Original Article

DOI: 10.7860/JCDR/2026/80778.22234

Dentistry Section

The Effect of Sandblasting on the Shutter Mechanism of Recycled Self-ligating Brackets: An In-vitro Study

SHEFALI SINGH[1], RIZWAN AZIZ GILANI[2], AISHWARYA ATEY[3], ABHIJEET KADAM[4], PRATIK RATHOD[5]

ABSTRACT

Introduction: Self-Ligating Brackets (SLBs) have become a popular alternative to conventional orthodontic brackets due to their reduced treatment times, improved patient comfort, and enhanced mechanical efficiency. A key feature of SLBs is the integrated shutter mechanism that allows ligation without elastomeric or wire ties. However, bracket debonding during treatment necessitates their reuse, and recycling methods-particularly sandblasting-are commonly employed to restore their bondability. While sandblasting improves surface adhesion, its effect on the functional integrity of the shutter mechanism remains under-explored.

Aim: To evaluate and compare the effects of sandblasting as a recycling technique on the shutter mechanism of various commercially available self-ligating orthodontic brackets.

Materials and Methods: This in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Sharad Pawar Dental College and Hospital, Wardha, Maharashtra, India, from November 2023 to February 2025. A total of 64 extracted premolars were divided into four groups (n=16) and bonded with SLB from four manufacturers: 3M Unitek™, American Orthodontics (AO) (Empower®), Ormco (Damon™ Q2), and JJ Ortho (Selfy™). Brackets were bonded, tested for shutter closing force using a universal testing machine, debonded, sandblasted with 50-micron aluminum oxide, and re-bonded. Shutter Force (SF) was measured again after recycling. Statistical analysis included repeated measures Analysis of Variance (ANOVA) and post hoc comparisons.

Results: Damon™ Q2 brackets exhibited the highest SF in both new and sandblasted conditions, while Selfy™ brackets showed the lowest. Sandblasting led to a statistically significant but clinically minimal increase in SF (mean difference=0.052 N, $p<0.001$). However, bracket performance rankings remained consistent across conditions, with no significant interaction effect between bracket type and condition.

Conclusion: Sandblasting is an effective and safe method for recycling SLB, preserving shutter mechanism functionality across all brands. Among the tested brackets, Damon™ Q2 demonstrated superior and most consistent performance, while Selfy™ brackets showed the lowest resistance but remained within acceptable clinical limits.

Keywords: 3M brackets, American orthodontic brackets, Bracket reusability, Damon™ brackets, Selfy™ brackets

INTRODUCTION

In dentistry, SLBs have a long history. They are a state-of-the-art technology dating back to the 1930s. Over the past three decades, there has been a renaissance in their popularity and many new developments have emerged in this field. Over time, other advantages over conventional appliance systems have been claimed, such as reduced noise and lower friction levels [1]. The strongest potential advantages of SLBs are a reduced duration of therapy and less subjective discomfort associated with the procedure. Reduced biostability is also thought to lead to better periodontal health and more efficient chairside manipulation [2]. Undoubtedly, they can be beneficial because they can reduce the number of appointments and the overall length of therapy by four to seven months [3]. They are thought to enable more physiologically harmonious tooth movement by preventing the musculature from being stressed and the periodontal vascular supply from being severed. It is believed that physiological movement can reduce anterior tooth proclination, lengthen the jaw, promote alveolar bone development, and reduce the need for extractions. In recent years, self-ligating orthodontic brackets have gained favor in orthodontics and are increasingly used by patients [4]. Over time, SLBs have grown in popularity as an alternative to conventional brackets. Through demonstrations of their attributes and features, such as frictional forces, torque expression, rotation capacity, bond strength, and reconditioning techniques, numerous studies have demonstrated that SLBs are superior in each of these domains [2-5]. The SLB do not require conventional elastomeric or wire ties, since the shutter is a precisely constructed part that holds the archwire firmly within the bracket slot. There are two primary types of shutters: active and passive. They are usually constructed from sturdy stainless steel or premium metal alloys. While passive shutters employ a sliding door mechanism to enclose the archwire with minimal pressure, active shutters use a spring-like clip or latch that imparts pressure to the archwire for enhanced engagement [6]. Because of their user-friendly form, shutters enable orthodontists to modify the archwire by rapidly opening and closing them using specialised instruments [7]. They promote effective force transmission, provide a snug fit for the archwire, and are strong enough to endure frequent handling during treatment. Modern shutters are also sleek and low-profile, which improves patient comfort and reduces soft tissue irritation. In modern orthodontics, SLB are a popular option due to their design and functionality [8].

