SAKARYA ÜNİVERSİTESİ

FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 e-ISSN 2147-835X Period Bimonthly Founded 1997 Publisher Sakarya University
http://www.saujs.sakarya.edu.tr/

Title: Lateral Buckling of Glare for Aerospace Application

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Recieved: 2022-08-10 00:00:00

Accepted: 2023-03-04 00:00:00

Article Type: Research Article

Volume: 27
Issue: 3
Month: June
Year: 2023
Pages: 564-571

How to cite
Burak ŞAHİN, Eyüp YETER; (2023), Lateral Buckling of Glare for Aerospace Application . Sakarya University Journal of Science, 27(3), 564-571, DOI: 10.16984/saufenbilder.1160160
Access link
https://dergipark.org.tr/en/pub/saufenbilder/issue/78131/1160160

Sakarya University Journal of Science 27(3), 564-571, 2023

Lateral Buckling of Glare for Aerospace Application

Burak ŞAHİN *[1], Eyüp YETER[1]

Abstract

Glare (Glass Reinforced Aluminium) which consists of fibre metal laminate composite consisting of aluminium and glass is used aerospace structures are supposed to buckling and impact loads. Lateral buckling analyses were made to determine critical buckling loads, and results were compared to Al 2024-T3 in this paper. Weight and load carrying capacity of Glare grades were taken into consideration and the importance of weight to critical load was stated. Numerical works were carried out by starting with Glass and Aluminum then continued for Glare Grades of Glare 2A, Glare 2B, Glare 3A, Glare 3B, Glare 4A, Glare 4B, Glare 5A, Glare 5B, Glare 6A and Glare 6B to estimate buckling load values. Several comparisons were presented for Glare grades based on Al 2024-T3 through paper. Glare 2A, 2B, 3A, 3B, 6A and 6B Grades have lower weight and buckling load values compared to Al 2024-T3. Lower weight is essential for aerospace applications. But optimum weight and load carrying capacity can be selected for intended applications by taking weight and load into consideration at same time. Although Glare grades of 4A 2-1, 4B 2-1, 5A 2-1 and 5B 2-1 having closer weight (17.60g, 17.60g, 19.13g and 19.13g respectively) to Al 2024-T3 (17.31g), higher buckling loads were determined for Glare grades numerically. The best choice for Glare as an alternative to Al 2024-T3 under lateral buckling loading can be decided for point of views of less weight to critical load ratio.

Keywords: Glare, lateral buckling, load carrying capacity, aerospace applications

1. INTRODUCTION

As it is well known, mechanical components fail by material failure and structural instability. The second one is also called as buckling. Machine elements and mechanical components can buckle under compressive loads.

Lateral buckling occurs because of bending on beams. Translational and rotational movement of beam section due to deformation are defined as lateral bucking.

Fibre metal laminates (FMLs) were developed as a hybrid material owing to need of light weight and high-performance structure [1]. In industries of aerospace and construction, fibre-reinforced composites have been extensively used in recent years (Figure 1).

Banat et al investigated thin-walled members of seven layers Glare which are supposed to axial compression. FML are hybrid composites consisting of alternating thin

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aluminium sheet layers and fibre-reinforced epoxy prepreg of glass fibres [2].

Glare (Glass Reinforced Aluminium) is a fibre metal laminate composite consisting of aluminium and glass (Figure 2).

Figure 1. Glare deployment in the Airbus A380 [1]

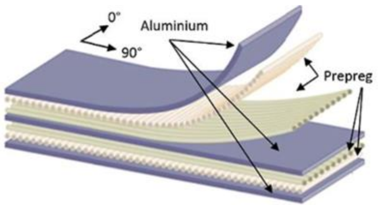

Figure 2. Lay-up Configuration of 7-layered Composite [2]

Aerospace structures are supposed to hail, bird strike, collision of service car, cargo or structure and maintenance damage owing to dropped tools so they require good impact properties [3].

Because of its superior damage tolerance properties, Glare is widely used for aerospace structures which are exposed to impact damages.

Airbus A-380 is very well-known example for Glare usage in aircrafts (Figure 1). Glare is used in the main fuselage skin and the leading edges of the horizontal and vertical tail planes of Airbus A380 [4].

