THE SIGNIFICANCE OF ISOFIX IN REDUCING MISUSE -ANALYSIS OF POTENTIAL ON THE BASIS OF FIELD OBSERVATIONS AND SLED TESTS

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ABSTRACT

An observation study carried out in 2000 (n = 430 children in vehicles) by the Institute for Vehicle Safety (IFM) revealed that two thirds of children are not properly secured in vehicles, even when child restraint systems (CRS) are employed, i.e. "misuse" can be observed. "Misuse" refers in this context to instances where children are secured incorrectly in the CRS and where child seats are not installed properly in the vehicle. At 96%, the proportion of children secured in vehicles in Germany is high, but parents still experience problems when fitting and using child seats. In particular, this concerns protection systems which require that the child seat is fitted separately using the adult seat belt in addition to the child actually being secured in the seat. Incorrect installation was observed in 60% of cases where the seat had to be secured separately in the vehicle.

The fact that the three-point seat belt is intended to provide an optimum fit for adults as well as the design of the child seats appear to cause problems when it comes to securing a CRS.

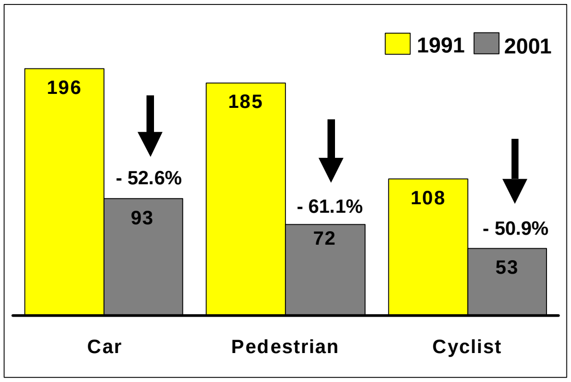
ISOFIX, a protection system that is independent of the adult seat belt, allows the child seat to be fitted securely, simply and always correctly in the vehicle. The most recent results of fitting tests at the Institute for Vehicle Safety have shown that, in comparison with the conventional method using the adult seat belt, fitting errors can be significantly reduced with ISOFIX. In practice, this means that a much higher level of protection can be expected due to the avoidance of errors in installation, since tests carried out in this context have demonstrated that misuse of child protections systems, such as the seat not being secured tightly enough, can increase load values for the child by up to 40%.

In addition to two rigid ISOFIX low anchorages, an anti-rotation device, i.e. top tether or support leg, is planned for future ISOFIX seats in Europe.

INITIAL SITUATION IN GERMANY

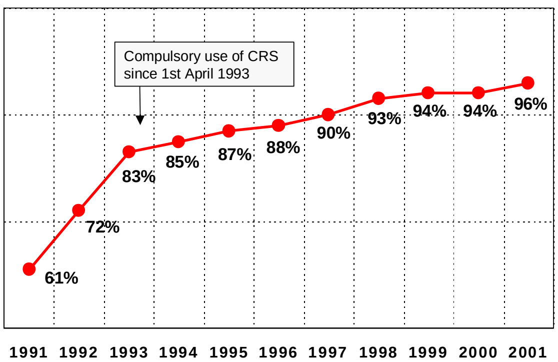
The increasing numbers of vehicles on the road coupled with the ever increasing expectations with regard to personal mobility means that child safety in vehicles is constantly subject to new requirements as the number of child passengers increases. These journeys represent a potential risk of accident and injury to children. In order to come to terms with the changing situation and the laws that apply to restraining children in vehicles which came into force in Germany as of 1 April 1993 [1], increasing demands are being made of parents themselves. These relate to, on the one hand, the correct use of CRS (selection, installation and use) and on the other, an increased awareness with regard to the correct behavior of a child when traveling.

In Germany since 1991, the number of children killed while traveling as passengers in cars has decreased by approximately 53%. However the number of children killed annually while traveling in cars is still higher than the figure when they are involved with traffic in other ways, such as pedestrians or cyclists (Figure 1). If we look back at the laws on child restraint introduced in 1993 we can see that the number of secured children have continued to increase constantly, and since 1997 the figure has remained at 90 percent and above (Figure 2). If we take the number of children restrained according to age group, we can see very clear differences (Figure 3). Whereas 92% of children up to the age of 5 years are secured in CRS, the rate for children aged 6-11 is only 59%. Children in the latter age group are generally restrained by an adult seat belt which is not suitable for them (34%), and the number of children who were not restrained at all (7%) is considerable. Accident investigations carried out by the IFM [2] show that an unrestrained child is seven times more likely to be killed or seriously injured than a restrained child.



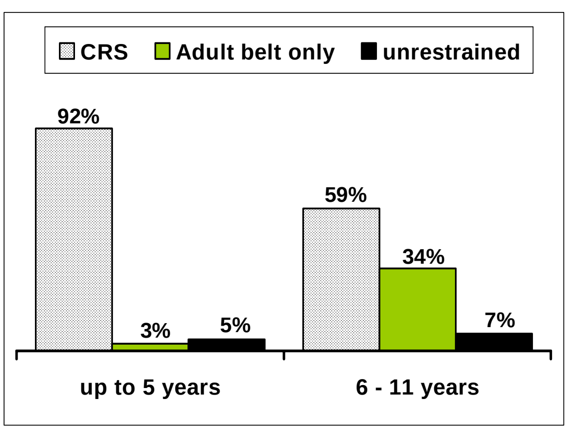
Source: Federal Statistical Office of Germany

Figure 1. Reduction in the number of children killed, according to type of traffic involvement (aged 0 through 14 years)



Source: Federal German Highway Research Institute

Figure 2. Trend in the use of restraints for children in cars



Source: Federal German Highway Research Institute; urban 2001

Figure 3. Use of child restraint according to age group

The introduction of laws stipulating the mandatory use of restraints did indeed influence the number of children that are restrained, but not the quality of restraint achieved. Previous studies in Germany [3] and the rest of Europe [4] have clearly shown that child restraint systems are often misused and that children are thus incorrectly secured which can be very detrimental to the level of protection afforded by a CRS. Studies carried out in USA [5] have also shown similar results. When asked, 96% of parents/guardians were of the opinion that the child was correctly secured and/or the installation of the CRS in question was correct, but a subsequent check showed that four out of every five children were not correctly restrained.

