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Original Article

Risk Factors for Bracket Bond Failure in Orthodontic Treatment: Findings from a Controlled Single-Centre Study

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ABSTRACT

This study examined factors affecting bracket detachment in 197 orthodontic patients (116 females, 81 males; mean age 16.3 years) treated with stainless steel non-self-ligating brackets over an average of 23.7 months. Bracket failure was recorded as the main outcome. Variables included patient demographics, oral hygiene, treatment duration, and cephalometric measures such as overjet, overbite, and skeletal relationships. Overall, 4.4% of brackets failed, with higher rates on posterior teeth and the right side. Male patients, poor oral hygiene, and increased overjet or overbite were associated with greater risk.

Keywords: Bracket detachment, Orthodontic treatment, Survival analysis, Risk factors

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Introduction

Bracket detachment during fixed appliance orthodontics can significantly affect both treatment outcomes and patient experience. Evidence suggests that a single bracket failure may extend treatment duration by 0.3–0.6 months [1, 2], potentially reducing patient compliance, impairing oral hygiene, and increasing the risk of white spot lesions [3, 4].

Although some bracket failures are unavoidable, the overall incidence ranges from 0.6% to 28.3% according to recent reviews [5]. Identifying factors that elevate the risk of detachment could enhance treatment planning and predictability. Reported influences include material and technique-related factors, operator experience, patient-specific characteristics (age, sex, oral hygiene, overjet, overbite, facial height, ANB angle), and bracket position (tooth type, arch, anterior vs. posterior) [6-8].

Research indicates that adults experience fewer bracket failures than adolescents [7, 9], while males may be at slightly higher risk than females [6, 10]. Vertical and sagittal skeletal features appear to have limited effect [11], though increased overbite has been linked to higher failure rates, whereas overjet seems less relevant [8]. Regarding location, posterior brackets, particularly mandibular second premolars, fail more frequently than anterior ones, and mandibular brackets overall show higher failure rates than maxillary brackets [7, 8, 12, 13].

While operator and technique-related factors can be standardized to reduce risk, patient-specific characteristics cannot be modified. Recognizing high-risk profiles may allow clinicians to adjust bonding methods or monitoring schedules accordingly. Previous studies often suffer from small sample sizes and multiple operators, introducing potential bias. Therefore, this study aims to examine the impact of patient-specific and bracket location-specific factors on bracket survival in a larger, single-operator cohort during comprehensive fixed orthodontic treatment.

Materials and Methods

This study retrospectively evaluated orthodontic patients who completed fixed appliance therapy at a

single centre under a single experienced right-handed operator (>10 years). All data were anonymized, and the study followed the Declaration of Helsinki.

Inclusion criteria

- Treatment conducted by the single operator;
- Full fixed appliance therapy completed;
- Direct bonding applied, with tubes on molars and brackets on all other teeth.

Exclusion criteria

- Lingual appliances on either arch;
- Use of indirect bonding;
- Prior orthodontic treatment;
- Cleft lip/palate or craniofacial anomalies;
- Enamel abnormalities (e.g., amelogenesis imperfecta, molar–incisor hypomineralization).

All teeth were bonded using Experience metal non-self-ligating brackets (GC Orthodontics Inc.) with Transbond™ XT adhesive (3M Unitek). Bonding steps included enamel cleaning, 37% phosphoric acid etching for 15 s, primer application (Ortho Solo™) without curing, bracket placement, and light curing (Ortholux, 440–465 nm, 1200 mW/cm²; 20 s on tubes, 10 s on other brackets).

Patients were monitored every six weeks. Bracket failures were recorded by a dental nurse, noting tooth number, timing, and whether it was the first or second failure. Teeth with crowns, veneers, non-enamel restorations, bands, or extracted for orthodontics were excluded. Rebonding at ~12 months to improve tooth positioning was not considered a failure.

Recorded variables included bracket failure, oral hygiene (poor, medium, good), age, sex, bonding day, missed appointments, treatment duration, and pre-treatment cephalometric measures (overjet, overbite, ANB, intermaxillary angle, gonial angle, posterior/anterior facial heights, posterior-to-anterior height ratio). Cephalometric tracings were performed by a blinded operator not involved in treatment **(Figure 1)**.

