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Review

Surgical treatment of orbital hypertelorism: Historical evolution and development prospects

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ABSTRACT

Orbital hypertelorism (OR.H) is defined as an abnormal increase in the distance between the two orbits secondary to a skeletal anomaly, and it occurs in association with numerous congenital craniofacial malformations. Since its description by Greig in 1924, OR.H and the associated corrective procedures have captivated many surgeons. Here we present a discussion of the historical evolution of surgery for OR.H and highlight its future prospects. In the mid-twentieth century, only cover-up techniques simulating approximation of the eyes via an optical illusion were used, such as frontonasal skin resection, epicanthal fold surgery, and rhinoplasty. Subsequently, numerous surgeons attempted to correct the deformation using orbitonasal osteotomies via an extracranial approach. However, the outcomes were largely inadequate. Finally, in 1967, Tessier developed an efficient two-stage technique for OR.H correction via an intracranial approach; this technique revolutionized the management of OR.H. In 1970, Converse refined Tessier's procedure by performing a one-stage surgery that preserved olfaction. In 1976, Van Der Meulen developed the facial bipartition technique, which simultaneously corrected maxillary and craniofacial deformities. Box osteotomies and facial bipartition are still used for the correction of OR.H. Using the technological advancements introduced in the early 2000s, several surgeons have attempted to improve these techniques with the use of three-dimensional (3D) surgical planning, preoperative 3D printing, augmented reality-based surgical navigation, and computer assisted surgery using cutting guides. These modern-day practices are rapidly developing and are expected to refine and standardize the surgical correction of OR.H in the future.

1. Introduction

The term hypertelorism is derived from Greek terms (*huper*: above, *tèle*: far, *orizein*: separate), and it corresponds to an abnormally increased distance between two organs or bodily parts. Since its description by Greig (1924) in 1924, orbital hypertelorism (OR.H) and its correction have captivated many surgeons. Tessier defined OR.H as abnormal widening of the distance between the two orbits secondary to a skeletal anomaly, generally in association with congenital craniofacial malformations (Rougier et al., 1977; Tessier et al., 1967). Depending on the interorbital distance (IOD), which corresponds to the gap between the two dacryons, Tessier described three degrees of OR.H severity (Tessier, 1972): first degree, 30 mm < IOD < 34 mm; second degree, 34 mm < IOD < 40 mm; and third degree, IOD > 40 mm.

OR.H management has been a fascinating surgical challenge since the mid-twentieth century. Surgery that facilitates a decrease in IOD via skull and face osteotomies is currently the only treatment for moderate to severe OR.H, with the surgical approaches and osteotomies used today being a result of the development of surgical techniques over >60 years. Here we present a discussion of the

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historical evolution of surgery for OR.H and highlight its future prospects.

2. Historical background

Initial surgical procedures for OR.H. did not correct the intrinsic deformation; instead, they altered the effects on the neighboring structures. Subsequently, extracranial techniques based on orbitofacial osteotomies were developed, although they proved ineffective. In 1967, Tessier described, for the first time, an effective two-stage surgery for orbital approximation via an intracranial approach (Tessier et al., 1967). This innovation was the result of a close collaboration between Tessier and neurosurgeons at the Foch Hospital (Guiot and Derome), leading to the decompartmentalization of two surgical specialties (Arnaud, 2010). With the development of this technique, Tessier not only revolutionized the surgical management of OR.H but also opened a field of possibilities for the management of other malformation syndromes affecting the skull and face. This led to the inception of craniofacial surgery. Tessier's work inspired an entire generation of surgeons, who used his concepts to further advance surgical techniques for OR.H correction.

2.1. Extracranial techniques

2.1.1. Cutaneous surgery and rhinoplasty

Webster and Deming (Webster and Deming, 1950) were the first to describe several surgical procedures for OR.H correction. Intervening only at the skin level, they used cover-up techniques for simulating approximation of the eyes via an optical illusion. Simple frontonasal skin resection or Y–V plasty reduced the intereyebrow space, while epicanthal attenuation was achieved by Z plasty (Fig. 1).