In order to assess the situation in the Federal Republic of Germany, the Federal Highway Research Institute commissioned the Munich-based Institute for Vehicle Safety to carry out a comprehensive fundamental study on improving the protection of children in cars (subsequently to be referred to as the BASt study [6]). An important focus of this study was "child safety and misuse", which was first investigated in 1995 by means of a comprehensive survey involving both observation and questioning. In total, 250 vehicles were subjected to investigation and the protection of 354 children was checked. The basic findings were that two thirds of these children were either incorrectly restrained, or seated in a CRS that itself was incorrectly installed. The questions revealed a range of information about how the errors occurred and the reasoning and motives of the parents. The most frequently made errors were subsequently replicated in sled tests in order to determine the loads placed on the dummies. The values measured during these tests clearly indicate that when a CRS is not used correctly, the protection it affords is diminished dramatically as a result.

In order to determine the current state of affairs, and to ascertain whether changes in quality of restraint had taken place since the BASt study [6], the IFM carried out a second observation and questioning study in 2000 [7] using a similar strategy to the previous one. Individual observations with regard to misuse based on these studies will be discussed below. The time difference between the two studies (five years) allowed comparisons to be drawn for the first time.

Furthermore, the results of these studies were to be used in order to show where the potential of the new "ISOFIX" restraint type lies. The presentation of results from ISOFIX test series and installation studies allows an opinion to be voiced on current initiatives to include the ISO standard 13216-1 [8] in ECE-R 44 [9] and thus to enable universal approval for ISOFIX seats.

RESULTS REGARDING MISUSE

Misuse frequency

In the 2000 study, the percentage of children secured incorrectly, or in a restraint system that was not correctly installed in the vehicle was 66.1%. This absolute "misuse frequency" value was thus approximately 3% higher than the frequency observed in the 1995 study (Figure 4).

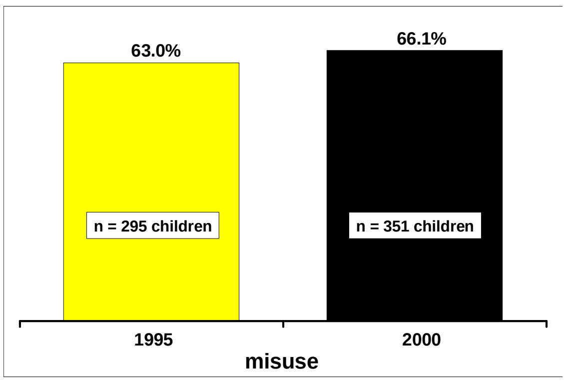


Figure 4. Frequency of misuse – comparison of the 2000 and 1995 studies

Severity of misuse

Since not all instances of misuse have the same consequences with regard to safety deficits, the types of misuse were divided into three categories "slight", "medium severe" and "severe".

The study carried out in 1995 showed that almost half of all handling errors fell into the "severe misuse" category because these errors resulted in the greatest impact on the level of protection. Figure 5 shows that fortunately the proportion of severe handling errors has dropped by 47.4% since the 1995 study. This means that although the actual frequency of occurrences of misuse remains at an unchanged high level, there was however a considerable improvement in the quality of installation and restraint as can be seen by the reduction in the number of severe errors.

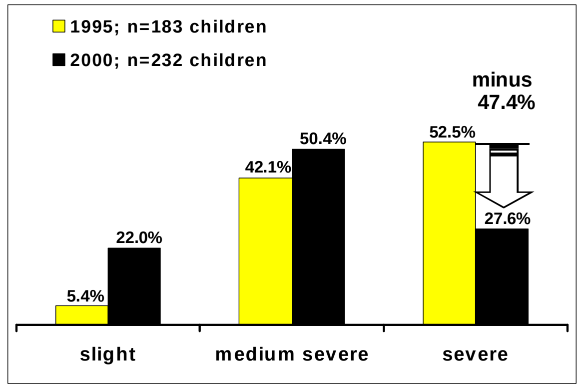


Figure 5. Severity of misuse - comparison of the 2000 and 1995 studies

System observations

Misuse rates

The misuse rate provides information on the extent to which at least one handling error occurred for each system type. Handling errors here refer to both the incorrect installation of a seat or to the incorrect restraint of a child in a seat. Figure 6 is an overview showing the number of seats of each system type investigated in the study and the rate of misuse that was observed for each of these systems. The highest rates of misuse were found for the 4 and 5 point harness systems of Group I with values of 100% and 82.8% respectively, followed by the rearward-facing systems of Group 0 with 68% and the booster cushion systems of Groups II-III with a value of 59.7%. The rates for the more recently introduced Group 0+ systems were considerably lower with values of 28.6%, and 45.8% and 47.8% for the 3 point harnesses of Groups I-III and II-III respectively. The impact shield systems of Group I showed a rate of 50%.

