

## **Dynamic assessment of aftermarket child restraint accessories – are there any safety implications?**

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### **Abstract**

There are many aftermarket child restraint accessories available on the Australian market, such as the gated buckle (used to convert a lap/sash belt to a lap only belt) and the chest strap (connects to the harness straps to make it harder for a child to remove their arms). These products are often perceived as serving a safety need, such as the chest strap preventing a child from removing their arms from a harness and being partially unrestrained. However, it is unknown if these products interfere with the safety performance of the restraint or present a hazard in themselves. This research explored whether adding an aftermarket accessory to a child restraint either affects the performance of the restraint or presents a safety hazard in the event of a crash. A test protocol was developed and dynamic testing was subsequently performed to determine whether any safety implications existed for two specific aftermarket child restraint accessories - the gated buckle and chest strap. The gated buckle was tested on both rearward and forward facing child restraints, while the chest strap was tested on a forward facing child restraint only. The results were compared to baseline dynamic test results that were performed without the accessory. This paper will report on the dynamic assessment process and will discuss whether any safety implications or hazards result from the use of these devices. Recommendations around the use of these devices will also be discussed.

### **Background**

There are various aftermarket child restraint accessories that are commonly used by parents. These devices are often used with the intent of improving child safety when travelling in a vehicle. In 2012, RACV commissioned research to undertake a desktop review of a variety of these accessories (Paine, Paine, Brown & Bilston, 2012). This work identified that many accessories had potential safety risks. Two of these devices, the gated buckle and the chest clip, warranted further investigation.

The gated buckle is a device that is designed to convert a lap/sash seatbelt into a lap only belt. It is generally used to provide a tight, secure installation of the child restraint and to ensure the restraint remains in the installation position throughout ongoing use. Previous RACV research identified that depending on how it is used, it may allow excess slack in the lap section of the belt and that it could also come into contact with the child in the event of a crash (Paine et al, 2012). There are also concerns that in a crash it may become unthreaded from the seatbelt or break, and act as a projectile.

The chest clip is designed to prevent the child restraint occupant from taking the shoulder straps off their shoulders by clipping the two shoulder straps together across the chest. However, in the event of a crash, depending on how it is positioned, there may be a risk of choking, strangulation, injury to the throat or chest. Use of this device may also make it more difficult or time consuming to remove a child from the vehicle in an emergency. However, without conducting dynamic testing to further understand the potential hazards of these devices, it is difficult to establish whether these theoretical risks are realistic, and hence whether devices are fit for use in a real world scenario.

Although the voluntary Australian Standard (AS/NZ 8005) *Accessories for Child Restraints for use in Motor Vehicles* was introduced in 2013 (Standards Australia, 2013), there is still very little known about whether devices meeting this standard affect the performance of a restraint detrimentally. The aim of this study was to investigate how child restraint accessories interact with a child restraint in a crash. RACV commissioned APV Tech Centre to develop a test protocol that can be used for the dynamic assessment of child restraint accessories. This protocol was subsequently used to undertake dynamic assessment of a gated buckle and chest clip to determine whether there are any potential safety implications of these devices in the event of a crash.

## Methodology

There were two phases to this study. The first phase involved developing a protocol for dynamic assessment of child restraint accessories, while the second phase involved using the protocol to perform testing of two products, the gated buckle and chest clip.

### *Protocol development*

A protocol for dynamic assessment was prepared from relevant sections of existing standards. AS/NZS 8005:2013 - *Accessories for child restraints for use in motor vehicles* (Standards Australia, 2013) was used as a base and increased performance requirements were further specified to match the Child Restraint Evaluation Program (CREP) protocol where appropriate. Other recognised standards were also used; e.g. seat belt modification devices (i.e. gated buckle) were subjected to sections of the Australian Design Rules 4/05 (Vehicle Standard, 2014) to verify the integrity of the belt would not be compromised. The protocol was reviewed by RACV Vehicle Engineers and a full protocol was finalised that will enable further testing of additional child restraint accessories to be completed independently of this research.