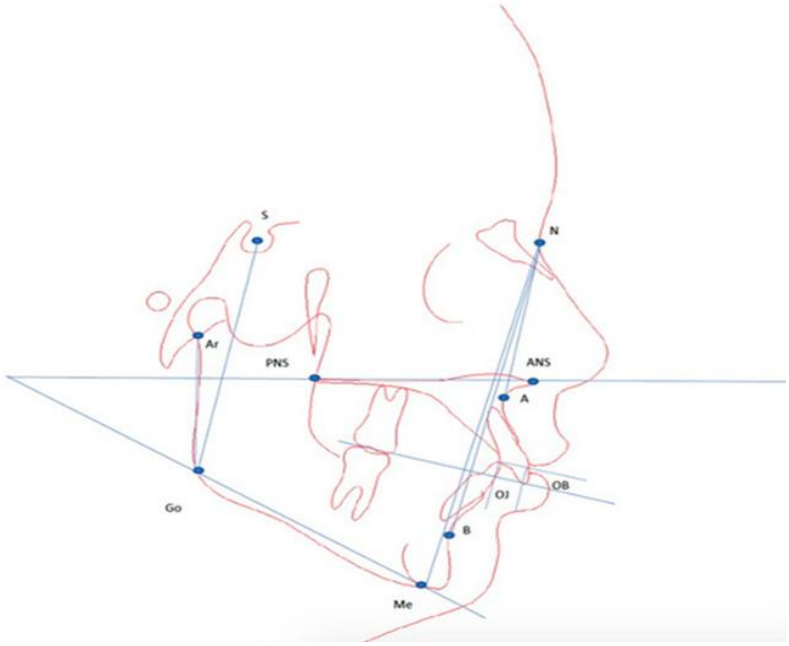

Figure 1. Dentofacial traits assessed from baseline lateral cephalograms of study participants. The cephalometric parameters, marked by blue lines, include overjet (OJ), overbite (OB), ANB angle, intermaxillary angle (ANS-PNS/Me-Go), gonial angle (Ar-Go-Me), posterior facial height (S-Go), and anterior facial height (N-Me). Key anatomical points are: A = A point, ANS = anterior nasal spine, Ar = articulare, B = B point, Go = gonion, Me = menton, N = nasion, PNS = posterior nasal spine, S = sella.

Using these 14 factors, a sample size was determined for a multiple linear regression, with an alpha error of 0.05, 95% power, and a target correlation coefficient of at least 0.2, calculated using G*Power 3.1 for Windows [14]. This indicated a minimum of 122 subjects was required. Data analysis was performed with IBM SPSS Statistics, Version 25.0 (IBM Corp., Armonk, NY, USA). Frequency and timing of bracket failures were evaluated using descriptive statistics and survival analysis, with Cox regression identifying factors influencing per-patient failure rates. Kaplan–Meier tests verified proportional hazard assumptions. Measurement reliability was tested by re-evaluating cephalometric data for 20 randomly selected

participants (chosen via random.org on 14 January 2021) after a minimum two-week interval. Paired t-tests checked for systematic error, and the Dahlberg formula assessed random error, which remained below 0.9 mm for linear measures and 1° for angular measures, with no systematic error detected [15, 16].

Results and Discussion

Initially, 220 patients were evaluated, but 23 were excluded due to not meeting the study criteria. The final cohort included 197 individuals (116 females, 81 males) who completed full fixed appliance orthodontic treatment at a single centre with one operator. Ages at the start of treatment ranged from 9 to 63 years, averaging 16.3 ± 10.6 years. Treatment duration averaged 23.7 ± 6.7 months, with a range of 5–47 months. Oral hygiene was rated poor in 21.8%, medium in 20.5%, and good in 57.7% of patients. Missed appointments were distributed as 1 for 30.4%, 2 for 14.6%, 3 for 8.4%, and 4 or more for 10.7%, while 35.8% of patients had perfect attendance.

