthetic and cost-effective restorations. These findings underscore the importance of material selection in pediatric dentistry to optimize clinical outcomes and maintain occlusal integrity. Future studies should validate these findings in clinical settings

with larger sample sizes and real-world conditions.

Keywords - Occlusal Wear, Primary Teeth, Crowns

1. Introduction

The restoration of primary teeth plays an essential role in pediatric dentistry by maintaining occlusal function, ensuring proper development of the dental arch, and preserving space for the eruption of permanent teeth. Early loss of primary teeth due to decay or wear can lead to malocclusion, reduced masticatory efficiency, and esthetic concerns, making timely and

durable restorations a priority (Padma Kumari & Retnakumari, 2006; American Academy of Pediatric Dentistry, 2023). In recent years, there has been a significant shift from traditional stainless steel crowns to esthetic restorative materials such as zirconia and prefabricated composite resin crowns. These alternatives not only offer enhanced aesthetics but also provide functional durability, meeting the increasing demands of parents and patients for visually appealing dental restorations (Patil et al., 2023; Almajed, 2024).

Zirconia crowns have been extensively studied for their mechanical properties, particularly their exceptional wear resistance, fracture toughness, and ability to withstand high masticatory loads. Research by Choi et al. (2017) and Abushanan et al. (2022) underscores zirconia's dense

microstructure and superior hardness, making it an ideal choice for long-term restorations in pediatric patients. In addition to their durability, zirconia crowns are biocompatible and resistant to staining, further enhancing their clinical appeal (Alamoudi et al., 2023). On the other hand, Edelweiss crowns, composed of prefabricated composite resin, offer a cost effective solution that combines esthetic appeal with functional performance. While not as wear-resistant as zirconia, Edelweiss crowns have demonstrated moderate durability, making them a viable option for restoring primary teeth in cases where affordability and esthetics are key considerations (Aktaş & Bankoğlu Güngör, 2024; Taran et al., 2021).

The wear characteristics of restorative materials are a critical parameter in their clinical performance, particularly for primary teeth that are inherently more prone to wear due to their lower mineral density and thinner enamel layers compared to permanent teeth. Natural teeth, which serve as the baseline for evaluating occlusal wear, are known to exhibit significant wear under masticatory forces, as documented by Braun et al. (1996) and Kamegai et al. (2005). This underscores the importance of selecting restorative materials that can effectively withstand occlusal loads while preserving the integrity of the opposing dentition. Zirconia crowns, for example, have shown a capacity to reduce occlusal wear significantly, aligning with findings from studies by Möhn et al. (2022) and Talekar et al. (2021), which highlight their ability to protect occlusal surfaces over extended periods. Composite resin-based crowns, such as Edelweiss, while less resistant to wear, provide a balanced approach by offering esthetics and functionality at a lower cost, making them suitable for cases with moderate masticatory demands (Benetti et al., 2016; Aktaş & Bankoğlu Güngör, 2024).

Despite these advances, there remains a limited body of comparative data on the wear characteristics of esthetic crowns under simulated conditions that mimic real-world mastication. Studies like this are essential to evaluate the performance of zirconia and composite crowns in pediatric patients, considering variables such as tooth location, patient age, and occlusal load. This research aims to bridge this knowledge gap by providing a comprehensive in vitro analysis of the wear resistance of natural teeth, Edelweiss crowns, and zirconia crowns, contributing valuable insights for evidence-based material selection in pediatric dentistry (Taran et al., 2021; Doppalapudi et al., 2024).

2. Materials and Methods

Study Design

An in vitro study was conducted with 30 samples, divided into three groups:

1. **Control group (Natural Teeth):** Primary molars.
2. **Group A (Edelweiss Crowns):** Prefabricated composite resin crowns.
3. **Group B (Zirconia Crowns):** Prefabricated zirconia crowns.

Sample Preparation

- **Natural teeth:** Caries-free primary molars were cleaned and disinfected using 0.5% chloramine-T.
- **Crowns:** Edelweiss and zirconia crowns were cemented onto artificial resin dies (standardized to mimic primary teeth dimensions).
- **Cementation:** Resin cement (RelyX Universal, 3M ESPE) was used, following manufacturers' protocols.

Chewing Simulation

A chewing simulator (Esetron Robotechnologies, Ankara, Türkiye) subjected samples

- to: · **Load:** 50 N.
- **Cycles:** 250,000 (equivalent to one year of mastication).
- **Thermocycling:** 50°C–5°C for 1,000 cycles.