Glare has superior properties of excellent impact characteristics and flame-resistant capability. So it is used for fire walls and cargo-liners. In addition, cockpit crown, forward bulkheads and leading edge are usage areas of Glare [4].

Glare provides 10% reduction in weight compared to monolithic aluminium. It has advantages over carbon fibre reinforced polymers owing to improved impact, fire and corrosion resistance, and increased damage tolerance. It takes place for application of the Airbus A380 fuselage, the Learjet 45, floor panels for the Boeing 737 and the cargo doors of the Boeing C-17 Globemaster III [5].

Glare has main advantages of low weight, longer fatigue life, low weight, high impact resistance and corrosion resistance. Glare structure has improved strength and stiffness over traditional materials on a unit weight.

Mania and York searched the thin-walled fibre metal laminates' buckling behaviour and load carrying capacity under axial load in compression analytically and experimentally [6].

Banat and Mania conducted a numerical and experimental study to determine stability of open cross section top hat and Z shaped sections under axial compression load [7].

Eglitis et al conducted numerical and experimental works on the buckling of composite cylinders under concentric and eccentric compressive loads [8].

Bikasis et al studied on the elastic buckling of Glare under different support types exposed to shear stress by finite element and eigenvalue buckling analysis [9].

Muddappa et al made an investigation for the Glare with different thickness and boundary conditions under various loading and stress distribution by applying dynamic approach to determine buckling behavior [10].

Banat et al investigated buckling behaviour of thin-walled fibre metal laminate profiles for various composite arrangements and Z-shaped and channel shaped geometries by finite element method and experimentally [11].

Wu and Yang investigated mechanical behaviour of fibre reinforced metal laminates, especially Glare for aerospace structures under tensile and compressive loadings. They stated that the importance of Glare for aerospace applications such as Airbus A380 with wings leading edge and tails [3].

The high demand on weight reduction and high level of damage tolerance necessitates fibre metal laminates. From this point of view, Glare is a unique material for applications of aerospace industry especially for fuselage skin structures for new aircrafts [12].

Erklig et al investigated the impacts of triangular, circular, square, rectangular and elliptical cutouts on the lateral buckling behaviour of composite beams experimentally [13].

Erklig and Yeter studied the effects of cutouts on buckling behaviour of polymer matrix composites numerically for different boundary conditions [14].

Yeter et al investigated the effect of hybridization on lateral buckling behavior of composite beams with different ply orientations, different cutouts and length/thickness ratio [15].

Erklig and Yeter studied the effects of circular, triangular, elliptical and square cutouts on composite plates buckling behaviour by conducting finite element analyses [16].

In consideration of literature works, there is obviously good reason to investigate the buckling behaviour of Glare grades because of superior properties and its usage in aerospace industry.

Structural elements such as ribs and spars of aircraft wings are exposed to lateral buckling loads during their service life [1].

Due to these reasons, this paper is primarily intended for lateral buckling analysis of Glare.

2. BUCKLING ANALYSIS

Finite element analyses were conducted to determine critical buckling loads for different Glare grades which have different combinations of glass fibres and thin layer sheets of Al 2024-T3 in different thickness values (Table 1). These combinations directly affect weight (Table 1) and load bearing capacity (Table 2) of Glare.

Before starting lateral buckling analysis, critical buckling load values of Al 2024-T3 under axial load were determined for fixed-free, fixed-fixed, fixed-pin and pin-pin theoretically and by finite element analyses. Results are presented in Table 3.

Boundary and loading conditions for fixed-free and fixed-pin are given in Figure 3, 4, 5 and 6 respectively. Axial buckling load values which were determined theoretically and by finite element method are very close to each other for different constraints. The smallest difference is 1.69% for pin-pin whereas the biggest one is 6.56% for fix-fix situation.

After completing axial buckling load determination, lateral buckling analysis of Glare 2A, Glare 2B, Glare 3A, Glare 3B, Glare 4A, Glare 4B, Glare 5A, Glare 5B, Glare 6A, Glare 6B and Al 2024-T3 have been carried out to determine the critical load values for buckling under specific boundary and loading conditions (Figure 7-8) for width of 50 mm and length of 100 mm (overall thickness values are presented in Table 1).