Regarding bracket failures, 81 patients had none, 45 had a single failure, 34 had two, 11 had three, 13 had four, and 13 experienced five or more failures. The mean bracket failure per patient was 4.8%, and the overall failure per bracket was 4.4%, meaning roughly 1 in 23 brackets failed. Analysis by month showed that October had the highest number of failures ($p < 0.001$) **(Figure 2)**.

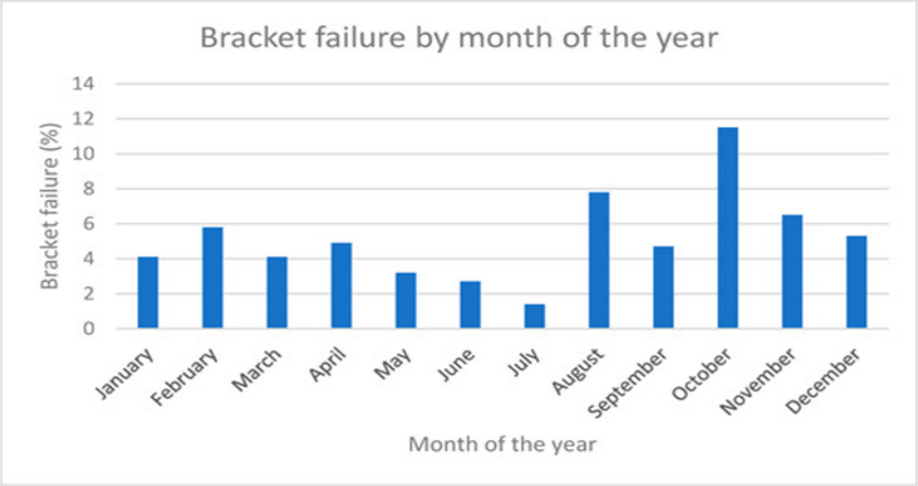

Figure 2. Monthly distribution of bracket failures.

Bracket position

Bracket failures were assessed by individual tooth type. The upper left second premolars and first molars exhibited the highest failure rate at 9.3%, whereas the upper left lateral incisors and lower left first premolars showed no failures (0%) **(Table 1)**.

Table 1. Bracket failure frequency per tooth.

Tooth Number	17	16	15	14	13	12	11	21	22	23	24	25	26
Total Brackets Applied	242	225	242	225	304	233	277	269	231	277	214	248	225
Bracket Breakages (Count)	14	19	16	10	11	1	5	4	0	4	4	23	21
Breakage Rate (%)	5.8%	8.4%	6.6%	4.4%	3.6%	0.4%	3.8%	1.5%	0.0%	1.4%	1.9%	9.3%	9.3%
Tooth Number	47	46	45	44	43	42	41	31	32	33	34	35	36
Total Brackets Applied	260	223	250	214	220	223	249	246	231	222	225	249	231
Bracket Breakages (Count)	13	18	16	3	4	6	10	13	7	2	0	6	19
Breakage Rate (%)	5.0%	8.1%	6.4%	1.4%	1.8%	2.7%	4.0%	5.3%	3.0%	0.9%	0.0%	2.4%	8.2%

Note: The total count of brackets surpasses 197 as it also accounts for brackets that were rebonded to refine tooth alignment.

No notable difference in bracket failures was found between the upper (maxillary) and lower (mandibular) arches. However, a side-related difference was observed, with the right side experiencing a higher failure rate than the left ($p = 0.0036$) **(Figure 3)**.

Regarding the position along the dental arch, posterior teeth showed a significantly greater frequency of bracket failure compared with anterior teeth ($p < 0.001$) **(Figure 4)**.