For a variety of causes, including inadequate access, moisture accumulation, or occlusal stress during chewing, brackets may get de-bond from the teeth after bonding. The forces required to open and close the shutter that engage the wire inside the bracket should be understood in order to prevent bracket damage or debonding [9]. Clinicians can benefit from this information when handling these devices. In reality, excessive pressure on the shutter can cause the bracket to separate or break, while insufficient opening and closing pressures prevent shutter sliding movements [10].

The de-bonded brackets can be re-bonded using a variety of recycling techniques, such as tungsten carbide burs, green stones, sandblasting, and direct flame. Recycling brackets has been linked to quality deterioration, decreased bond strength, and an elevated risk of cross-infection, according to studies [9,11,12]. Sandblasting is a surface treatment applied to orthodontic brackets that roughens the surface by applying fine abrasive particles, usually aluminum oxide, under high pressure. This strengthens the adhesion between the brackets and enamel or adhesives. By increasing the bracket base surface area, this procedure enhances mechanical interlocking with the adhesive and lowers the possibility of debonding during treatment. Sandblasting is frequently used to recondition previously used brackets, restoring their bondability. It works especially well on metallic brackets or brackets with smooth bases [12]. Additionally, it ensures a cleaner finish by reducing the amount of adhesive left on the enamel following bracket removal. But too much sandblasting can weaken brackets, especially ceramic ones, by compromising their structural integrity. Sandblasting greatly increases the adhesion and overall dependability of orthodontic brackets when done correctly [13].

Despite the growing clinical use of SLBs, limited literature exists regarding the implications of recycling on their mechanical integrity, particularly the delicate shutter mechanism and its influence on treatment outcomes [11]. The present study was undertaken to bridge this research gap by evaluating the impact of sandblasting on the functional performance of both routinely used and commercially available SLBs. By comparing the force required to re-engage the shutter mechanism after recycling, this research seeks to uncover whether an eco-friendly, cost-effective bracket reuse strategy can be adopted without compromising clinical reliability. The present study is part of a larger study which assesses other characteristics of recycled brackets.

Evaluation and comparison of the effects of recycling on the SF of various commercially available SLBs. Hence, the objectives of the present study were to evaluate and compare the effects of recycling on the SF of various commercially available SLBs.

MATERIALS AND METHODS

The present in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Sharad Pawar Dental College and Hospital, Wardha, Maharashtra, India, from November 2023 to February 2025. After obtaining approval from the Institutional Ethics Committee of DMIHER (Deemed to be University), the reference number DMIHER (DU)/IEC/2023/573 was obtained.

Inclusion criteria:

- Maxillary and mandibular permanent premolars extracted for orthodontic purposes.
- Teeth that were not carious and had intact dentin and enamel intact.

Exclusion criteria:

- Fluorosis, attrition, abrasion, or other enamel defects.
- Teeth with developmental abnormalities.
- Teeth with internal resorption.

Sample size calculation: The sample size formula for difference between two means:

$$n = \frac{(Z\alpha+Z\beta)^2\,(\delta 1^2 + \delta 2^2\ 1K)}{\Delta^2}$$

Where,

$Z\alpha$=level of significance at 5% i.e., 95%

Confidence Interval (CI)=1.96

$Z\beta$ is the power of test=80%=0.84

$\delta 1$=Standard Deviation (SD) of SBS in Group-1=2.9011 [13],

$\delta 2$=SD of SBS in Group-2=3.8872

Δ=Difference between two means=22.443-19.057=3.386

K=1

n=1.96+0.8422.90112+3.88722/13.3862=16.08

n ≈ 16 teeth per group (n=16.08 in the calculation)

Total sample size: 64 teeth

Study reference: Agarwal K et al., [13]

Study Procedure

The present study used 64 healthy premolar teeth extracted for orthodontic purposes. They were collected and stored in saline to prevent brittleness. Pumice and rubber prophylactic cups were used to clean and polish the teeth for 10 seconds, followed by washing with water. The samples were divided into four groups with 16 premolars in each group and were mounted in with cold cure resin in cylindrical blocks that were labelled on the rear surface accordingly for each group to permit subsequent identifications.