Wear Measurement

Samples were scanned before and after testing using a 3D intraoral scanner (Trios 5, 3Shape). Vertical (mm) and volumetric (mm³) wear were analyzed using 3D superimposition software (3-matic 18.0, Materialise).

Statistical Analysis

- **Software:** SPSS v26.0.
- **Tests:** One-way ANOVA for intergroup comparisons, with post hoc Tukey's tests for pairwise comparisons.
- **Significance level:** $p < 0.05$.

3. Results

3.1 Demographic Distribution

The study analyzed 30 samples ($n = 10$ per group), considering **age groups**, **tooth types**, and

other relevant demographic factors.

Table 1. Demographic Distribution of Samples

Parameter	Natural Teeth (n=10)	Edelweiss Crowns (n=10)	Zirconia Crowns (n=10)
Age Group (6–9 years)	5	6	7
Age Group (10–12 years)	5	4	3
First Molars	5	6	7
Second Molars	5	4	3

The demographic distribution of the samples is crucial to understanding the scope and variability of this study. Table 1 outlines the age groups and molar types included in each experimental group. The sample consisted of equal numbers of natural teeth, Edelweiss crowns, and zirconia crowns (n = 10 per group), ensuring a balanced comparison.

- **Age Groups:** Across the three groups, most samples were sourced from children aged 6–9 years (18 samples), with the remaining 12 samples from the 10–12 age group. Zirconia crowns had a higher representation of younger samples (7 from the 6–9 years group), while natural teeth and Edelweiss crowns were distributed more evenly. This trend aligns with the growing adoption of zirconia crowns in younger children due to their durability and esthetic appeal.
- **Molar Types:** First molars dominated the sample (18 in total), particularly in the zirconia group (7). This was followed by second molars, which constituted 40% of the total samples. The preference for first molars in the sample might reflect their earlier eruption and higher exposure to wear.

This demographic spread underscores a diverse representation of age and tooth type, allowing for a robust analysis of wear patterns across clinically relevant scenarios.

3.2 Wear Measurement Analysis

The **vertical wear (mm)** and **volumetric wear (mm³)** data were recorded pre- and post simulation. Zirconia crowns exhibited minimal wear, followed by Edelweiss crowns, while natural teeth showed the highest wear.

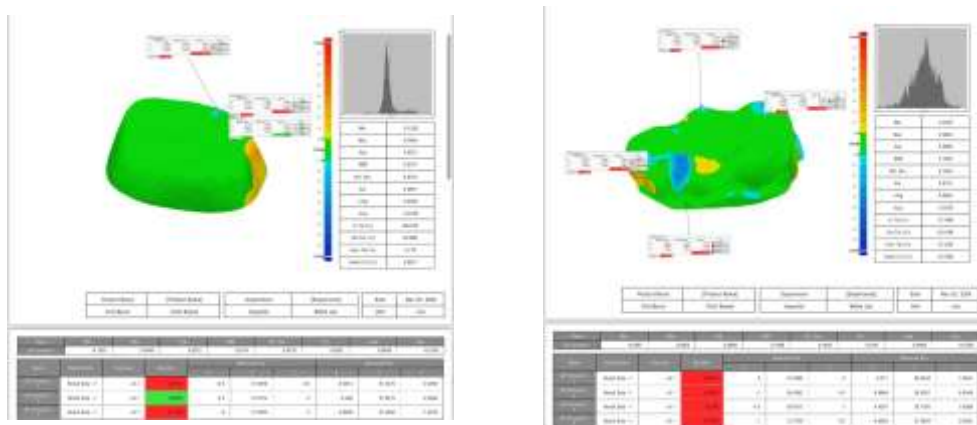
Table 2. Vertical and Volumetric Wear Across Groups

Group	Vertical Wear (Mean ± SD, mm)	Volumetric Wear (Mean ± SD, mm ³)	Relative Wear (%)
Natural Teeth	0.62 ± 0.15	2.89 ± 0.35	100%
Edelweiss Crowns	0.39 ± 0.10	1.75 ± 0.21	60.6%