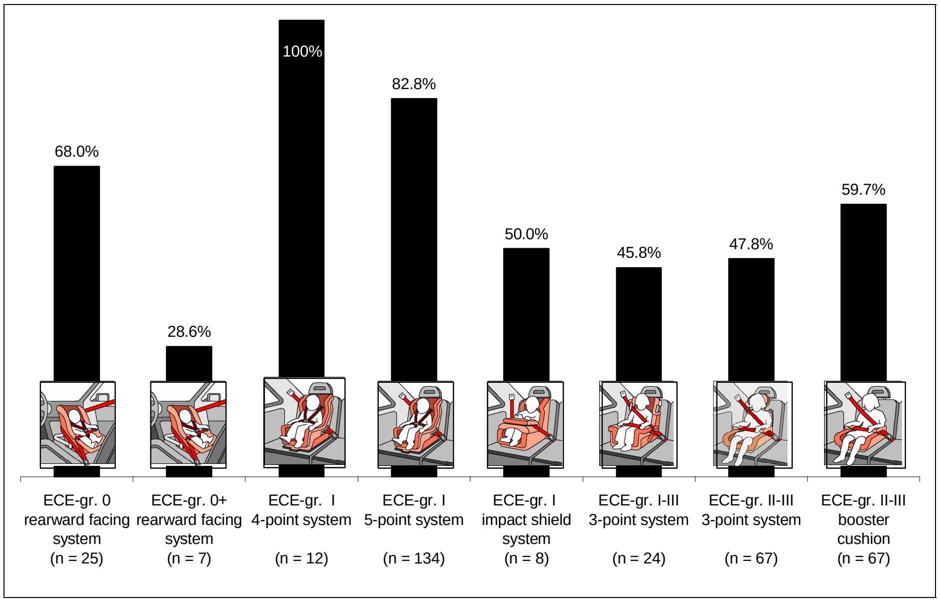


Figure 6. Misuse rates for the various types of system
Only systems with a sufficient number of cases (n>5) are shown here

Severity of misuse according to system type

As shown in Figure 5, the tendency shown by the current study was towards "medium severe" misuse with a value of 50.4%, followed by severe misuse (27.6%) and slight misuse (22.0%). Looking at the differences in results according to system types (Figure 7) clearly shows that systems which require two separate processes to install the seat and to secure the child lead to more frequent occurrences of serious misuse. This rate is particularly high for the rearward-facing systems of Group 0, namely 70.6%, and for the 4/5 point harness systems which are 41.7% and 29.7% respectively.

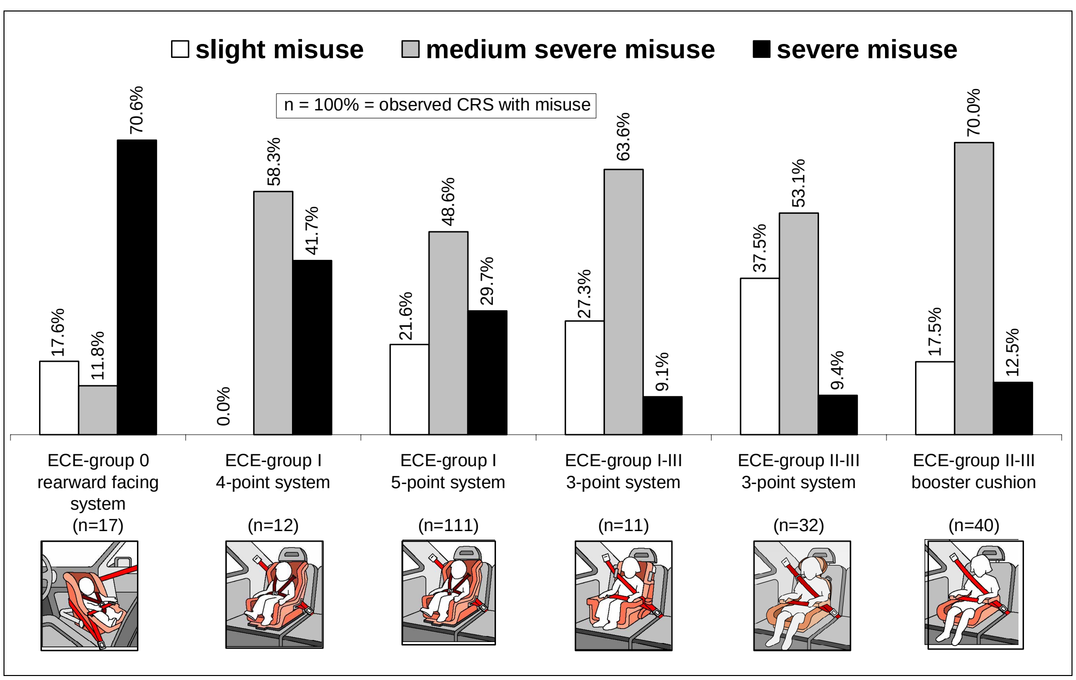


Figure 7: Misuse severity for the various types of system
Only systems with a sufficient number of cases are shown here

Differentiation of misuse in terms of CRS installation and securing of child

A further criterion regarding potential misuse of a CRS can be derived by observing two different factors, the installation of the child restraint system in the vehicle and the securing of the child in the restraint.

Table 1 shows that systems which need to be installed separately in the vehicle were incorrectly installed in 59.4% of the observed instances. This applied, in particular, to the 4/5 point harness systems of Group I and the rearward-facing Group 0 systems which both show that correct conventional installation of the CRS with an adult seat belt poses problems.

The securing of the child in the CRS was seen to be incorrect in 58.7% of the observed instances. Almost all systems showed high degrees of misuse here, and in particular the 4 point harness systems with 91.7% and the 5 point harness systems with 67.9%, as well as the booster cushions and rearward-facing Group 0 systems both of which were also very high. Positive trends could be seen in the rearward-facing systems of the recently introduced Group 0+. The 5 point harness system showed a considerable improvement over the previously common 4 point harness. The rearward-facing Group 0/1 systems only occurred twice in the survey. Both of these instances showed installation errors and one also showed a child securing error. Because of the very low number of cases for these systems, and of the five impact shield systems (one of which had a incorrectly secured child) these will not be taken into account any further.

Table 1.
Comparison of installation and securing misuse for the different types of CRS

	Installation misuse		**Type of child restraint system**			**Securing misuse**	
	%	No.	No.		No.	No.	%
	40.0	10	25	**ECE-GROUP 0** rearward-facing system	25	14	**56.0**
	14.3	1	7	**ECE-GROUP 0+** rearward-facing system	7	1	**14.3**
	*****	2	2	**ECE-GROUP 0/I** rearward-facing system	2	1	*****
				ECE-GROUP I			
	58.3	7	12	4-point system	12	11	**91.7**
	64.9	87	134	5- point system	134	91	**67.9**
Total	**59.4**	**107**	**180**	impact shield system	8	4	**50.0**
				ECE-GROUP I-III 3- point system	24	11	**45.8**
				ECE-GROUP II-III 3- point system	67	32	**47.8**
				ECE-GROUP II impact shield system	5	1	*****
				ECE-GROUP II-III booster cushion	67	40	**59.7**
Total					**351**	**206**	**58.7**

* Due to small number of cases, no percentage rate is given

RESULTS OF INSTALLATION MISUSE

In 1999, the IFM performed sled tests [12] to study the consequences of a loosely installed seat with a view to the biomechanical loads (for limits see Table 2) exerted on the restrained child. An impact shield system was installed both correctly and incorrectly (with 75 mm belt slack) using a three-point seat belt in a real car body (VW Golf IV) mounted on a deceleration sled. The measurement data presented in Figure 8 indicates that the dummy loads in the misuse tests were approx. 30–40% higher than with correct installation.