Group 1: 16 SLB of 3M Unitek™ Gemini SL Self-Ligating System;

Group 2: 16 SLB of Empower® Metal Brackets American Orthodontics;

Group 3: 16 SLB of Damon™ Q2 Ormco;

Group 4: 16 SLB of JJ Ortho Selfy™ Passive Metal SLB Kit.

Bonding procedure: For 30 seconds, each tooth's buccal surface was coated with a 37% phosphoric acid gel. The buccal surface of the etched teeth was then made to seem chalky white by rinsing them with a water spray and drying them with an air source. The etched surfaces were coated with the bonding agent. On each bracket base, the transbond XT adhesive was applied. After that, the bracket was placed correctly on the tooth's surface keeping in mind the orientation of the shutter was such that, the Instron testing machine could apply a closing force on the SLB. An explorer was used to remove extra adhesive. After that, the bracket was light-cured for 15 seconds. Before being examined in an Instron testing machine, the mounted teeth were kept for 72 hours at room temperature in distilled water.

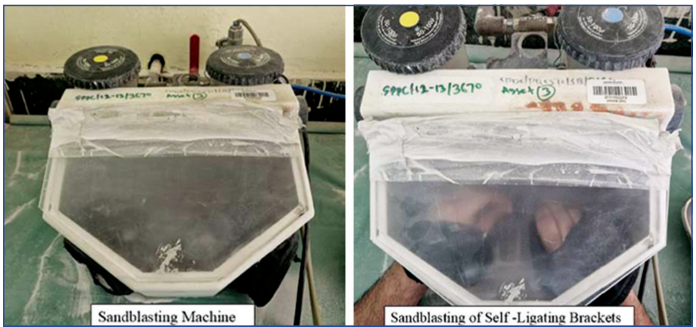
Evaluation of Shutter Force (SF): The universal testing machine was used to measure the force required to close the shutter of the SLB. The specimen mounted in acrylic block was secured to the lower grip of the machine (fix head). To maintain a consistent force, a custom head was fixed in the upper grip (movable head) connected to the load cell. The head was positioned in such a way that it touched the shutter of the different companies of SLB [Table/Fig-1].

Recycling of the brackets: All the debonded brackets of four companies were recycled by sandblasting method, 50-micron aluminum oxide abrasive powder was used. The distance between the bracket base and the handpiece head was fixed at 10 mm. Each bracket base was sandblasted for 20-40 seconds under 80 psi pressure [Table/Fig-2]. After the recycling procedure, the brackets were again re-bonded to the enamel surfaces that had been re-prepared for bonding, using the same method as for the new brackets. The teeth were stored in distilled water for 72 hours before the brackets were tested for shutter closing force.

STATISTICAL ANALYSIS

Statistical analysis using Microsoft Excel, Jeffrey's Amazing Statistics Program (JASP) (v0.19.3), and RStudio was conducted. Excel was used for data organisation and preprocessing, while JASP and RStudio supported advanced statistical testing and visualisation. To evaluate differences in SF across bracket types

[Table/Fig-1]: Evaluation of Shutter Force (SF) of Self-Ligating Brackets (SLB) using universal testing machine.



[Table/Fig-2]: Sandblasting procedure of Self-Ligating Brackets (SLB).

and groups, repeated measures ANOVA was used. All analyses were conducted with a 95% confidence interval and a significance level (α) of 0.05.A p-value <0.05 was considered statistically significant, indicating that the observed differences were unlikely due to chance.

