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Edited by Yogesh Singh Bisht & Ruby Singh
E-mail: yogeshbishttech@gmail.com & bioinformationruby@gmail.com
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A comparative study of three fluoride-releasing orthodontic bracket adhesives - A randomized controlled trial

Yashvi J. Patel[1,*], Bhavikkumar Trivedi[2], Kushal Pancholi[3], Khushboo A. Jaiswal[4], Utsav Patel[5], Gayatree Peshne[6] & Shrikant Patel[7]

[1]Department of Orthodontics, Ahmedabad Dental College & Hospital, Ahmedabad, Gujarat, India; [2]Department of Public Health, Stomato Scope, Inc., United States; [3]Department of Health Informatics, Researcher, Stomato Scope, Inc., United States, [4]Department of Prosthodontics, Darshan Dental College and Hospital, Udaipur, Rajasthan India; [5]Department of Dental Surgery, Pacific Dental College, Udaipur, Rajasthan, India; [6]Department of Dentistry, NYU School of Dentistry, New York, United States; [7]Department of Cariology and Comprehensive Care, NYU School of Dentistry, New York, United States; *Corresponding author

Affiliation URL:

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https://dental.nyu.edu/

Author contact:
Yashvi J. Patel - E-mail: yashvi410@gmail.com
Bhavikkumar Trivedi - E-mail: bhavik.Trivedi99@gmail.com
Kushal Pancholi - E-mail**:** kush03pancholi@gmail.com
Khushboo A. Jaiswal - E-mail: drkhushboojaiswal.101@gmail.com
Utsav Patel - E-mail**:** utsavkumars765@gmail.com
Gayatree Peshne - E-mail**:** gvp6830@nyu.edu
Shrikant Patel - E-mail: shrikantpatelmds@gmail.com

Abstract:
Enamel demineralization around brackets is a common complication of fixed orthodontic treatment. Therefore, it is of interest to compare the fluoride-releasing Fuji Ortho LC with other orthodontic adhesives for bond failure, enamel demineralization and patient satisfaction. Fuji Ortho LC reduced enamel demineralization while maintaining clinically acceptable bonding performance. Transbond XT showed the lowest bracket bond failure rate, while Fuji Ortho LC showed higher ARI scores and patient satisfaction. Thus, Fuji Ortho LC is a useful option for protecting enamel during fixed orthodontic treatment.

Keywords: Orthodontic adhesives, fluoride release, enamel demineralization, orthodontic brackets

Background:
Enamel demineralization remains one of the most frequent complications associated with fixed orthodontic treatment. Orthodontic brackets and archwires promote plaque accumulation by creating areas that are difficult to clean, increasing the risk of white spot lesions (WSLs), which may develop within weeks after appliance placement. Despite advances in orthodontic bonding materials, prevention of enamel demineralization continues to be a major clinical concern because of its adverse effects on esthetics and long-term oral health **[1].** An ideal orthodontic adhesive should provide adequate bond strength throughout treatment while minimizing microleakage and protecting enamel **[2]**. Fluoride-releasing adhesives have attracted considerable attention because they continuously release fluoride at the tooth–adhesive interface, thereby promoting remineralization, reducing demineralization and inhibiting cariogenic bacterial activity. Many of these materials also possess fluoride recharge capability, prolonging their cariostatic effect during orthodontic therapy **[3].** Transbond XT is widely regarded as the clinical gold standard owing to its excellent bond strength and reliable performance; however, it lacks intrinsic fluoride-releasing properties **[4].** In contrast, Heliosit Orthodontic is a light-cured fluoride-releasing composite that offers simplified handling and satisfactory bond strength, while Fuji Ortho LC, a resin-modified glass ionomer cement, provides sustained fluoride release, chemical adhesion to enamel, moisture tolerance and fluoride recharge capability, although concerns remain regarding its mechanical performance compared with conventional composite adhesives **[5].** Bracket material also influences bonding performance. Metallic brackets remain the most commonly used because of their durability and predictable clinical behavior, whereas ceramic brackets are increasingly preferred for esthetic reasons. Differences in bracket base design and bonding mechanisms may affect adhesive performance, bond failure patterns and clinical outcomes **[6].** Although previous studies have evaluated individual fluoride-releasing adhesives, direct randomized clinical comparisons of Transbond XT, Heliosit Orthodontic and Fuji Ortho LC bonded to both metallic and ceramic brackets remain limited **[7]**. Therefore, it is of interest to compare the clinical performance of these three orthodontic adhesives by evaluating bracket bond failure, enamel demineralization, adhesive remnant index scores and patient satisfaction in patients treated with metallic and ceramic brackets.