Table 2. Limits for assessing the results of measurements

Limits for acceleration according to ECE-R 44 [9]	
res. chest acceleration ($a_{res\ 3\ ms}$)	55 g
chest acceler. vertical ($a_{Z\ 3\ ms}$)	30 g
head excursion horizontal	550 mm
Limits for acceleration according to CMVSS 213 [10] / FMVSS [11]	
head ($HIC_{36\ ms}$)	1000
head acceleration ($a_{res\ 3\ ms}$)	80 g
Used biomechanical tolerance limits	
neck moment (M_Y)	*20 Nm*
neck force(F_Z)	*2.0 kN*

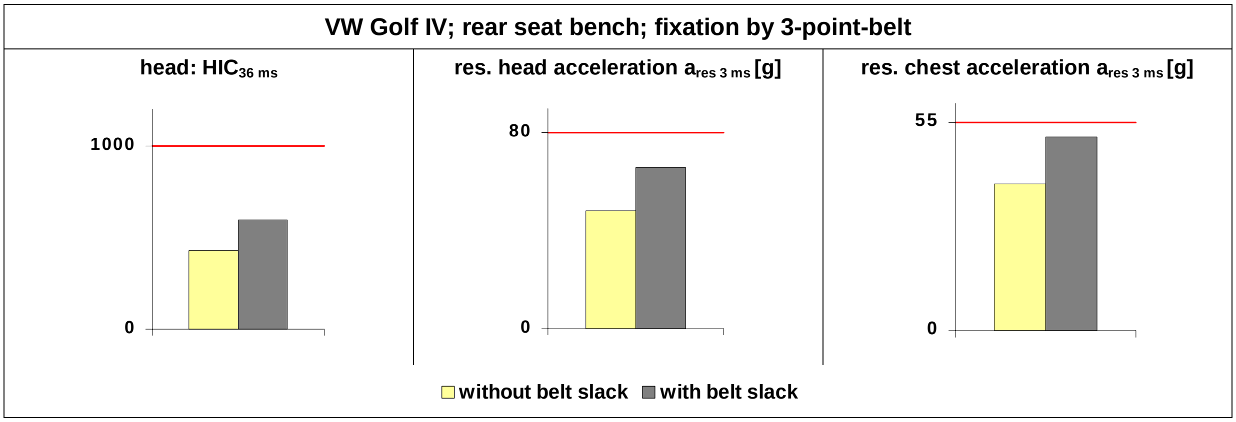


Figure 8. Rear seat of a VW Golf IV: 3-point belt attachment with and without belt slack

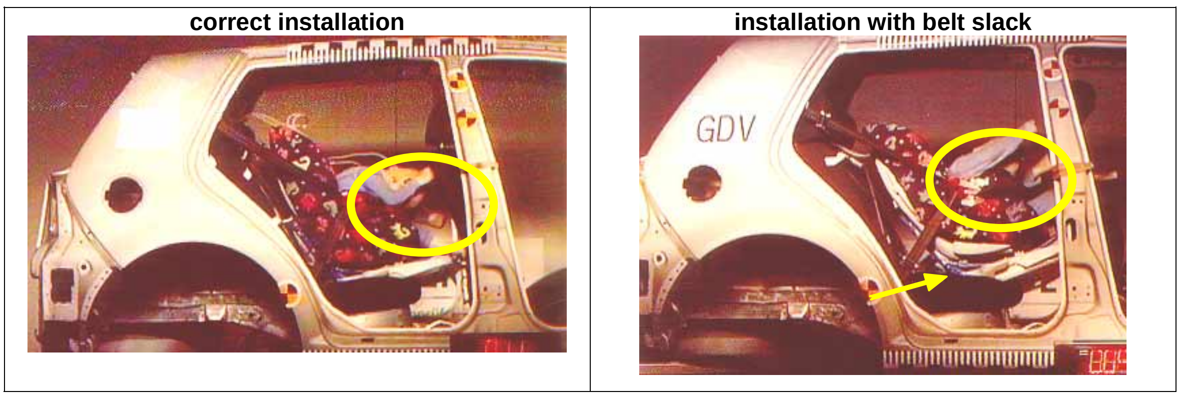


Figure 9. 3-point belt attachment: a comparison of "correct" and "incorrect" attachment

The reasons for these higher biomechanical loads are due both to the uncontrollable kinematic processes of the slack CRS as well as to the "principle of speed adjustment" [13]. Whereas the velocity of the vehicle decreases after the beginning of the collision, the belt slack makes it possible for the CRS to continue moving at the same velocity. The CRS does not begin to decelerate until the belt slack has been taken up. During the remaining time, the CRS experiences a greater velocity change (deceleration) than the vehicle itself. Firm installation of the CRS with no belt slack, on the other hand, makes it possible for the restraint system to actively participate in the deceleration of the vehicle. A comparison of the sequence of movements shown in Figure 9 illustrates another danger. The belt slack makes substantially greater forward displacement of the entire CRS possible. This in turn favours the impact of the head against a hard object in the interior of the vehicle or against the back of the front seat.

ISOFIX

As already mentioned, users evidently have problems correctly installing the CRS using the adult seat belt. In some cases, the design issues are also a contributory factor. The vehicle seat belts make it impossible to install the CRS perfectly in all cases. Unfavourable belt geometries with an upper belt anchorage point located too far forward, asymmetrical lower anchorage sites, or long belt lock lashes can all result in incorrect attachment. In addition, there is sometimes poor compatibility between the vehicle seat and the CRS, e.g. sculpted vehicle seats or seat belts that are too short for rearward facing systems.