### *Gated buckle*

The gated buckle was tested using a rearward and forward facing child restraint. Table 1 outlines the specific tests that were conducted, the test type, dummy type, and sled acceleration for each test. The following items were purchased for use in the testing:

- Six Babylove Ezy-Switch restraints (1754:2010 BL72C/2010) for use in the rearward facing position (mode A2).
- Six Mothers Choice Nimbus restraints (1754:2010 GS2010) for use in the forward facing position (mode B).
- Six bowed gated buckles (as shown in Figure 1).

The child restraints were specifically chosen for a number of reasons. In particular, they both performed reasonably well from a safety perspective (i.e. both scored 3 stars for safety in CREP testing), and from a consumer perspective they are reasonably priced. This suggested they may be popular choices for parents. The bowed gated buckle was specifically chosen as it appeared to be the most commonly available to the public. An online store was also able to confirm that they sold significantly more bowed gated buckles as opposed to the flat gated buckle. Additionally, RACV restraint fitters perceived the bowed gated buckle to be more effective in keeping the seatbelt tensioned than the flat gated buckle.

***Table 1. Tests conducted to assess the gated buckle.***

Child restraint	Baseline /	Dummy	Test type	Sled acceleration
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<b>Direction</b>	<b>gated buckle</b>	<b>type</b>		<b>(km/h)</b>
Rear facing	Baseline	TNO P1.5	Frontal	56.3
Rear facing	Gated buckle	TNO P1.5	Frontal	56.1
Rear facing	Baseline	TNO P1.5	perpendicular struck side	32.6
Rear facing	Gated buckle	TNO P1.5	perpendicular struck side	32.5
Rear facing	Baseline	TNO P1.5	66° struck side	32.8
Rear facing	Gated buckle	TNO P1.5	66° struck side	32.8
Forward facing	Baseline	TNO P6	Frontal	56
Forward facing	Gated buckle	TNO P6	Frontal	56.3
Forward facing	Baseline	TNO P3	perpendicular struck side	32.7
Forward facing	Gated buckle	TNO P3	perpendicular struck side	32.3
Forward facing	Baseline	TNO P3	66° struck side	32.5
Forward facing	Gated buckle	TNO P3	66° struck side	32.5



*Figure 1. A gated buckle prior to testing*

### ***Chest clip***

The chest clip was tested using a forward facing child restraint only. A rearward facing restraint was not used in this testing because the issue of a child removing their arms from a harness is most common for toddlers who are in a forward facing restraint in Australia. Additionally, the chest clips are mainly marketed towards children when in forward facing mode. Table 2 outlines the specific tests that were conducted, the test type and sled acceleration for each test. The following items were purchased for use in the testing:

- Three Houdini Stops (as shown in Figure 2)
- Six Mothers Choice Nimbus child restraints (1754:2010 GS2010) for use in a forward facing position (mode B).

The child restraint was specifically chosen for a number of reasons. In particular, it performed reasonably well from a safety perspective (i.e. scored 3 stars for safety in CREP testing) and is reasonably priced, suggesting it may be a popular choice for parents. The specific chest clip was chosen as it appears to be the most widely available device in stores within Australia, and hence the most likely to be used by parents.

**Table 2. Tests conducted to assess the gated buckle.**

Child restraint Direction	Baseline / chest clip	Dummy type	Test type	Sled acceleration (km/h)
Forward facing	Baseline	TNO P6	Frontal	56.3
Forward facing	Chest clip	TNO P6	Frontal	56.3
Forward facing	Baseline	TNO P3	perpendicular struck side	32.7
Forward facing	Chest clip	TNO P3	perpendicular struck side	32.3
Forward facing	Baseline	TNO P3	66° struck side	32.5
Forward facing	Chest clip	TNO P3	66° struck side	32.9

**Figure 2. Packaging of the chest clip that was purchased and used for the testing****Dynamic Assessment Procedure**

As specified in the protocol, a comparison of key measurements was made from tests with the accessories fitted to a series of baseline tests.