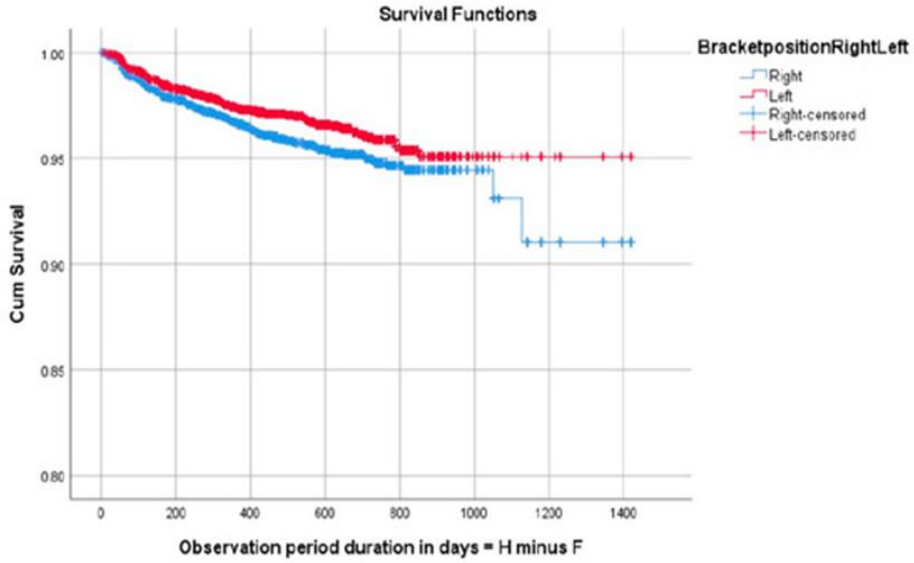

Figure 3. Survival curve indicating a higher probability of bracket survival on the left side compared with the right dental arch. *Cum Survival = cumulative survival; F = degrees of freedom; H = cumulative hazard rate.*

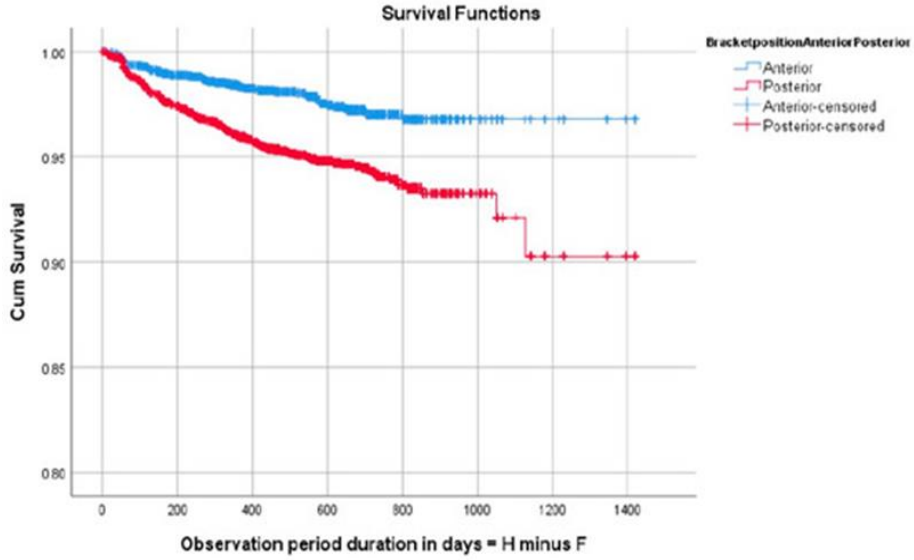

Figure 4. Survival curve demonstrating greater bracket longevity in the anterior regions of the arches compared with posterior areas. *Cum Survival = cumulative survival; F = degrees of freedom; H = cumulative hazard rate.*

Patient-specific variables

Evaluation of demographic and behavioral factors showed clear trends. Bracket failure occurred more frequently in males than in females ($p = 0.0032$) **(Figure 5)**. Hygiene status also influenced survival: individuals with good hygiene maintained the best outcomes, while those with poor hygiene showed the greatest incidence of failure ($p < 0.001$) **(Figure 6)**. Age, whether considered as a continuous measure or split at 18 years into adolescent versus adult groups, did not show any significant association. Likewise, appointment attendance, the day of bonding, and overall treatment length had no measurable effect [17-21].