RESULTS

The insights into the mean SF, standard deviation, and Coefficient of Variation (CV) for each group under both the New Bracket and Sandblasted Bracket categories have been presented in [Table/Fig-3]. Damon™ Q2 shows the highest and most consistent SF across both new (4.600 N) and sandblasted (4.650 N) brackets, with the lowest coefficient of variation. Selfy™ records the lowest values in both categories, making it the weakest performer. A 3M Unitek™ ranks second with moderate and consistent results. A significant difference was observed between the groups before and after sandblasting (p<0.001).

A comparison of SF before and after treatment across four groups revealed no statistically significant differences, as all p-values were greater than 0.05 [Table/Fig-4].

The descriptive statistics for SF across different bracket brands and types has been presented in [Table/Fig-5]. Damon™ Q2 consistently shows the highest mean SF and lowest variability for both new {(4.600 N, CV: 0.029)} and sandblasted (4.650 N, CV: 0.032) brackets, indicating strong and consistent performance. In contrast, Selfy™ records the lowest SF and highest variability (New: 3.194 N, CV: 0.070; Sandblasted: 3.244 N, CV: 0.070), making it the weakest performer. A 3M Unitek™ and AO show intermediate SF values with moderate variability. Sandblasting results in slight SF increases across all brands, but overall performance rankings remain unchanged.

Post hoc comparisons of SF averaged across bracket types (new and sandblasted) is presented in [Table/Fig-6]. Damon™ Q2 consistently requires the highest force, significantly more than all other brackets (p<0.001), while Selfy™ requires the least, making it the easiest to open. The 3M Unitek™ shows slightly higher force (in Newtons) than AO (Mean Difference=0.309, p<0.001) and Selfy™ (0.581, p<0.001), while AO also exceeds Selfy™ (0.272, p<0.001). Damon™ Q2 shows the largest differences: 0.825 more than 3M Unitek™, 1.134 more than AO, and 1.406 more than Selfy™. These findings underscore the strong influence of bracket design on SF.

DISCUSSION

The present in-vitro study evaluated the influence of sandblasting on the shutter mechanism force of four commercially available self-ligating orthodontic brackets: 3M Unitek™, American Orthodontics, Damon™ Q2, and Selfy™. The key findings indicate that while sandblasting led to a slight increase in SF across all bracket types, these changes were not statistically significant. In contrast, bracket design had a significant effect on SF, underscoring the critical role of material composition and mechanical architecture in determining functional performance.

Parameters	New bracket SF				Sandblasted bracket SF			
	Group-1	Group-2	Group-3	Group-4	Group-1	Group-2	Group-3	Group-4
Median	3.750	3.500	4.600	3.200	3.800	3.500	4.600	3.250
Mean	3.769	3.469	4.600	3.194	3.831	3.513	4.650	3.244
Std. deviation	0.212	0.236	0.132	0.224	0.227	0.225	0.151	0.228
Variance	0.045	0.056	0.017	0.050	0.052	0.050	0.023	0.052
Minimum	3.500	3.000	4.400	2.800	3.500	3.200	4.400	2.800
Maximum	4.200	3.900	4.800	3.600	4.200	3.900	5.000	3.600
p-value	<0.001				<0.001			

[Table/Fig-3]: Shutter Force (SF) (in Newtons) for new and sandblasted orthodontic brackets.
ANOVA; p-value<0.05: statistically significant

Group	Shutter Force (SF)		p-value (Paired t-test)
	Before treatment (mean±SD)	After treatment (mean±SD)	
Group-1	3.769±0.212	3.800±0.227	0.8981
Group-2	3.469±0.236	3.513±0.225	0.2484
Group-3	4.600±0.132	4.650±0.151	0.5583
Group-4	3.194±0.224	3.244 ±0.228	0.0525

[Table/Fig-4]: Comparison of Shutter Force (SF) (in Newtons) before and after treatment across different bracket groups (Paired t-test; p-value>0.05: not statistically significant).