> *"The improvement of these peculiar deformities by surgery is brought about by using the principles of optical illusion to give apparent narrowing of the eyes. By this method, rather marked degrees of true hypertelorism may be made less noticeable in appearance." (Jerome P. Webster, 1950* (Webster and Deming, 1950)*)*

For bifid nose management, they proposed nasal root plasty via nasal or paranasal osteotomies more or less associated with resection of the excess median nasal skin (Fig. 2). Although this procedure refined the nasal bridge, it did not reduce IOD. In fact, bone thinning at the nasal root cleared the canthi, which made the intercanthal distance appear wider. At the same time, the craniofacial skeletal anomaly was not corrected. Thus, the overall results were unsatisfactory.

2.1.2. First orbitonasal osteotomies

For more than a decade, the surgical correction of OR.H seemed impossible, and only techniques based on optical illusions were used for that period (Webster and Deming, 1950; Lewin, 1952). Then, the first orbitonasal osteotomies, aimed at bringing the medial orbital surfaces together, were reported. Between 1959 and 1962, Converse and Smith (Converse et al., 1962) used their expertise in the treatment of traumatic orbitonasal dislocations to develop a surgical technique for OR.H correction. They were the first to attempt orbital approximation through complete osteotomy of the medial orbital walls, behind the lacrimal ridges. After medial nasal bone resection, the orbitonasal walls were brought together and held in position by medial canthopexies using steel wires. Although innovative, this technique was withdrawn because it did not perform well and damaged the lacrimal apparatus.

Converse and Smith subsequently modified the medial orbital wall osteotomy by extending it obliquely downward and inward up to the base of the pyriform orifice (Fig. 3). Ethmoidal cell resection facilitated mobilization of the medial orbital wall and lateral nasal wall containing the lacrimal sac and nasolacrimal duct. Although the outcomes were largely unsatisfactory, lacrimal complications

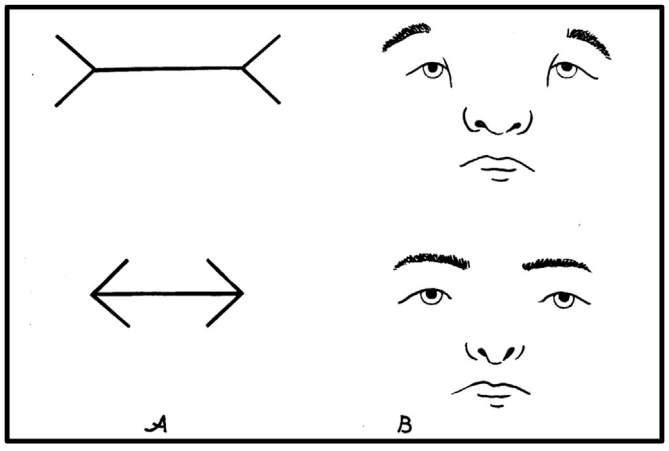

Fig. 1. Webster and Deming simulate approximation of the eyes via an optical illusion. (A) Common example of an optical illusion, making the bar of the upper figure appear longer than the bar of the lower figure. (B) Optical illusion to minimize the appearance of hypertelorism (Webster JP, Deming EG. The surgical treatment of the bifid nose. *Plast Reconstr Surg.* 1950; 6:1-37 (Webster and Deming, 1950)) (Permission for use granted from Wolters Kluwer Health, Inc., *Plastic and Reconstructive Surgery.*).