For each test the child restraint was mounted following the manufacturer's instructions to a seat fixture. The top tether adjuster and seat belt harness adjuster were both subjected to a 60-80N tensile force following the removal of slack.

Three digital high speed cameras (operating at 1000 frames per second) were utilised to capture each test. A mixture of on-board and facility mounted cameras were used. For the frontal test with the chest clip, an extra camera was added to the front left to capture head movement and potential contact with the accessory.

The sled acceleration during the pulse was measured using two accelerometers fixed at the rear of the sled then put through a Channel Frequency Class 60 (CFC60) filter compliant to Society of Automotive Engineers, SAE J211 1988 (Standards Australia, 1988). The sled velocity was measured using a raster strip mounted to the facility and two optical sensors on the sled.

During the chest clip testing, the shoulder pads were removed from the two shoulder straps of each child restraint in order to position the accessory as shown on the packaging (as no instructions on fitment height were provided). All chest clips were coated in blue and green zinc to show any interactions with the dummy. Blue zinc coated the two outer clips and green zinc coated the centre strap.

All gated buckles were fitted using the procedure provided by an RACV representative. This involved fitting the gated buckle to the retractor side of the restraint to pin the sash and lap belts together, with enough tension to fit a few fingers at the top back of the restraint, this equated to approximately 20 N through the lap belt once the gated buckle was fitted (with no occupant or weight applied).

## Results

### *Gated Buckle*

During the frontal test in the forward facing mode a small increase in forward knee travel was observed when the gated buckle was fitted. This extra movement forward is considered to have a negative effect upon occupant safety as occupant impact with the vehicle interior is more likely. However, the type or severity of any injuries resultant of such an impact is unknown.

Additionally, the use of the gated buckle was found to result in an increase in the head impact and decrease in the chest impact values during the forward facing frontal test. These results may have been influenced by the child restraint backrest twisting *more* at the top when fitted with the gated buckle, as shown in Figure 3.



**Figure 3.** *The backrest twisted more during the gated buckle test (right) when compared to the baseline test (left), at 96ms after impact.*

Conversely when a rear facing restraint was used in the frontal test, the head impact value decreased and the chest value increased when using the gated buckle. These results may have been influenced by the restraint twisting *less* when used with the gated buckle, as shown in Figure 4.



**Figure 4. The restraint twisted less during the gated buckle test (right) when compared to the baseline test (left), at 96ms after impact.**

These contrasting findings are also likely to be a result of a modified proportion of top tether loading vs seat belt loading.

During all side impact tests with the gated buckle, particularly in the rearward facing mode, the child restraint travelled a shorter distance and rotation was significantly reduced, predominantly after impact with the door. Due to this reduced rotation, improvements in occupant positioning within the restraint were apparent. As shown in Figure 5, the head was observed to remain within the enclosure of the child restraint for a greater period of time. This was evident for all side impact tests with the exception of the forward facing oblique test.



**Figure 5. Dummy position during testing without the gated buckle (left) & dummy position during testing with the gated buckle (right)**

This is considered to have a significant safety advantage as it could prevent head impact with the vehicle interior, other occupants or intrusion. Additionally, it places the occupant of the restraint in a safer position if there are to be further accelerations or impacts.

The injury results also support an outcome of positive safety benefits for side impact tests, as both head and chest injury values were found to decrease when the gated buckle was fitted for the side impact tests (with the exception of the rear facing oblique side test).

The reduced rotation during side impact tests is likely to be a result of the gated buckle providing a more laterally stiff lower mounting arrangement, which has appeared to restrict displacement and rotation of the restraint base.

Despite pre-test perceptions that the gated buckle may either break or become completely unthreaded from the seatbelt, the accessory itself remained attached for all tests. However, the webbing did become partially unthreaded during a number of tests, as shown in Figure 6. It is not known how likely it is that a gated buckle could become completely unthreaded or release webbing after or during the test. A number of gated buckles also showed significant signs of deformation following testing, an example is shown in Figure 7.