One end of beam was fixed and load was applied at the other end to make buckling analysis. Finite element analyses were conducted to determine buckling loads for Al 2024-T3, glass and Glare grades (Table 2).

Table 1. Material Thickness and Weight Values

Material	Thickness (mm)	Weight (g)
Al 2024-T3	1.250	17.31
Glare 2A	1.250	16.08
Glare 2B	1.250	16.08
Glare 3A	1.250	16.08
Glare 3B	1.250	16.08
Glare 6A	1.250	16.08
Glare 6B	1.250	16.08
Glass (0°)	1.250	15.25
Glass (0° 90°)	1.250	15.25
Glass (90° 0°)	1.250	15.25
Glass (90°)	1.250	15.25
Glare 4A 2-1	1.375	17.60
Glare 4A 3-2	2.250	28.27
Glare 4A 4-3	3.125	38.95
Glare 4B 2-1	1.375	17.60
Glare 4B 3-2	2.250	28.27
Glare 4B 4-3	3.125	38.95
Glare 5A 2-1	1.500	19.13
Glare 5A 3-2	2.500	31.33
Glare 5A 4-3	3.500	43.53
Glare 5B 2-1	1.500	19.13
Glare 5B 3-2	2.500	31.33
Glare 5B 4-3	3.500	43.53

Table 2 Lateral Buckling Load Values

Material	Buckling Load (N)
Al 2024-T3	265.59
Glare 2A	261.4
Glare 2B	260.3
Glare 3A	260.81
Glare 3B	260.81
Glare 6A	261.1
Glare 6B	261.09
Glass (0°)	68.165
Glass (0° 90°)	60.859
Glass (90° 0°)	60.861
Glass (90°)	38.704
Glare 4A 2-1	342.55
Glare 4A 3-2	1320
Glare 4A 4-3	3253.5
Glare 4B 2-1	341.02
Glare 4B 3-2	1302.6
Glare 4B 4-3	3195
Glare 5A 2-1	436.54
Glare 5A 3-2	1711
Glare 5A 4-3	4229.3
Glare 5B 2-1	434.5
Glare 5B 3-2	1707.4
Glare 5B 4-3	4224.6

Table 3. Critical Buckling Load Values of Al 2024-T3 under axial load for different boundary conditions

	Numerical (N)	Theoretical (N)	Diff. %
pin-pin	587.1	597.2	1.69
fix-free	146.8	153.1	4.14
fix-pin	1198.2	1251.9	4.29
fix-fix	2348.5	2513.3	6.56

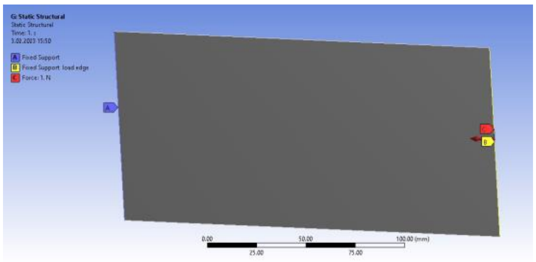

Figure 3. Boundary and Loading Conditions for Axial Buckling (fixed- fixed)

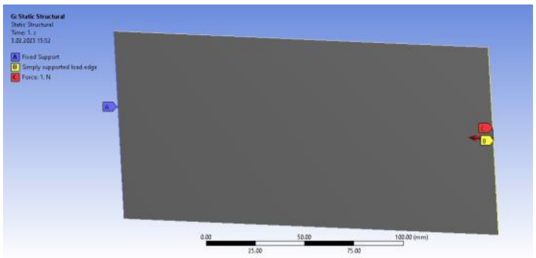

Figure 4. Boundary and Loading Conditions for Axial Buckling (fixed-pin)

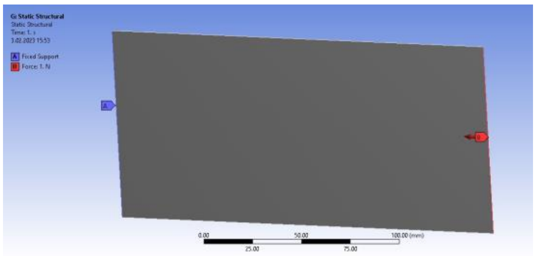

Figure 5. Boundary and Loading Conditions for Axial Buckling (fixed-free)