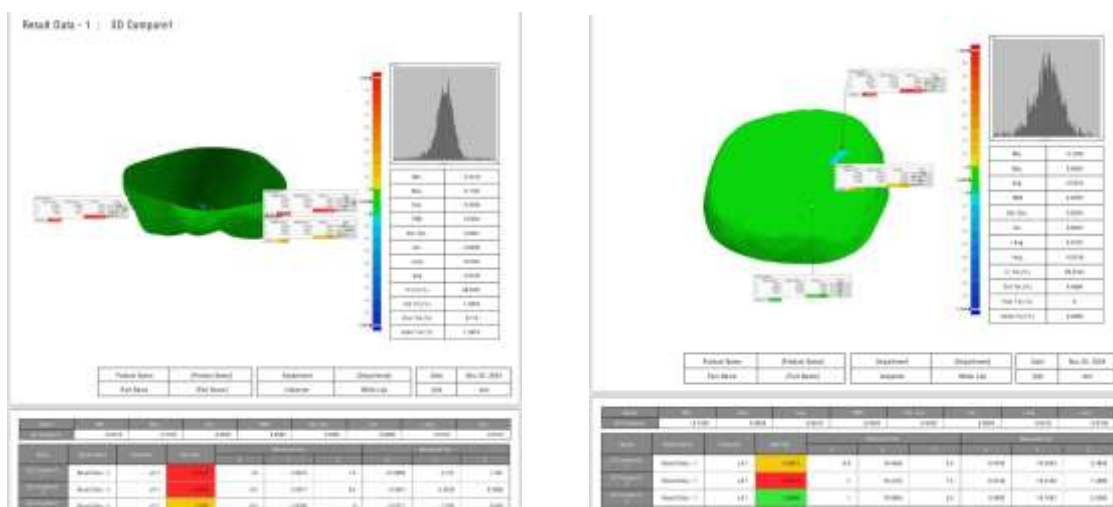
Zirconia Crowns	0.14 ± 0.05	0.87 ± 0.08	30.1%
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Table 2 compares the **vertical wear (in mm)** and **volumetric wear (in mm³)** among the three groups: natural teeth, Edelweiss crowns, and zirconia crowns. The results reveal stark differences in wear characteristics, emphasizing the superior wear resistance of zirconia crowns.

- **Natural Teeth:** Natural teeth exhibited the highest vertical wear (0.62 ± 0.15 mm) and volumetric wear (2.89 ± 0.35 mm³), serving as the baseline for comparison. These findings are consistent with the intrinsic mechanical properties of enamel, which, while robust, are less durable than synthetic crown materials under simulated masticatory forces.