**Figure 6: The gated buckle following testing, showing the partially unthreaded belt.**



**Figure 7. The bent gated buckle following testing.**

### ***Chest clip***

Figure 8 shows the chest clip fitted prior to testing. Frontal testing found that there was an increase from a likely serious head injury (baseline test) to a likely critical head injury (accessory test). An increase in head injury of this scale was a somewhat unexpected finding, as prior to testing it was expected that the addition of the chest clip was more likely to influence the results for a chest injury in a frontal test, rather than head injury. Therefore, it is unclear how much of this variation can be attributed to the use of the chest clip alone.



*Figure 8. Chest clip in position before test*

It is possible that this finding is a result of a variation in the dummy's head direction and speed, which was observed to change slightly during the accessory test when compared to the baseline test. While the addition of the chest clip may have played a role in this variation, it is also believed to be in part due to the removal of the shoulder pads from the harness (which was required in order to secure the chest clip to the harness).

During the oblique side impact tests, severity of both head and chest impacts was reduced with the addition of the chest clip compared to baseline testing. The chest clip is considered to play a significant role in this finding, as the likely outcome of the chest clip holding the two shoulder belts at a set distance prevented the belt from slipping over the shoulder. It is considered vitally important if the shoulder straps are kept on the occupant's shoulders prior to an impact and this finding is considered to have positive safety implications.

At no point during any of the testing did the chest clip contact the occupant neck nor did the neck appear to move significantly towards the clip, which previous research suggested could be a risk. The chest clip also did not slip up the harness straps. However, the chest clip was observed to make impact with the face during the frontal test, which could potentially result in facial injuries. As facial injuries were unable to be measured, the type or severity of any potential facial injuries from use of these devices remains unknown.

In addition, in all tests the chest clip maintained its integrity, no items detached, and no damage was noted to the device, suggesting no parts of this device would act as a projectile in a crash. It was also able to be easily unclipped following testing. This fails to support the finding of the desktop review, which suggested damage to the device may result in difficulties removing the child from the restraint in the event of a crash. However, use of the chest clip is still likely to result in additional time removing the child from the restraint in an emergency, whether the device is damaged or not.

## **Discussion**

While some positive safety outcomes were observed when using the gated buckle with a rearward and forward facing restraint, there are also some small safety concerns apparent, although the severity of these concerns are unknown. In particular, the way the restraint responded to the stiffness changes caused by the gated buckle appeared to reduce the restraint rotation in side impact crashes and hence improve occupant positioning during and after the crash. This was supported by a reduction of head and chest injury results when the gated buckle was fitted. On the other hand,

during a frontal crash with a forward facing restraint the occupants' knees were more likely to come into contact with the interior of the vehicle, the implications of which are unknown.

The previous RACV desktop review outlined that if the gated buckle was to be used incorrectly it may allow excess slack in the lap section of seatbelt or it could also come into contact with child. Although misuse was not investigated in this particular research, the webbing was observed to become partially unthreaded during the rearward and forward frontal tests and during the rear facing oblique side impact test. It may be assumed that such a situation will have a detrimental effect on any subsequent impacts. For example, it may result in excess slack of the seatbelt or may result in the gated buckle coming completely loose and acting as a projectile in the vehicle. However, the real world consequences of this finding are unquantified. It is recommended that further tests be conducted to validate this assumption.

The gated buckle is designed to convert a lap/sash seatbelt into a lap only belt. It is generally used to provide a tight, secure installation of the child restraint and to ensure the restraint remains in the installation position throughout ongoing use. When deciding whether to use an aftermarket gated buckle consideration should first be given to the manufactures instructions. Many restraints already come with a gated buckle or have an inbuilt 'locking clip', and hence these devices should be used where recommended by the manufacturer. Consideration should also take into account how the vehicle seatbelt interacts with the child restraint system during installation. For example, if secure installation is problematic or the restraint is becoming loose over time without a gated buckle, then the use of the device may be required.