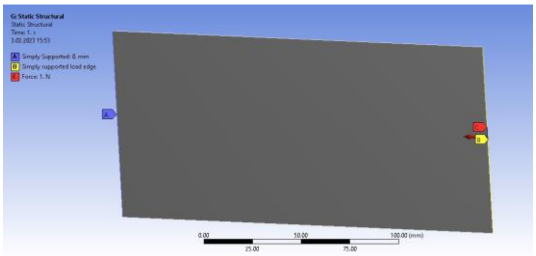

Figure 6. Boundary and Loading Conditions for Axial Buckling (pin-pin)

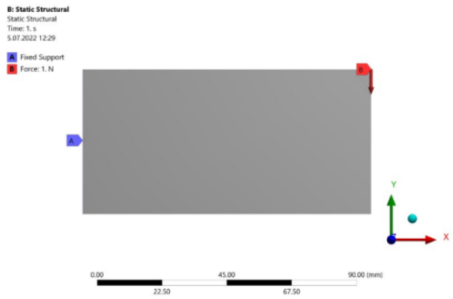

Figure 7. Boundary and Loading Conditions-1

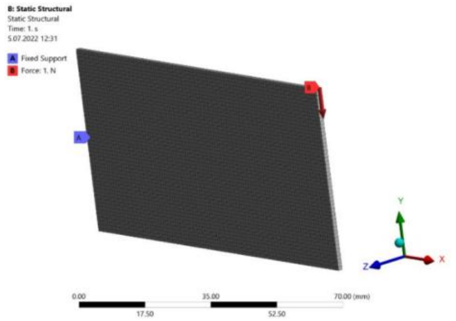

Figure 8. Boundary and Loading Conditions-2

3. RESULTS AND DISCUSSION

As expected, glass with different orientation (0°, 90°, 0°90° and 90°0°) has the lowest values of weight and critical buckling load compared to Al 2024-T3 and Glare. Glare 2A, 2B, 3A and 3B have greater weight in comparison with glass.

Weight is very significant for many applications especially for aerospace industry.
In addition, critical buckling load play a vital role for wings and fuselage. Therefore, critical buckling load must be taken into consideration. Although increase of 0.83 gram (5.44%) for selected specimen dimensions was obtained for Glare 2A, 2B, 3A and 3B compared to glass (Table 1), allowable buckling load increased four times more (Table 2).

This comparison is valuable but not enough because of rare usage of glass in mechanical systems which are subjected to different loading types such as tension, compression, shear, bending and combination of them. Comparison of change in weight and buckling load of Glare grades with Al 2024-T3 gives exact information.

Glare 2A, 2B, 3A and 3B have lower weight (7.65%) compared to Aluminum alloy for same specimen sizes (Table 1). Additionally, there is a drop in buckling load compared to Al (Table 2). Glare 2A, 2B, 3A and 3B have almost 2% lower buckling load than Al.

Weight and buckling load and values of Glare grades of 4A, 4B, 5A and 5B increase by depending on thickness increase (Table 1, 2 and Figure 9-16).

Though Glare 4A 2-1 and 4B 2-1 have almost same weight (17.60 gr) with Aluminum (17.31 gr), buckling load values of these glare grades are higher than that of Al 2024-T3.

Glare 4A/4B 3-2 and 4A/4B 4-3 have 28.27g and 38.95g weight values respectively (higher than Al) (Figure 10 and 12). Buckling loads of 4A 3-2, 4B 3-2, 4A 4-3 and 4B 4-3 are 1320, 3253.5, 1302.6, 3195N by turns (Figure 9 and 11).

Glare 4A 3-2 and 4B 3-2 have almost 39% more weight while corresponding increase in buckling load is almost 80% compared to Al (Figure 10-12). When similar comparison is made for Glare 4A 4-3, 4B 4-3 and Al 2024-T3, it is seen that weight and buckling load increase are 55% and over 90% respectively based on values of Al 2024-T3. Glare 5 grades have higher weight and buckling load values (Figure 13, 14, 15 and 16) compared to reference values (values of Al 2024-T3).