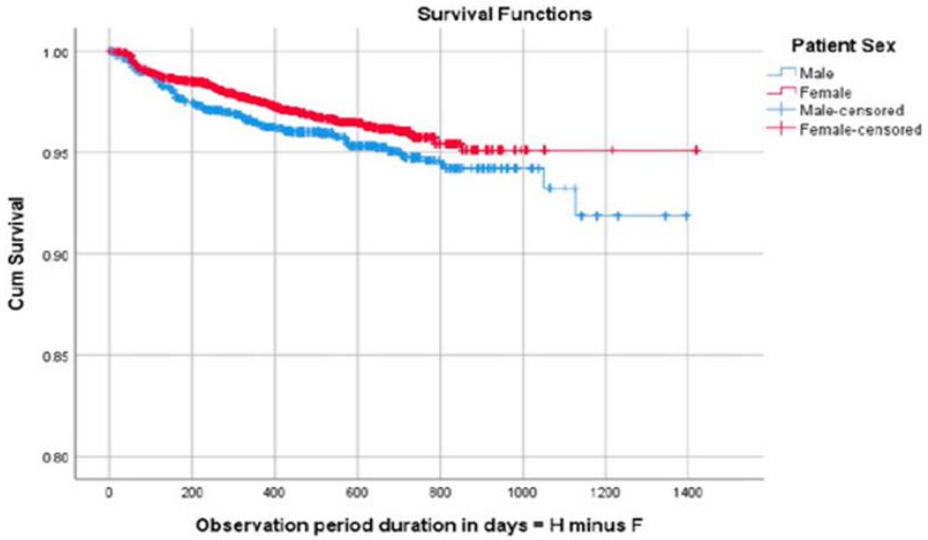

Figure 5. Survival plot indicating longer bracket retention in females compared with males. *Cum Survival = cumulative survival; F = degrees of freedom; H = cumulative hazard rate.*

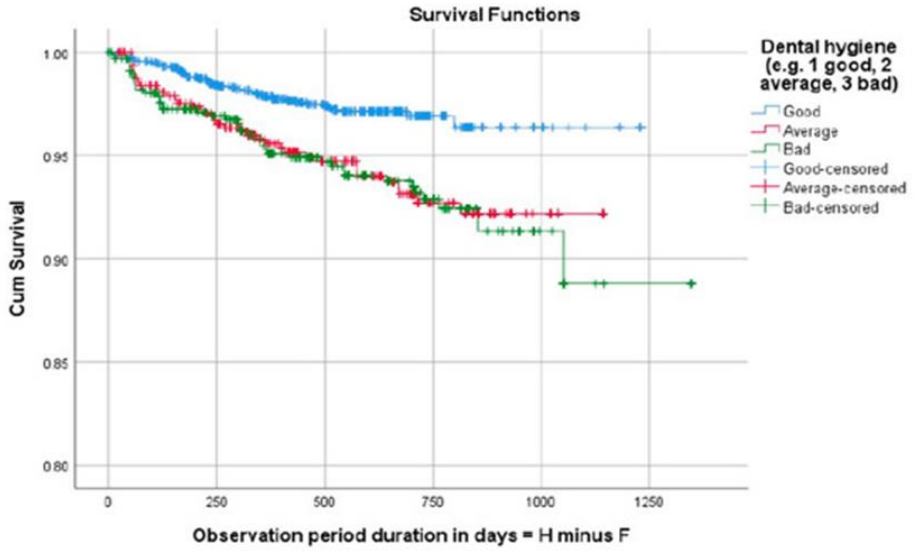

Figure 6. Survival plot showing a gradient in survival from good, to average, to poor hygiene. *Cum Survival = cumulative survival; F = degrees of freedom; H = cumulative hazard rate.*

Baseline cephalometric readings were generally unrelated to bracket loss across the entire dataset. However, when results were separated into four arch regions (upper vs. lower; anterior vs. posterior), some significant patterns emerged. Cox regression revealed that failure was more likely in:

- maxillary anterior brackets with overjet >4 mm ($p = 0.048$),
- mandibular posterior brackets with overjet <1 mm ($p = 0.005$),
- mandibular anterior brackets with overbite >4 mm ($p = 0.011$).