It is important to note that these results are dependent on the specific method used to fit the gated buckle. A strict installation method that is taught throughout the RACV restraint fitter network was investigated, as was the use of a particular style of gated buckle. However, it is possible that inconsistent positioning of these devices is likely by those that have not been trained in this particular method, in which case comparable outcomes may not be achieved.

The minor safety concerns identified in the frontal test with a forward facing restraint may be offset by the benefits reported in side impact crashes. For example, despite the knees being more likely to come into contact with the vehicle interior in a frontal crash, it is unknown what injuries will occur as a result. Whereas in a side impact crash, an improvement in restraint and occupant positioning was observed, suggesting improved protection particularly for the head and chest. Therefore, the findings of the current study indicate that these devices can be used with some caution, taking into account the minor risk of knee/leg injury, the benefits of improved head and chest protection, and the practicality of fitting restraints appropriately.

Earlier RACV research found that chest clips may pose a number of safety issues in the event of a crash, such as a risk of choking/strangulation; injury to the throat or chest (especially if the device is comprised of hard materials); and/or difficulties or additional time required to remove a child from the restraint in an emergency. However, the current research was unable to verify many of these concerns.

During testing the use of the chest clip appeared to result in changes to the dynamics of the dummy in a frontal crash situation. This was evidenced by the change in head direction and speed during the frontal tests. However, it is important to note that it is unlikely that the chest clip alone influenced this change. It is possible that the removal of the shoulder pads between the baseline and accessory tests was also a significant factor in this variation.

Additionally, because the baseline test found that a likely serious head impact already existed with the use of this particular restraint, these results may not be representative when using a chest clip

with other restraints that do not already have the existing head injury during a baseline test. Further testing should be undertaken to validate such assumptions.

There appeared to be some safety benefit of using the chest clip in the event of a side impact crash, which was evidenced by the chest clip assisting the harness to remain on the dummy's shoulders. This is considered to result in better occupant retention within the restraint. Any consequences of having the occupants shoulders free of the harness during a crash are unknown. It is considered vitally important that the shoulder straps are kept on the occupants shoulders prior to an impact, so in circumstances where children are regularly removing the harness from their shoulders the chest clip may be a benefit while this behaviour persists.

The chest clip is an aftermarket device that is intended to prevent the child restraints occupants from taking the shoulder straps off their shoulders at the incorrect time (e.g. during travel). When determining whether the chest clip is to be used, it should first be ensured that the harness straps are appropriately tightened and the restraint is being used correctly. Consideration should then be a compromise between preventing the occupant wriggling out from the restraint; fitting the device so contact with the neck is avoided (includes being mindful of the potential that misuse may result in neck contact during any impacts); and ensuring contact with the face is avoided in the event of a frontal crash. It is also worth carefully considering the added step of needing to remove the device in the event of an emergency, as it may not be the parent or even an adult removing the child from the restraint and unfamiliarity with the device may result in unnecessary complications.

## Conclusion

The current research focused on correct use of two child restraint accessories, the gated buckle and the chest clip. Future research may benefit from considering the safety implications of misusing these devices. Additionally, as two devices were able to be tested in the current research, follow up research may consider assessing how other types of accessories influence the safety implications of child restraints. Furthermore, in a similar style to CREP, there may be some benefit in comparing different variations of the same type of accessory and providing a rating from a safety perspective. For example, comparing a bowed style gated buckle with the flat style gated buckle.

Future research may also benefit from including a strict dummy positioning process or dimensional verification using a 3D measuring device prior to each test, which would minimise unintended variations from baseline tests.

This research has assisted in providing better knowledge on the safety of the gated buckle and chest clip device. However, there are many other child restraint accessories available on the market. Additionally, there are also many different variations of the same device. The protocol developed in the current study has been created with these other devices in mind, and can similarly be used to assess safety implications of other products.

## References

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