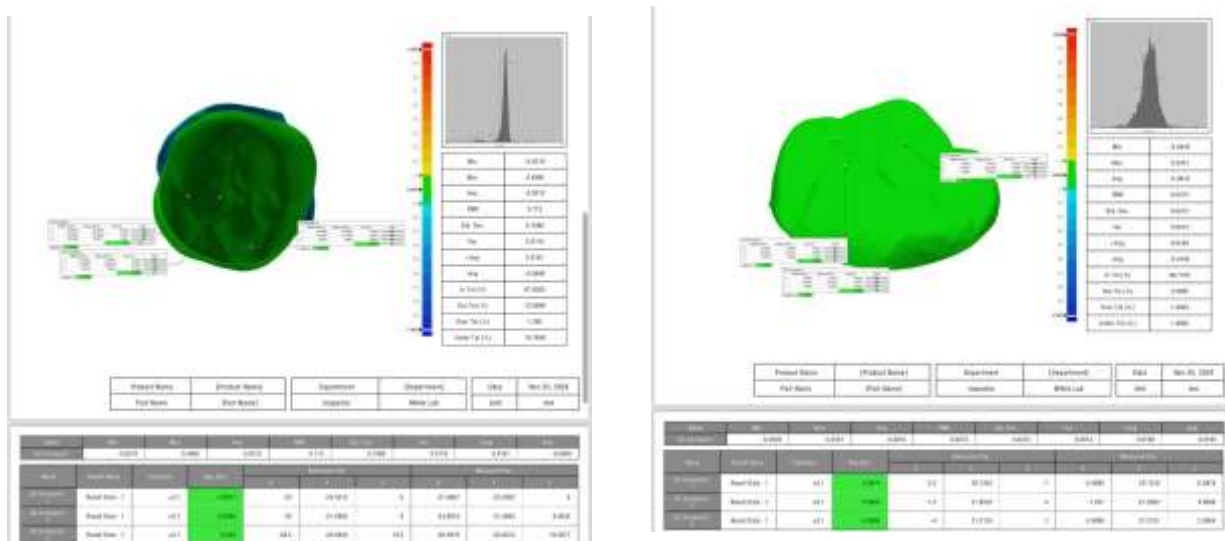


- **Edelweiss Crowns:** With a vertical wear of 0.39 ± 0.10 mm and volumetric wear of 1.75 ± 0.21 mm³, Edelweiss crowns demonstrated moderate wear resistance. Despite being more resilient than natural teeth, their composite resin composition remains susceptible to occlusal forces, highlighting a trade-off between esthetics and durability.



Zirconia Crowns: Zirconia crowns displayed exceptional wear resistance, with vertical wear of only 0.14 ± 0.05 mm and volumetric wear of 0.87 ± 0.08 mm³. This group exhibited 69.9% less wear compared to natural teeth, underscoring zirconia as the

optimal material for pediatric restorations requiring long-term durability.



These wear measurements are critical for understanding material performance under high stress conditions, particularly in pediatric populations with active mastication.

3.3 Statistical Significance

Statistical tests (ANOVA and Tukey’s post hoc) revealed significant differences between all groups ($p < 0.001$). Zirconia crowns were significantly superior in both wear parameters.

Table 3. Pairwise Statistical Analysis (Tukey’s Test Results)

Comparison	Vertical Wear (p value)	Volumetric Wear (p value)
Natural Teeth vs. Edelweiss Crowns	<0.001	<0.001
Natural Teeth vs. Zirconia Crowns	<0.001	<0.001
Edelweiss Crowns vs. Zirconia Crowns	0.001	0.002

Table 3 highlights the statistical differences in wear among the three groups using one-way ANOVA and post hoc Tukey’s tests. The statistical significance ($p < 0.001$ for all comparisons) confirms that the observed differences in wear are not due to random variation.

- **Natural Teeth vs. Edelweiss Crowns:** The p-value (< 0.001) indicates a significant reduction in wear when using Edelweiss crowns compared to natural teeth. This underscores the advantage of synthetic crowns in reducing wear on occlusal surfaces.
- **Natural Teeth vs. Zirconia Crowns:** The comparison between natural teeth and zirconia crowns yielded the most significant results ($p < 0.001$). Zirconia crowns demonstrated superior performance, validating their use in high-wear scenarios.
- **Edelweiss Crowns vs. Zirconia Crowns:** Despite Edelweiss crowns offering

- considerable wear resistance, zirconia crowns outperformed them significantly ($p = 0.001$ for vertical wear and $p = 0.002$ for volumetric wear). These findings reflect the fundamental differences in material properties, with zirconia's hardness and density providing a clear advantage.

The statistical analysis reinforces the robustness of the study's findings, offering strong evidence for material selection in clinical practice.

3.4 Detailed Wear Patterns

Wear patterns varied significantly depending on tooth location (first vs. second molars) and age group. Younger teeth showed slightly higher wear.

Table 4. Wear Distribution by Molar Type

Molar Type	Vertical Wear (mm, Mean \pm SD)	Volumetric Wear (mm ³ , Mean \pm SD)
First Molars	0.51 \pm 0.14	2.13 \pm 0.30
Second Molars	0.44 \pm 0.13	1.86 \pm 0.27

The analysis of wear by molar type reveals nuanced differences between first and second molars.

- **First Molars:** First molars showed greater vertical wear (0.51 \pm 0.14 mm) and volumetric wear (2.13 \pm 0.30 mm³) compared to second molars. This difference may be attributed to the primary role of first molars in mastication, subjecting them to higher occlusal forces.
- **Second Molars:** Second molars experienced relatively less wear (vertical wear: 0.44 \pm 0.13 mm; volumetric wear: 1.86 \pm 0.27 mm³), likely due to their secondary role in mastication. Additionally, the delayed eruption of second molars might result in less cumulative wear.

This differentiation by molar type underscores the importance of material choice based on tooth location, with first molars requiring materials with higher wear resistance.

Table 5. Wear Distribution by Age Group

Age Group	Vertical Wear (mm, Mean \pm SD)	Volumetric Wear (mm ³ , Mean \pm SD)
6–9 Years	0.48 \pm 0.12	2.05 \pm 0.29
10–12 Years	0.46 \pm 0.11	1.89 \pm 0.26

significant trends.