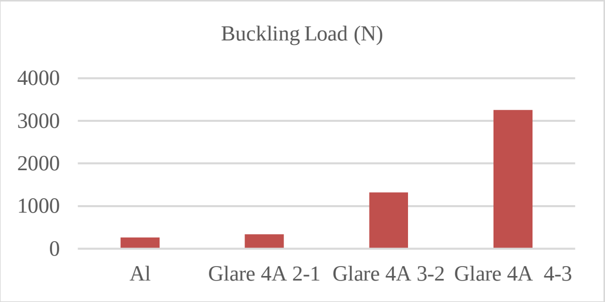

Figure 9. Buckling Load of Glare 4A Grades and Al 2024-T3

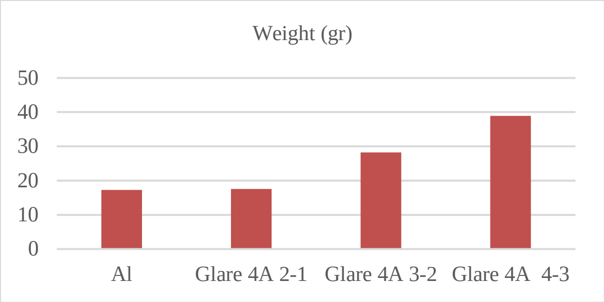

Figure 10. Weight of Glare 4A Grades and Al 2024-T3

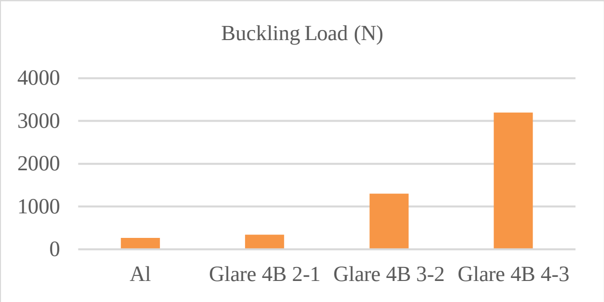

Figure 11. Buckling Load of Glare 4B Grades and Al 2024-T3

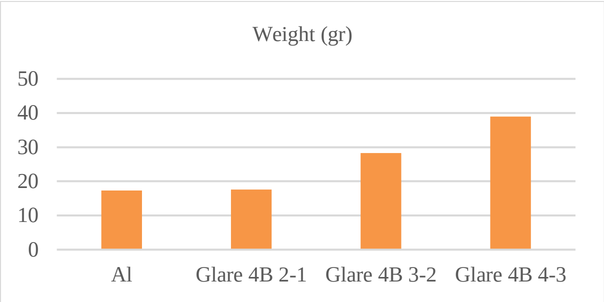

Figure 12. Weight of Glare 4B Grades and Al 2024-T3

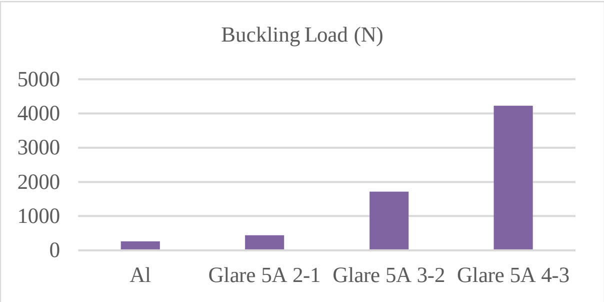

Figure 13. Buckling Load of Glare 5A Grades and Al 2024-T3

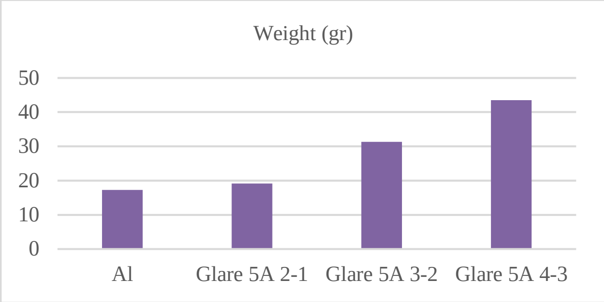

Figure 14. Weight of Glare 5A Grades and Al 2024-T3

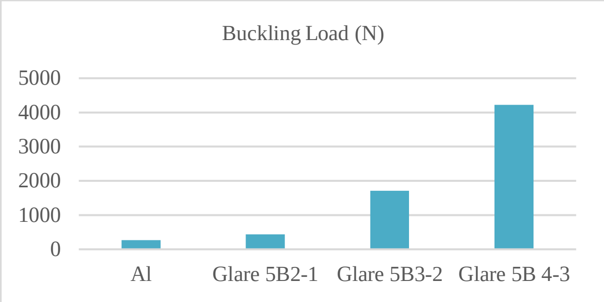

Figure 15. Buckling Load of Glare 5B Grades and Al 2024-T3

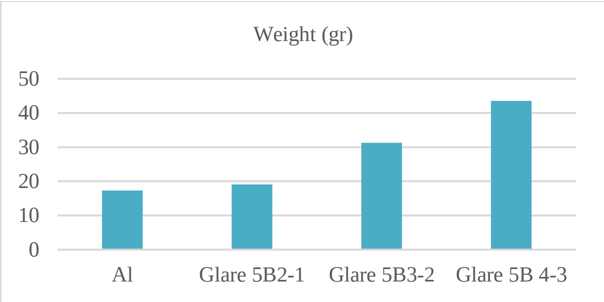

Figure 16. Weight of Glare 5B Grades and Al 2024-T3

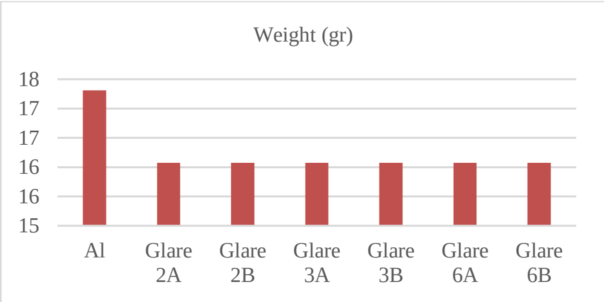

Figure 17. Weight of Glare 2A, 2B, 3A, 3B, 6A, 6B Grades and Al 2024-T3

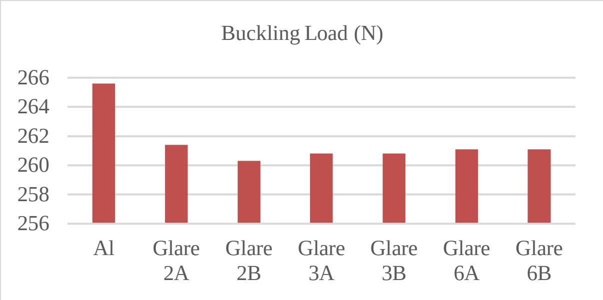

Figure 18. Buckling Load of Glare 2A, 2B, 3A, 3B, 6A, 6B Grades and Al 2024-T3

4. CONCLUSION

As it is known, increasing thickness of material yields in higher critical buckling load. This situation is intended for structures such as wings and fuselage which are exposed to lateral buckling. Conversely, weight increase is undesirable because lightness is very essential for aerospace structures.