Mode of Functioning of Controllable Attachment

The **ISOFIX** fixation system developed by the "International Organisation for Standardisation (ISO)" [8] constitutes a "standardised quick rigid connection system" for Child Restraint Systems which makes installation simple. This rigid interface between the CRS and the vehicle permits proper installation in all cases irrespective of the vehicle seat belt.

The CRS is firmly anchored in the motor vehicle by two anchorages which are 6 mm thick, spaced 280 mm apart and located in the seat bight. When installing the seat, two snap fasteners located on the CRS connectors snap around these anchorages and firmly bolt the seat to the vehicle (Figure 10). In the event of an accident, this form of attachment enables immediate, controllable participation of the CRS in the deceleration of the vehicle.

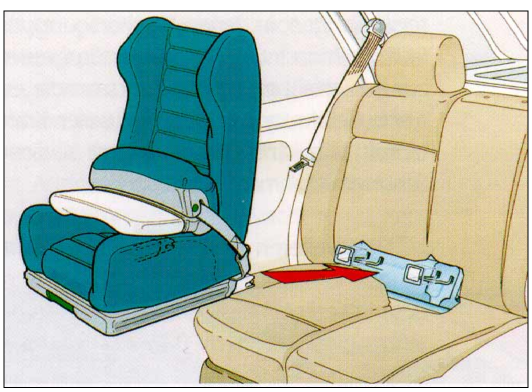


Figure 10. Schematic illustration of a 2-point ISOFIX system (source: VW/Audi)

Potential improvements as a result of ISOFIX

Previous ISOFIX installation studies

In order to ascertain the improvement potential that ISOFIX is able to offer, a range of installation tests have been carried out using ISOFIX prototypes (4 point ISOFIX system) and conventional child seats. The comparison was designed to obtain information about the type of handling errors that are likely to be made when using the two installation methods, and to judge the acceptance of the ISOFIX method.

The observations carried out by Britax Römer [14] showed that when installing using the ISOFIX system considerably fewer errors were made than when installing a conventional seat. Whereas half of the cases of conventional seats examined were installed incorrectly, misuse was only observed in approximately 10% of the ISOFIX seats. The test persons rated the ISOFIX systems higher in terms of user-friendless. The perceived advantages stated included easier handling and assembly, as well as increased stability and safety. Similar results were observed in a Swedish study [15] but the differences in the misuse rates were not as extreme.

The most comprehensive installation tests that have been performed up to now were carried out by IFM as part of the BASt study [6, Chap. 5.4]. Here, 150 test persons were asked to compare the ISOFIX system with two conventional CRS systems. Again fewer errors were made installing the ISOFIX system than when installing conventional seats. The misuse rates for conventional seats lay between 60 and 80%, whereas the misuse rate recorded for ISOFIX seats was only 4%. Thus only 6 of the 150 test persons installed an ISOFIX seat incorrectly. The test persons were subsequently asked their opinions of the ISOFIX system. The majority stated that the ISOFIX seat was easier to install than a similar conventional seat. They were also convinced that the ISOFIX was more stable, that the anchorage was better and that as a result, in the event of a collision, a child would be afforded more protection.

New ISOFIX installation study

In order to obtain current and realistic results, IFM carried out another ISOFIX installation study in 2002. Now for the first time, it was possible to test commercial series production seats that use the ISOFIX system. The seats used in the survey were 2 point ISOFIX harness systems which meet the ISO standard 13216 from May 1999. The ISOFIX seats made available by German child restraint manufacturers were installed and tested in a midsize family car. The car had been equipped as standard with ISOFIX anchorage points on both outer rear seats and the ISOFIX seats had the vehicle-specific approval required for use. The ISOFIX seats were, 1) a Group 0+ rearward-facing seat, made up of a ISOFIX frame and a shell seat (Figure 11) and 2) a Group I forward-facing seat with harness system and integrated ISOFIX (Figure 12).

Figure 11. ISOFIX frame with baby shell seat (Group 0+)

Figure 12. Group I seat with integrated ISOFIX

Test procedure – The adult test persons were first shown by the instructors how to install the relevant ISOFIX seat. The written instructions had been reduced simply to the installation/deinstallation instructions and these were handed over to the test person who was then allowed to carry out the installation themselves. The installation and deinstallation procedures were checked for correctness and this information was recorded. The test persons were then asked to comment on their impressions with regard to handling, stability and safety, and to indicate any perceived advantages and disadvantages as well as to make suggestions for improvement of the ISOFIX system. In addition, the test persons were also asked to comment on their willingness to purchase an ISOFIX seat, as well as being asked to give their age, gender and marital status.

Sample – The testing took place over a total of six days in the car park of a large furniture store. The test participants approached were informed both by means of posters and in person of both the purpose of and the background to the study. The participants were also given information about ISOFIX in the form of brochures. A total of 120 people volunteered to take part, the majority of this group, namely 87% were in the 20-40 age group. The vast majority (approximately 84%) were parents and more than three quarters of the testers were women.

Results

ISOFIX seat (Group I) - This seat was tested by 100 people. The individual installation/deinstallation steps were monitored and documented by the technical experts on hand. The experts noted whether both catches had locked properly and whether correct locking was tested using status displays, whether the seat was pressed into place and whether the final check of the stability of the seat was carried out.