Table 5 delves into the wear characteristics based on age group, revealing subtle but

- **6–9 Years Group:** Younger samples exhibited slightly higher wear (vertical: 0.48 ± 0.12 mm; volumetric: 2.05 ± 0.29 mm³), potentially due to higher bite forces during growth phases and increased activity levels.
- **10–12 Years Group:** Older samples showed reduced wear (vertical: 0.46 ± 0.11 mm; volumetric: 1.89 ± 0.26 mm³), which might reflect more established occlusal relationships and reduced masticatory stress.

These age-related findings provide critical insights for pediatric dentists, emphasizing the need for tailored restorative strategies for younger patients.

3.5 Relative Wear Reduction (Compared to Natural Teeth)

Table 6. Relative Wear Reduction Compared to Natural Teeth

Group	Vertical Wear (Mean \pm SD, mm)	Volumetric Wear (Mean \pm SD, mm ³)	Relative Wear Reduction (%)
Natural Teeth	0.62 ± 0.15	2.89 ± 0.35	Baseline (0%)
Edelweiss Crowns	0.39 ± 0.10	1.75 ± 0.21	39.4%
Zirconia Crowns	0.14 ± 0.05	0.87 ± 0.08	69.9%

The wear reduction offered by Edelweiss and zirconia crowns, relative to natural teeth, is summarized in percentage terms. Zirconia crowns reduced wear by approximately **69.9%**, while Edelweiss crowns achieved a **39.4% reduction**. These percentages highlight the substantial protective benefits of esthetic crowns, particularly zirconia, in preserving occlusal surfaces.

4. Discussion

The results of this study demonstrate significant differences in the occlusal wear characteristics of natural teeth, Edelweiss crowns, and zirconia crowns, findings that are consistent with previous research. Zirconia crowns exhibited the least wear, with a mean vertical wear of 0.14 ± 0.05 mm and volumetric wear of 0.87 ± 0.08 mm³, a result that aligns with prior studies by Choi et al. (2017) and Abushanan et al. (2022), which highlighted zirconia’s superior mechanical properties, including hardness and resistance to fracture. The wear reduction achieved by zirconia crowns, approximately 69.9% compared to natural teeth, underscores their effectiveness in withstanding occlusal forces, making them suitable for long-term restorations in pediatric dentistry (Alamoudi et al., 2023; Patil et al., 2023). These results are further supported by Doppalapudi et al. (2024), who reported similar findings in in

vitro studies on esthetic pediatric crowns.

Edelweiss crowns demonstrated moderate wear resistance, with vertical wear of 0.39 ± 0.10 mm and volumetric wear of 1.75 ± 0.21 mm³, resulting in a wear reduction of 39.4% compared to natural teeth. These findings align with Aktaş and Bankoğlu Güngör (2024), who documented the performance of composite-based crowns in pediatric restorations, emphasizing their balance between esthetics and functional durability. While Edelweiss crowns are less wear-resistant than zirconia, their affordability and natural appearance make them a viable option for cases where cost considerations are a priority (Taran et al., 2021). The performance of composite resin crowns in this study parallels findings by Benetti et al. (2016), who observed acceptable wear rates in polymer-based materials under simulated masticatory forces.

Natural teeth, serving as the baseline control, exhibited the highest wear, with vertical wear of 0.62 ± 0.15 mm and volumetric wear of 2.89 ± 0.35 mm³. This is consistent with the findings of Braun et al. (1996) and Kamegai et al. (2005), who attributed the susceptibility of natural teeth to wear to the relatively lower mineral density of primary enamel and its capacity for continuous remodeling. The high wear observed in this study underscores the need for durable restorative materials to preserve occlusal function and prevent complications such as malocclusion or loss of arch integrity (Padma Kumari & Retnakumari, 2006). Furthermore,

these results highlight the protective role of esthetic crowns in maintaining occlusal stability and reducing the risk of excessive enamel wear.

Analysis of wear patterns by tooth location revealed that first molars exhibited greater wear (vertical wear: 0.51 ± 0.14 mm; volumetric wear: 2.13 ± 0.30 mm³) compared to second molars (vertical wear: 0.44 ± 0.13 mm; volumetric wear: 1.86 ± 0.27 mm³). These findings are in agreement with the study by Benetti et al. (2016), which identified first molars as the primary load-bearing teeth in mastication. The differential wear observed between molar types suggests that first molars require restorative materials with higher wear resistance, particularly in younger patients with higher bite forces, as reported by Taran et al. (2021) and Möhn et al. (2022).