This retrospective cohort investigation explored bracket loss patterns and influencing variables in a uniform patient group, all treated with fixed appliances by one clinician using a consistent bonding approach. The findings indicated that most individuals who experienced debonding lost multiple brackets, while only about 23% reported a single incident. The total failure rate across the sample was 4.4%, aligning with figures presented in a recent systematic review [5]. The mean treatment duration was roughly 24 months, which appears slightly longer than the average reported in earlier publications [5, 12], though in this analysis it showed no link to bracket loss.

When examining tooth-related differences, no statistically significant variations were detected, which partially contrasts with prior reports [12, 22, 23]. Nonetheless, posterior teeth were more frequently

affected, with the highest failure observed in the upper left second premolars and first molars. Age did not emerge as a relevant predictor, although other authors have found greater loss rates in younger cohorts [24]. In contrast, sex differences were evident: males exhibited more frequent debonding than females. This may stem from stronger bite forces in men [25, 26] or greater appliance care and compliance among women [10, 27]. Arch position also played a role, with posterior regions showing higher susceptibility to failure. Potential explanations include heavier occlusal loading during chewing [28, 29], greater challenges in maintaining a dry field [10, 30], or bracket–tooth adaptation issues linked to morphology [10].

A further observation was that brackets placed on the right side of the arch were more prone to failure than those on the left, a trend also highlighted in other publications [31]. Contributing factors could involve differences in chewing patterns, dietary preferences, the operator's right-handed technique, or prolonged saliva exposure if right-sided teeth were bonded later in the procedure.

The current investigation revealed a notable association between poor oral hygiene and higher rates of bracket loss. Oral hygiene was judged in a subjective manner, primarily through visual inspection on a qualitative scale. This naturally raises concerns about the accuracy of such an assessment, and the results should be interpreted with caution. Additionally, every patient was asked to brush their teeth upon arrival using toothbrushes supplied at the clinic, which could have influenced the evaluation and introduced bias. Even so, this observation remains relevant, since poor hygiene may also reflect other behaviors—such as less careful appliance management or greater consumption of hard or sticky foods—that indirectly contribute to bracket debonding. Comparable outcomes have been reported in other investigations using visual oral hygiene grading, with patients showing poor scores or frequent hygiene warnings experiencing higher bracket loss [32, 33]. However, not all research has found the same relationship [11].

A key strength of this study was the broad assessment of several clinical variables potentially linked to bracket survival. Another advantage was the relatively large cohort treated by a single orthodontist, using one bracket type and a unified bonding procedure. This design ensured consistency, since earlier research has demonstrated differences in bracket survival between clinicians [10, 34]. Likewise, bonding protocols themselves can affect outcomes [35], and therefore, employing a standardised method helped reduce variability within the sample.

Despite these strengths, limitations must also be acknowledged. Being a retrospective cohort, the study inherits inherent drawbacks, including the possibility of random error. For instance, the nurse recording data might have overlooked or misattributed a bracket failure. Moreover, as this was a single-centre study, results may not be widely generalisable, even though homogeneity was achieved. Multi-centre trials would enhance external validity. Another limitation involves the timing of bracket failure: the exact day was not always clear, as failures were logged only when patients attended appointments. This means an event could have occurred days or weeks earlier. The apparent peak in failures during October may therefore be misleading, since that month often coincides with the first follow-up visit after the summer holidays, when previously detached brackets could have been documented, even though the actual debonding occurred earlier.

In conclusion, this retrospective study reinforces the role of patient-related variables in influencing bracket stability during orthodontic treatment. Identifying such risk factors can support orthodontists in recognising high-risk individuals and adapting bonding methods or scheduling closer follow-up. Continued research is required to validate these associations and improve treatment predictability.

Conclusion

The rate of bracket loss in this study was 4.4%. Failures occurred more frequently on posterior teeth and on the right arch, with higher incidence in males and in patients with poor hygiene. Increased overjet and overbite raised the likelihood of anterior bracket failure, whereas age, missed visits, treatment length, and skeletal cephalometric values showed no clear effect.

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Conflict of Interest: None

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Ethics Statement: None

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