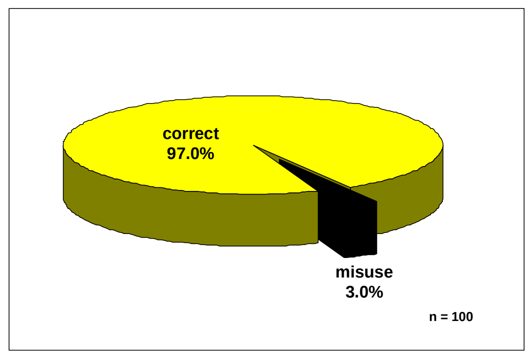


Figure 13. Frequency of installation errors made when using the ISOFIX, Group I seat

Figure 13 shows that 97% of test persons installed the ISOFIX seat correctly. Only 3 of 100 installations showed instances of misuse; in one case the test person was unable to lock the system into place, and in two cases only one side locked. At this point we should also mention that in 14 instances the installation of the seat was not successful at the first attempt. This indicates that the functionality of ISOFIX could still be improved in a way that would do even more justice to the "click and go" claim. It would also appear that the principle of individual locking hinders simple and instantaneous locking. Apart from the instances in which misuse was observed, the locking was checked using the status display and a subsequent tug test. When it came to pressing the seat into place, however, the test persons were not so diligent, and in seven instances, the seat was not pressed into place and in eleven instances this was not carried out to a sufficient degree. In a real life situation, this can lead to a risk of reduced protection since errors of this type can lead to the seat and child being displaced more than they should thus bringing increased risk of injury. The release of the ISOFIX lock did not cause any problems for the testers and was considered easy.

ISOFIX seat (Group 0+) – This seat was a combination seat made up of an ISOFIX frame and a baby shell seat. The two items are installed separately. The ISOFIX frame differs from the Group I ISOFIX seat in that the locks do not operate separately. Instead, they operate synchronously and the frame does not have to be pressed into place subsequently. Of the 20 installation attempts carried out, all test persons were able to successfully install the seat, and on only two occasions was a second attempt necessary (Figure 14). When compared to the Group I seat, the fundamentally different construction (separate locking compared to coupled locking) meant that the functionality of ISOFIX must be seen as better. All attempts to install the seat were tested by checking correct locking using the status display, and a tug test on both sides. The deinstallation/removal of the ISOFIX frame was considered difficult (requiring a relatively high degree of strength) by 10% of test persons.

As Figure 14 clearly shows, the installation of the baby shell seat proved more difficult and resulted in misuse in 5 instances (25%) of 20. The reasons for this were, in one case that the shell seat was not attached, and in two cases that it was not locked into place. On two further occasions the shell seat was neither attached nor locked into place. In the event of a collision taking place, errors of this nature would lead to a serious risk of injury to the child and, in a worst case scenario, would result in a complete lack of protection. Here the manufacturers of child seats need to implement better thought-out concepts in order to preclude all possible handling errors.

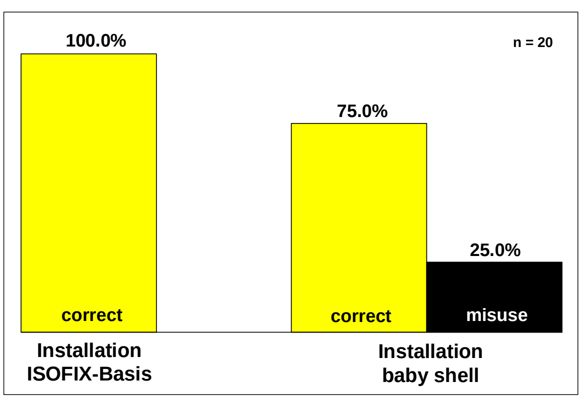


Figure 14. : **Frequency of installation errors; ISOFIX frame and baby shell seat Group 0+**

Evaluation of ISOFIX - The test persons were subsequently asked to comment on their impressions of the ISOFIX system compared to the conventional method using an ordinary seat belt, and to comment on the seat they tested.

Figure 15 shows the responses of the 120 test persons to these questions. At approximately 84%, the vast majority of testers were of the opinion that the ISOFIX system makes the CRS easier to install. Just 11% saw no difference between the ISOFIX seat and the conventional seats that they have used, and only 4% said that the ISOFIX was more difficult to install.

With regard to stability of installation compared with child seats installed using an ordinary seat belt, approximately 81% of testers believed that ISOFIX gave greater stability of installation. In 15% of cases the impression was that stability levels were equal, given that the conventional method of securing was carried out systematically and without error. Only 2.5% (3 instances) believed the stability to be worse and 1.7% (2 instances) did not respond.

The question "Does the special attachment method used by ISOFIX mean that the child is better protected?" was answered positively by approximately 82% of testers, a very high value. The proportion of testers that were of the opinion that the level of safety is equal to that of conventional systems lay at approximately 8% and 5% of testers believed that ISOFIX was not safer than conventional methods. Approximately 5% of test persons were unable to give an opinion.

The 100 testers that installed the Group I ISOFIX seat were also asked whether the greater weight of the ISOFIX system was still acceptable. Approximately a third replied with yes, 19% replied that it was just about acceptable, and 7% found the seat too heavy. This result suggests that this issue would also play a part when parents are deciding what seat to purchase. Manufacturers of ISOFIX design seats should not ignore this aspect.