Materials and Methods:
The Department of Orthodontics and Dentofacial Orthopedics at a postsecondary dentistry education institution served as the site of this randomized controlled clinical trial. For the study, a total sample size of 150 individuals in need of fixed orthodontic treatment was chosen. Included were patients between the ages of 15 and 30 who needed complete orthodontic treatment with permanent teeth and adequate oral hygiene. Patients with systemic diseases affecting oral health, enamel defects, extensive restorations on bonding surfaces, active carious lesions, periodontal disease, or Individuals who had undergone prior orthodontic treatment were excluded from the study. After obtaining informed written agreement, participants were randomly randomized to three 50-person groups, utilizing a computer-generated randomization sequence. Group I received bonding with Transbond XT Light Cure Adhesive, Group II received bonding with Heliosit Orthodontic and Group III received bonding with Fuji Ortho LC. In each adhesive category, both ceramic and metallic brackets were affixed following the established treatment guidelines. Before bonding, every tooth was completely cleaned with non-fluoridated pumice and

washed. A thorough wash with water and air-drying followed 30 seconds of 37% phosphoric acid etching on enamel surfaces. Each adhesive system was bonded according to its manufacturer's recommendations. Ceramic brackets and metallic brackets were positioned accurately on the facial surfaces of teeth and light cured where applicable. Patients were followed periodically at monthly intervals throughout the observation period. Clinical assessment included evaluation of bracket bond failures, adhesive performance and evidence of enamel demineralization around brackets. All examinations were performed by calibrated investigators using standardized clinical criteria to ensure consistency and reliability of observations. Before bonding, every tooth was completely cleaned with non-fluoridated pumice and washed. A p-value less than 0.05 were considered statistically significant.

Results:

Table 1 shows study participants' three adhesive group allocations. A total of 150 people were studied, 50 per group. The average age of participants was similar between groups, with Transbond XT at 20.98±3.42 years and Fuji Ortho LC at 21.46±3.68 years. Male participants constituted 46.0%, 50.0% and 48.0% of Groups I, II and III, respectively. Age and gender distribution were not significantly different between groups, indicating successful randomization and baseline comparability of participants **(Table 2)** compares the bracket bond failure rates among the three adhesive groups during the follow-up period. The lowest bond failure rate was observed in the Transbond XT group (6.0%), followed by Heliosit Orthodontic (10.0%) and Fuji Ortho LC (14.0%). Although Transbond XT demonstrated superior bond retention, the difference among the groups was not statistically significant (p>0.05). The highest prevalence of demineralization was observed in the Transbond XT group (22.0%), whereas lower rates were noted in the Heliosit Orthodontic group (12.0%) and Fuji Ortho LC group (8.0%). Group differences were statistically significant. (p=0.041), indicating superior preventive efficacy of fluoride-releasing adhesives, particularly Fuji Ortho LC, against enamel demineralization **(Table 3). Table 4** compares research group mean Adhesive Remnant Index (ARI) scores. The Fuji Ortho LC group had the highest mean ARI score (2.24±0.71), followed by Heliosit Orthodontic (2.02±0.68) and Transbond XT (1.78±0.64). Data showed significant group differences (p=0.018). High ARI scores indicate greater dental adhesive after debonding, which may protect enamel. **Table 5** compares bond performance according to bracket type. Ceramic brackets demonstrated a lower bond failure rate of 8.0% compared to 12.0% for metallic brackets. Enamel demineralization was observed in 10.7% of ceramic bracket cases and 16.0% of metallic bracket cases. However, neither comparison reached statistical significance (p>0.05), suggesting that both bracket systems exhibited similar clinical performance when used with the tested adhesive materials. **Table 6** presents patient satisfaction scores recorded at the end of the observation period. The highest mean satisfaction score was observed in the Fuji Ortho LC group (8.78±0.91), followed by Heliosit Orthodontic (8.42±1.03) and Transbond XT (8.08±1.12). Statistical analysis showed substantial group differences. (p=0.023). The improved satisfaction observed with fluoride-releasing adhesives may be attributed to lower incidence of enamel changes and favorable clinical outcomes.

Table 1: Baseline demographic characteristics of study participants (n=150)

Variable	Transbond XT (n=50)	Heliosit Orthodontic (n=50)	Fuji Ortho LC (n=50)	p-value
Mean age (years)	20.98 ± 3.42	21.18 ± 3.55	21.46 ± 3.68	0.781
Male, n (%)	23 (46.0)	25 (50.0)	24 (48.0)	0.923
Female, n (%)	27 (54.0)	25 (50.0)	26 (52.0)	0.923

Table 2: Comparison of bracket bond failure rates among adhesive groups

Adhesive Group	Bond Failure Present n (%)	Bond Failure Absent n (%)	Total	p-value
Transbond XT	3 (6.0)	47 (94.0)	50	
Heliosit Orthodontic	5 (10.0)	45 (90.0)	50	
Fuji Ortho LC	7 (14.0)	43 (86.0)	50	0.287
Total	15 (10.0)	135 (90.0)	150	

Table 3: Comparison of enamel demineralization among adhesive groups

Adhesive Group	Demineralization Present n (%)	Demineralization Absent n (%)	Total	p-value
Transbond XT	11 (22.0)	39 (78.0)	50	
Heliosit Orthodontic	6 (12.0)	44 (88.0)	50	
Fuji Ortho LC	4 (8.0)	46 (92.0)	50	0.041*
Total	21 (14.0)	129 (86.0)	150	