Bracket type	Group	N	Mean	SD	SE	Coefficient of variation
New bracket	Group-1	16	3.769	0.212	0.053	0.056
	Group-2	16	3.469	0.236	0.059	0.068
	Group-3	16	4.600	0.132	0.033	0.029
	Group-4	16	3.194	0.224	0.056	0.070
Sandblasted bracket	Group-1	16	3.831	0.227	0.057	0.059
	Group-2	16	3.513	0.225	0.056	0.064
	Group-3	16	4.650	0.151	0.038	0.032
	Group-4	16	3.244	0.228	0.057	0.070

[Table/Fig-5]: Descriptive statistics of Shutter Force (SF) (in Newtons) for new and sandblasted orthodontic brackets.
* SE: Standard error

Post hoc comparisons - Group						
Group		Mean difference	SE	df	t	p-value
Group-1	Group-2	0.309	0.072	60	4.295	<0.001
	Group-3	-0.825	0.072	60	-11.453	<0.001
	Group-4	0.581	0.072	60	8.069	<0.001
Group-2	Group-3	-1.134	0.072	60	-15.748	<0.001
	Group-4	0.272	0.072	60	3.774	<0.001
Group-3	Group-4	1.406	0.072	60	19.523	<0.001

[Table/Fig-6]: Post hoc comparisons of Shutter Force (SF) (in Newtons) between bracket groups.
Note. "p-value adjusted for comparing a family of 6 estimates."
Note. Shutter Force (SF) averaged across bracket types (new and sandblasted).

The observed increase in SF following sandblasting may be attributed to surface micro-alterations induced by aluminum oxide abrasion. These micro-abrasions could alter the interface between the movable shutter and the bracket housing, potentially increasing internal friction and affecting mechanical performance [11]. This phenomenon has been previously highlighted in a systematic review by Anita P and Kailasam V (2021), which concluded that while sandblasting is effective for recycling brackets, it may influence bracket-base topography and bonding characteristics depending on particle size and intensity [14].

Among the tested brackets, Damon™ Q2 consistently exhibited the highest SF, indicating superior structural integrity and resistance. 3M Unitek™ and AO brackets demonstrated moderate shutter performance, suitable for routine clinical applications, whereas Selfy™ brackets showed the lowest mean SF values with greater variability, suggesting decreased reliability and potential mechanical compromise following recycling. The uniform effect of sandblasting across all groups further reinforces that shutter mechanism performance is more strongly determined by bracket design than by surface treatment alone.

These results affirm that recycling techniques such as sandblasting can be used without significantly compromising bracket performance, though mechanical nuances such as shutter resistance must be considered. The relatively consistent SF across new and sandblasted conditions for each brand, especially Damon™ Q2, supports the clinical feasibility of bracket reuse.

From a clinical perspective, the findings of this study offer reassuring evidence that recycling SLBs using sandblasting can be a viable, cost-effective option without compromising their mechanical performance. As bracket reuse reduces material costs and contributes to environmental sustainability, having a standard recycling protocol could greatly benefit orthodontic practice. However, clinicians should be aware of bracket-specific responses to recycling, particularly with systems like Selfy™ that may not maintain optimal SF consistency after reuse.

Future studies should aim to replicate these findings in in vivo settings and over longer time periods to evaluate the effects of wear, saliva, and mechanical loading on the recycled bracket's performance.

Limitation(s)

The present in-vitro study does not fully replicate the oral environment, where factors such as saliva, temperature changes, and masticatory forces may influence results. Only one recycling method (sandblasting with 50 μm aluminum oxide) and four bracket systems were evaluated, limiting generalisability. Additionally, only SF was assessed, without examining other important clinical parameters such as friction, long-term retention, or patient comfort.

CONCLUSION(S)

The present study concluded that there were minimal differences in SF between new and recycled SLBs, with no clinically significant impact observed. Among the bracket systems evaluated, Damon™ Q2 demonstrated the highest SF values and maintained its mechanical integrity even after sandblasting, suggesting superior resistance to recycling-related alterations. In contrast, Selfy™ brackets exhibited the lowest SF values; however, their performance remained within clinically acceptable limits. Overall, sandblasting emerged as an effective, cost-efficient, and environmentally sustainable reconditioning method. Recycled brackets retained adequate durability and functionality, supporting their potential for reuse in orthodontic practice.