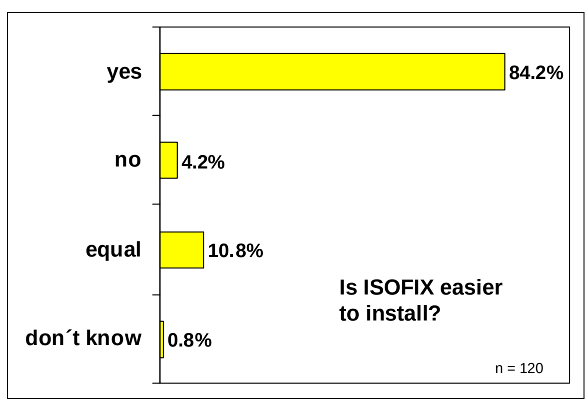


Figure 15a. Responses to the various questions

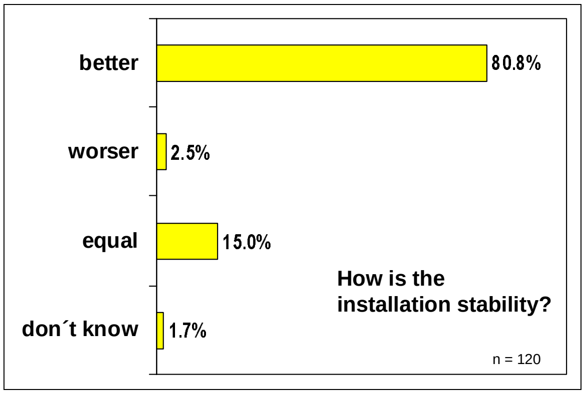


Figure 15b. Responses to the various questions

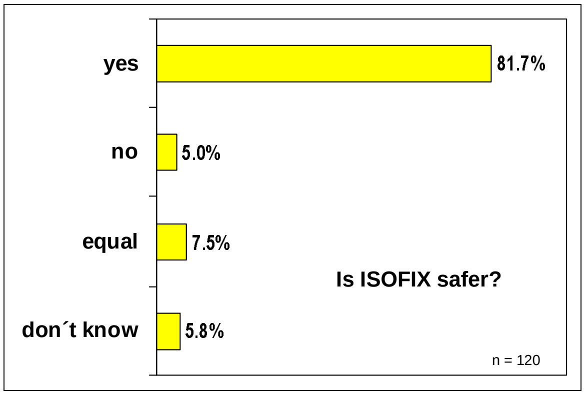


Figure 15c. Responses to the various questions

Avoidance of installation misuse with ISOFIX

As can be seen from Table 1 (on page 5), installation misuse only occurred with system types where installation and securing are carried out as two separate procedures. This refers to the rearward-facing systems of Groups 0, 0+ and 0/I and the 4/5 point harness systems of Group I. Figure 16 shows the levels of installation misuse observed for these system types. Almost 60% of child seats that require a separate installation were not installed correctly. 85% of these errors were of the medium severe or severe categories. Of the 107 CRS installations where misuse occurred, the most frequent error with a value of 78.5%, was of the type "loose seat attachment", followed by "incorrect belt route" and "incorrect installation direction" at 11.2% and 4.7% respectively. Exactly how these installation errors affect the loads exerted on dummies was tested during the sled testing which was carried out as part of the BASt study [6, Chap. 5.3]. The forward displacement as well as the load placed on the head and chest of the dummies were, in part, considerably higher than the relevant reference values. In the event of an accident taking place, this would result in a considerable reduction in the level of protection afforded to the child. Even in the event of an accident with a severity lower than is simulated in testing for ECE-R 44, these installation misuses could lead to severe/life-threatening injuries for the child. The results that have been gathered by this study clearly indicate the extent to which installation misuse can be eliminated by the use of ISOFIX.

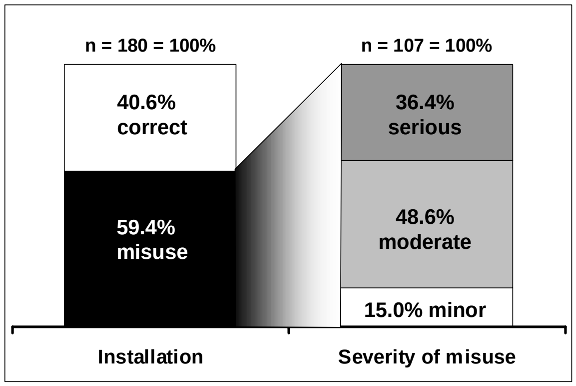


Figure 16. : Proportion of misuse when installing seats and severity of this misuse

Dynamic test series for ISOFIX

Dynamic test series have been used to provide additional information about the loads exerted on a child in the event of a collision when using the ISOFIX method compared with the use of a conventional child seat attachment method. The sled tests carried out by Britax Römer [14] using 5 point harness systems resulted in 25% less load being placed on the head when using ISOFIX than when using a conventionally attached seat. The measured values for the chest deceleration were 15% to 21% lower. Although the resulting forces on the neck were approximately the same, the 4-point ISOFIX system showed approximately 140 mm less forward displacement of the head.

The series of dynamic tests were carried out by TÜV-Rheinland [16] using a Golf IV chassis. The ISOFIX child seat available specifically for use with this vehicle model was compared with a conventional seat. Both the seats used were "impact shield" systems where the ISOFIX seat is rigidly fastened to the vehicle using two locking arms (2 point system). The dummy is secured using the impact shield attached to the child restraint. With the conventional seat, the three-point seat belt already in the vehicle was used to secure both the dummy and the seat. The recorded acceleration values for head and chest were only marginally different, but the ISOFIX seat permitted a considerably greater forward displacement of the head. However, all measurements remained within the limits laid down in ECE-R 44.

Integration in ECE-R 44 - the current situation

In order to be able to introduce ISOFIX universally onto the market, it must be granted universal approval in accordance with ECE-R 44. This is currently not possible since the ISO standard 13216-1 [8] passed in May 1999 is not yet a component of the testing procedure according to ECE-R 44 [9].

In the interests of the worldwide harmonization of ISOFIX, the ECE-GRSP ad-hoc group "ISOFIX" is currently discussing whether and in what form, a third anchorage point ("top tether") as stipulated in the US standard FMVSS 213 [11] and designed to reduce the amount of forward rotation of ISOFIX seats, should be included in ECE R-44.

In order to test the effects of the top tether system, the IFM carried out a further series of tests [17]. In this series, three different ISOFIX seats (CRS *A*, CRS *B*, CRS *C*) were tested with and without the a top tether in a real vehicle chassis (BMW 3 Series) in accordance with FMVSS 213. The measured values, as shown in Figure 17 indicate that the use of a top tether has no real effect on the biomechanical loads. Both the loads exerted on the head ($HIC_{36\ ms}$ and $a_{res\ 3\ ms}$), and the chest acceleration remained below under the legal limits regardless of the type of installation. The differences between an installation using a top tether and a pure ISOFIX installation were within the measuring tolerances. The vertical chest acceleration ($a_{Z\ 3\ ms}$) also showed that the use of a top tether did not reduce the loads. Indeed, in one case, the use of a top tether even led to the legal limits being exceeded. The vertical forces on the neck are almost identical for both types of installation. The legal limit was only exceeded by the model "CRS B without top tether", but even with the top tether this particular model was at the upper limit.