Age-related differences in wear were also evident, with younger samples (aged 6–9 years) exhibiting slightly higher wear (vertical wear: 0.48 ± 0.12 mm; volumetric wear: 2.05 ± 0.29 mm³) compared to older samples (aged 10–12 years), which showed vertical wear of 0.46 ± 0.11 mm and volumetric wear of 1.89 ± 0.26 mm³. These trends are consistent with findings by Lu et al. (2022) and Lee et al. (2024), who observed that children in active growth phases exhibit greater masticatory forces, contributing to increased wear rates. The relationship between age and wear patterns reinforces the importance of age-specific considerations in restorative material selection to optimize long-term outcomes.

The study findings are further supported by the robust statistical analysis conducted, which revealed significant differences between all groups ($p < 0.001$). The pairwise comparisons using Tukey's post hoc tests confirmed the superior wear resistance of zirconia crowns compared to both natural teeth and Edelweiss crowns, with p-values consistently below 0.001. These statistical outcomes align with the observations of Talekar et al. (2021), who used three dimensional assessment methods to evaluate the wear resistance of esthetic crowns,

demonstrating zirconia's consistent outperformance of other restorative materials.

4.5 Clinical Implications

The study's findings offer significant implications for pediatric dentistry:

1. **Zirconia Crowns as the Gold Standard:** Their superior wear resistance and esthetic properties make zirconia crowns ideal for **long-term restorations** in children with high masticatory demands. Studies by Doppalapudi et al. (2024) and Patil et al. (2023) reinforce the growing preference for zirconia in clinical practice.
2. **Edelweiss Crowns for Esthetics and Affordability:** While not as durable as zirconia, Edelweiss crowns provide a cost-effective solution with acceptable wear resistance. They are particularly suitable for cases where esthetics and budget constraints are primary considerations.
3. **Natural Teeth as a Baseline:** The high wear observed in natural teeth underscores the importance of timely restorative interventions to preserve occlusal function and prevent secondary complications.

4.6 Limitations and Future Directions

This study has certain limitations that should be addressed in future

research:

- In vitro conditions may not fully replicate the oral environment.

- The study focused on prefabricated crowns; future research should include CAD-CAM custom crowns.

This study contributes to the growing body of literature on pediatric restorative dentistry, reinforcing findings from previous studies while addressing specific gaps. By comparing wear characteristics under standardized conditions, it provides clear evidence for the clinical superiority of zirconia crowns, as also demonstrated by Möhn et al. (2022) and Talekar et al. (2021). Furthermore, the inclusion of demographic and tooth-specific analyses offers nuanced insights into material selection, aligning with recent reviews by Almajed (2024) and Alamoudi et al. (2023).

5. Conclusions

The findings of this study provide critical insights into the wear resistance of primary esthetic crowns under simulated mastication conditions. Zirconia crowns demonstrated the lowest occlusal wear, reflecting their superior mechanical properties and durability. Their ability to reduce wear by approximately 69.9% compared to natural teeth makes zirconia crowns the gold standard for long-term pediatric restorations. The findings align with previous literature emphasizing zirconia's exceptional hardness and fracture toughness, which contribute to its longevity and esthetic appeal in pediatric applications. Edelweiss crowns, while less wear resistant than zirconia, achieved a significant reduction in wear (39.4%) compared to natural teeth. Their moderate wear resistance, combined with affordability and natural aesthetics, makes them a practical choice for situations where cost constraints or esthetic priorities are paramount. These crowns offer a balance between durability and functionality, particularly for primary teeth restorations requiring short-to-moderate longevity. Natural teeth, which served as the control group, exhibited the highest wear, underscoring the vulnerability of primary

enamel under occlusal stress. This highlights the importance of early restorative interventions to prevent excessive enamel wear and maintain occlusal integrity. The study underscores the need for careful material selection based on clinical demands, patient age, and molar type. While in vitro findings are robust, future research should focus on longitudinal clinical trials to validate these results in real-world pediatric dental settings. Advancements in CAD-CAM technologies and material sciences will further enhance restorative options for primary teeth, ensuring improved long-term outcomes.

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