REFERENCES

[1] Mathur P, Tandon R, Chandra P, Dhingra R, Singh P. Self-ligating brackets: From past to present. IP Indian J Orthod Dentofac Res. 2021;7:216-22. Doi: 10.18231/j.ijodr.2021.035
[2] Harradine N. The history and development of self-ligating brackets. Semin Orthod. 2008;14(1):05-18.
[3] Yang X, He Y, Chen T, Zhao M, Yan Y, Wang H, et al. Differences between active and passive self-ligating brackets for orthodontic treatment: Systematic review and meta-analysis based on randomized clinical trials. J Orofac Orthop. 2017;78(2):121-28. Doi: 10.1007/s00056-016-0059-8.
[4] Basudan AM, Al-Emran SE. The effects of in-office reconditioning on the morphology of slots and bases of stainless steel brackets and on the shear/peel bond strength. J Orthod. 2001;28(3):231-36. Doi: 10.1093/ortho/28.3.231. PMID: 11504901.
[5] Grazioli G, Hardan L, Bourgi R, Nakanishi L, Amm E, Zarow M, et al. Residual adhesive removal methods for rebonding of debonded orthodontic metal brackets: Systematic review and meta-analysis. Mater Basel Switz. 2021;14(20):6120.
[6] Jones SP, Tan CCH, Davies EH. The effects of reconditioning on the slot dimensions and static frictional resistance of stainless steel brackets. Eur J Orthod. 2002;24(2):183-90.
[7] Fleming PS, Johal A. Self-ligating brackets in orthodontics. A systematic review. Angle Orthod. 2010;80(3):575-84.
[8] Praveen Kumar Varma D. Recycling of Orthodontic bracket by sandblasting - An in-vitro study. J Indian Dent Assoc. 2011;5:544-45.
[9] Bansal N, Valiathan A, Bansal K. The effects of various in-office reconditioning methods on shear bond strength, morphology of slots and bases of stainless brackets: An in-vitro study. J Indian Orthod Soc. 2011;45:175-82.
[10] Gandini P, Orsi L, Sfondrini MF, Scribante A. Opening and closure forces of sliding mechanisms of different self-ligating brackets. J Appl Oral Sci Rev FOB. 2013;21(3):231-34.
[11] Carneiro GKM, Roque JA, Segundo ASG, Suzuki H. Evaluation of stiffness and plastic deformation of active ceramic self-ligating bracket clips after repetitive opening and closure movements. Dent Press J Orthod. 2015;20:45-50. Doi: 10.1590/2176-9451.20.4.045-050.oar.
[12] Iluru R, Nellore C, Karnati PKR, Thalapaneni AK, Myla VB, Ramyasree K, et al. The effects of in-office reconditioning on the slot dimensions and static frictional resistance of stainless steel brackets. J Clin Diagn Res. 2016;10(1):ZC74-ZC78.

[13] Agarwal K, Shetty S, Desai A. Effect of various mesh designs on shear bond strength of new and recycled brackets -A comparative, in-vitro study. Indian J Forensic Med Toxicol. 2020;14(4):211-18.

[14] Anita P, Kailasam V. Effect of sandblasting on the shear bond strength of recycled metal brackets: A systematic review and meta-analysis of in-vitro studies. Int Orthod. 2021;19(3):377-88.

PARTICULARS OF CONTRIBUTORS:

1. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.
2. Professor, Department of Orthodontics and Dentofacial Orthopaedics, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.
3. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.
4. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.
5. Postgraduate Student, Department of Conservative Dentistry and Endodontics, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Shefali Singh,
Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics,
Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher
Education and Research, Sawangi (Meghe), Wardha-442107, Maharashtra, India.
E-mail: 2502shefali@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Jun 18, 2025
- Manual Googling: Jul 24, 2025
- iThenticate Software: Aug 05, 2025 (7%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **May 21, 2025**
Date of Peer Review: **Jul 08, 2025**
Date of Acceptance: **Aug 07, 2025**
Date of Publishing: **Jan 01, 2026**