Regardless of the installation method, the measured neck moment was considerably greater the reference value for all three models (Table 2). Further development is still required here.

The results of the two test series discussed here cannot provide sufficient support for the need to introduce an additional anchorage point in the form of a top tether or a support leg in order to reduce forward displacement by limiting rotation. This statement cannot, however, be generally applied to all ISOFIX seats, since differences in design will naturally result in different behavior during testing.

But it appears that a satisfactory solution to the "top tether problem" may have been found: At the GRSP meeting in December 2002, it was decided that forward-facing ISOFIX systems which are fixed in place using the two lower anchorage points and an additional upper "top tether" point should be universally approved provided that the forward displacement is reduced from 550 mm to 500 mm.

In addition to this, all ISOFX systems when used just with the two lower anchorage points must meet the current ECE-R44 stipulations with a forward head displacement of 550 mm. This ensures that even when the top tether is not used, i.e. in the event of a handling error, as can be expected in 20-30% of instances, the protection of a child secured in a forward-facing ISOFIX system seat can still be guaranteed.

However, for rearward-facing ISOFIX restraint systems, the upper anchorage point or top tether will not be prescribed. The important thing here is that an additional anti-rotation system is used, either a support leg, a lower-tether, an upper-tether or a different form of tether. The decision as to which of these is used should be left up to the manufacturer.

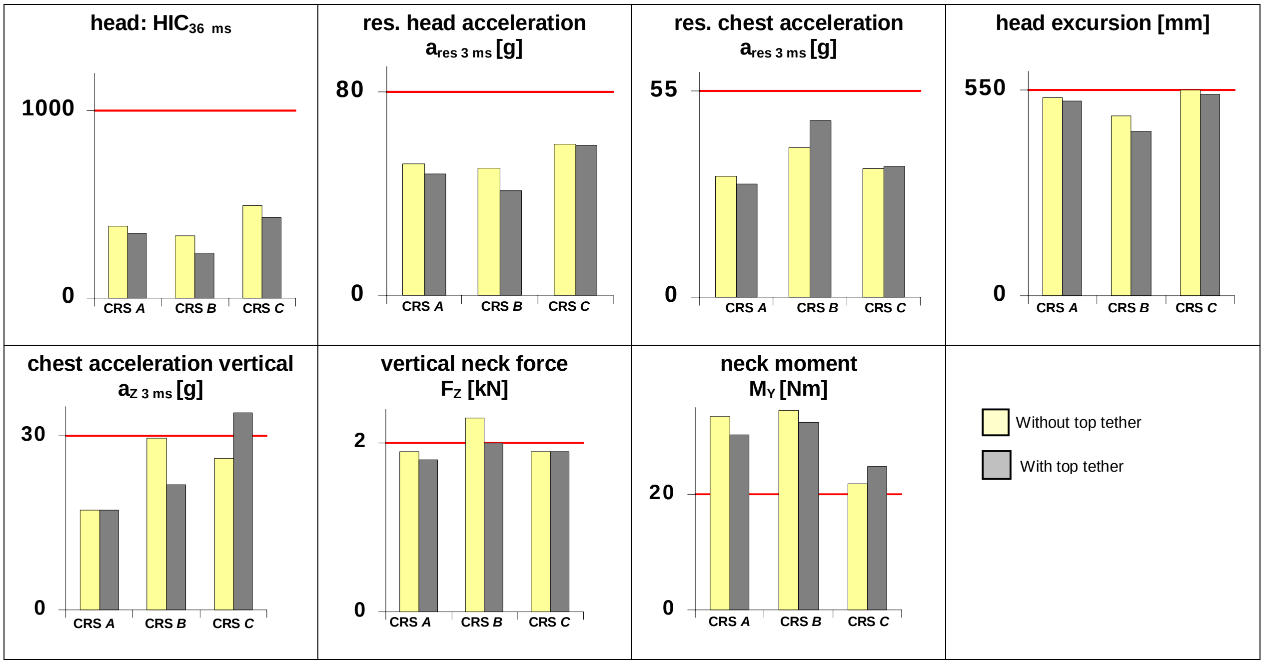


Figure 17: Results of measurement with and without top tether

SUMMARY

For many years now the number of children killed in cars in Germany has been decreasing. An important factor in this trend is the very high level of restraint use.

However, what still remains unsatisfactory is the quality of restraint which significantly impacts the level of protection afforded by a CRS. Observations made by IFM have shown that both the process of installing a child restraint system in a vehicle and the securing of a child in the CRS are often prone to errors: The frequency of this type of misuse lies at approximately 60 %.

Depending on the type of CRS used, installation errors occur with a frequency of anything from 15% through 65%. The studies carried out by IFM found that the average rate of installation misuse lies at 59.4%.

The dynamic tests that have been carried out show that a seat which has been installed incorrectly (e.g. with slack belts) can lead to increased loads on the dummy in the region of 30 to 40% compared to values for a correctly installed seat.

The vast majority of installation errors can be avoided by the use of ISOFIX. The most recent installation studies by IFM showed that ISOFIX seats are almost always installed correctly. Thus, 97% of installations of a forward-facing Group I system were carried out correctly and 100% of Group 0+ seats with ISOFIX frames were installed correctly.

A number of test series have shown lower load values for ISOFIX child seats compared with conventional seats. The most important advantage of ISOFIX seats is that correct and fixed installation is ensured **long-term**, which is not the case with conventional seats.

The discussions surrounding the integration of ISOFIX in ECE-R 44 are coming to an end: the planned regulations for universal approval of ISOFIX provides for a top tether for forward-facing systems but the associated seats must also meet the current ECE-R 44 even if there is no top tether (seat is secured with just the two lower ISOFIX points). With a top tether anchorage point, the forward displacement may only be a maximum of 500 mm to ensure that the risk of impact of the child's head in the interior of the vehicle is reduced further. One important aspect in this context is that the loads on the head, chest and cervical spine must still remain below critical levels.

By taking these aspects into account and ensuring a rapid and universal introduction of ISOFIX it will be possible to increase the safety of children in cars in the future.

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