Table 4: Comparison of adhesive remnant index (ARI) scores among adhesive groups

Adhesive Group	Mean ARI Score	Standard Deviation	p-value
Transbond XT	1.78	0.64	
Heliosit Orthodontic	2.02	0.68	
Fuji Ortho LC	2.24	0.71	0.018*

Table 5: Comparison of clinical outcomes according to bracket type

Variable	Ceramic Brackets (n=75)	Metallic Brackets (n=75)	p-value
Bond failure, n (%)	6 (8.0)	9 (12.0)	0.412
Enamel demineralization, n (%)	8 (10.7)	12 (16.0)	0.337
Mean ARI score	2.16 ± 0.69	1.94 ± 0.66	0.081

Table 6: Comparison of patient satisfaction scores among adhesive groups

Adhesive Group	Mean Satisfaction Score	Standard Deviation	p-value
Transbond XT	8.08	1.12	
Heliosit Orthodontic	8.42	1.03	
Fuji Ortho LC	8.78	0.91	0.023*

**Statistically significant at p < 0.05.*

Discussion:

The Present study evaluated bracket bond failure, enamel demineralization, adhesive remnant index (ARI) scores and patient satisfaction among 150 orthodontic patients. The findings demonstrated that fluoride-releasing adhesives, particularly Fuji Ortho LC, provided superior protection against enamel demineralization while maintaining clinically acceptable bond strength and overall performance. In the current research, Transbond XT had the lowest bond failure rate (6.0%), followed by Heliosit Orthodontic (10.0%) and Fuji Ortho LC (14.0%). Transbond XT had slightly better bond retention, which is constant with Sfondrini *et al.* **[8]** who stated that conventional composite adhesives generally demonstrate higher shear bond strength than fluoride-releasing alternatives. The authors concluded that while fluoride-containing adhesives provide preventive benefits, slight reductions in mechanical performance may occur because of modifications in filler composition and fluoride incorporation. Nevertheless, the bond strengths

achieved by all tested materials remained within clinically acceptable limits for orthodontic treatment. A key finding of this study was the significantly lower incidence of enamel demineralization observed in the Fuji Ortho LC group (8.0%) compared with Heliosit Orthodontic (12.0%) and Transbond XT (22.0%). These results support the concept that fluoride release plays a critical role in preventing white spot lesion formation around orthodontic brackets. Comparable findings were documented by Türkkahraman and Küçükeşmen **[9],** who showed that fluoride-releasing orthodontic adhesives significantly reduced enamel demineralization compared with conventional composite resins. Their study emphasized that sustained fluoride availability around bonded brackets creates a protective environment that enhances remineralization and inhibits cariogenic activity. The current research also showed notably elevated ARI scores in the Fuji Ortho LC group in comparison to the other adhesive systems. Higher ARI scores suggest that more adhesive stayed on the enamel surface following bracket removal, which may lower the likelihood of enamel fracture and surface damage during the debonding process. These findings align with those reported by Pascotto *et al.* **[10].** The authors proposed that the properties of chemical adhesion and fluoride release in glass ionomer-based materials enhance the safety of debonding and provide better protection for enamel. Comparison of bracket types demonstrated slightly lower bond failure and enamel demineralization rates in ceramic brackets than metallic brackets, despite the fact that the disparities were not statistically significant. These findings indicate that both bracket systems can be effectively used with the evaluated adhesive materials. Similar observations were described by Sonis and Snell **[11],** who found that fluoride-releasing orthodontic bonding systems provided acceptable clinical performance irrespective of bracket design. Their investigation highlighted that adhesive properties may have a greater influence on clinical outcomes than bracket material alone. Patient satisfaction was highest among participants bonded with Fuji Ortho LC. This may be attributed to reduced enamel changes, fewer esthetic concerns associated with demineralization and satisfactory bracket retention throughout treatment. The classic work of Ogaard *et al.* **[12]** further supports the overall findings of the present study, which established the relationship between enamel demineralization and orthodontic appliances. Their research underscored the significance of preventive strategies during orthodontic treatment and established the groundwork for the advancement of fluoride-releasing bonding materials **[13]**. The lower demineralization rates observed in the present study among fluoride-releasing adhesive groups reinforce the long-term clinical relevance of fluoride-based preventive approaches **[14]**. Overall, the present study demonstrated that although Transbond XT exhibited slightly superior bond retention, fluoride-releasing adhesives, particularly Fuji Ortho LC, offered substantial advantages in preventing enamel demineralization without compromising clinical acceptability. These findings support the incorporation of fluoride-releasing orthodontic adhesives into routine clinical practice, especially for patients considered at elevated risk of enamel demineralization during fixed appliance therapy.

Conclusion:

All three orthodontic adhesives showed clinically acceptable performance with ceramic and metallic brackets. Transbond XT showed the lowest bond failure, while Fuji Ortho LC showed the lowest enamel demineralization and highest patient satisfaction. Fuji Ortho LC may be considered when enamel protection is prioritized, whereas Transbond XT may be preferred when bond retention is the primary con cern.

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