Several comparisons were carried out for Glare grades based on Al 2024-T3 above sections of this paper. Glare 2A, 2B, 3A, 3B, 6A and 6B Grades have lower weight compared to Al 2024-T3 (Figure 17). Lower weight is essential for many applications especially aerospace ones. On the other hand, load carrying capacity must be at required level. Critical buckling load values of mentioned grades are lower than Al 2024-T3 (Figure 18). Optimum weight and load carrying capacity can be selected for intended applications by taking weight and load into consideration.

One more comparison of lateral buckling load can be performed here based on Glare grades of 4A 2-1, 4B 2-1, 5A 2-1 and 5B 2-1 having closer weight (17.60g, 17.60g, 19.13g and 19.13g respectively) to Al 2024-T3 (17.31g). Whereas these Glare grades have closer weight values to Al 2024-T3, higher buckling loads are determined for Glare grades numerically.

The best choice for Glare as an alternative to Al 2024-T3 under lateral buckling loading can be decided for point of views of less weight to critical load ratio.

Experimental works are intended for axial and lateral buckling load determination of Glare with different grades and fiber metal laminates (FMLs) as a future work.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the author.

The Declaration of Ethics Committee Approval

The author declares that this document does not require an ethics committee approval or any special permission.

The Declaration of Research and Publication Ethics

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