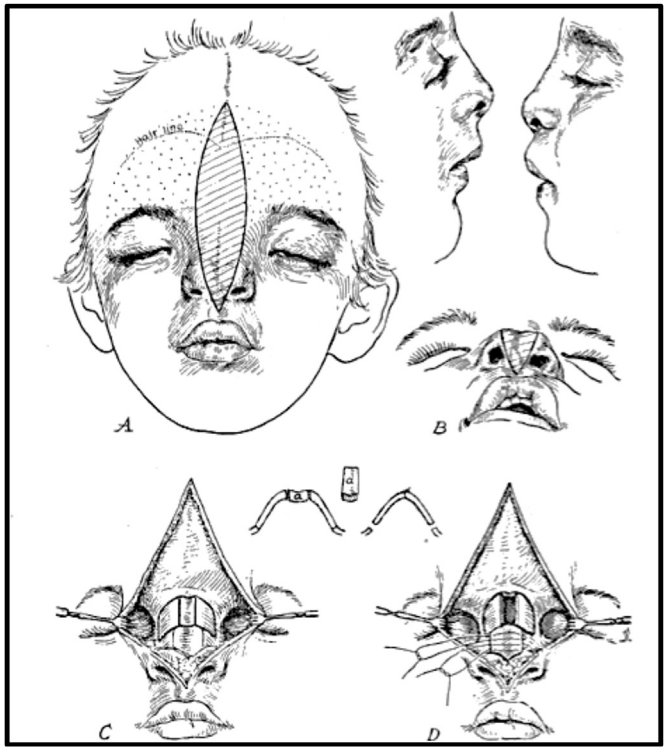

Fig. 2. Nasal root plasty using nasal or paranasal osteotomies for the correction of bifid nose by Webster and Deming. (A and B): Amount of skin and subcutaneous tissue excised (C and D): Excision of nasal bones (Webster JP, Deming EG. The surgical treatment of the bifid nose. *Plast Reconstr Surg.* 1950; 6:1- 37 (Webster and Deming, 1950)) (Permission for use granted from Wolters Kluwer Health, Inc., *Plastic and Reconstructive Surgery.*).

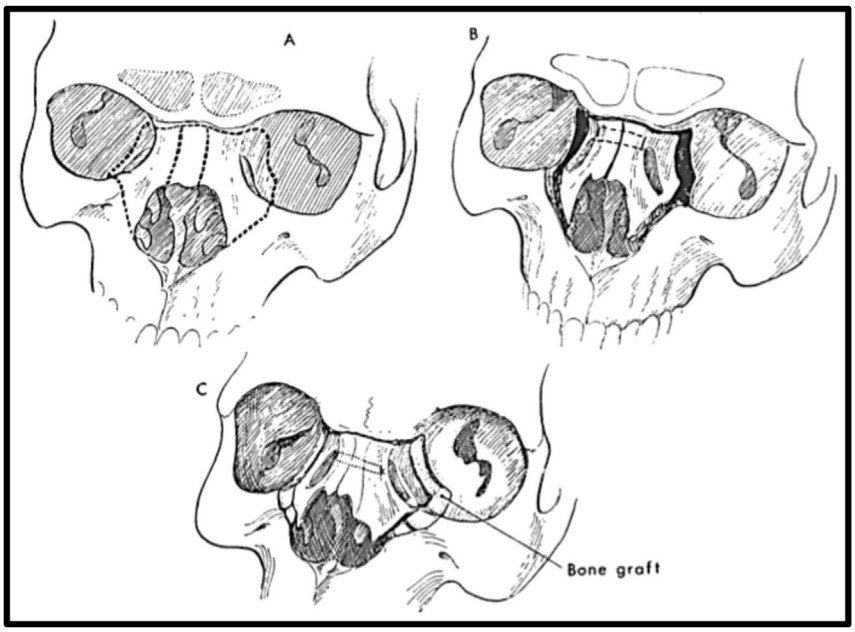

Fig. 3. Technique of subcranial naso-orbital osteotomy used by Converse et al. (Converse et al., 1970) A. Outline of the osteotomy. B. After resection of the central segment, the bony structures are medially moved. Note that the lacrimal sac and nasolacrimal duct are included in the mobilized bony segments. C. The defects in the medial orbital wall, orbital floor, and maxillary areas are filled with bone grafts (Converse JM, Ransohoff J, Mathews ES, Smith B, Molenaar A. Ocular hypertelorism and pseudohypertelorism. Advances in surgical treatment. *Plast Reconstr Surg.* 1970; 45:1-13 (Converse et al., 1970)). (Permission for use granted from Wolters Kluwer Health, Inc., *Plastic and Reconstructive Surgery.*).

were prevented. Accordingly, surgeons began to redesign and expand their osteotomy outlines.

In 1966 (Schmid, 1968), modified the orbital osteotomy procedure to integrate the anterior wall of the frontal sinus and a large part of the orbital floor into the movable portion. He was the first and only clinician to propose skull osteotomy for correction of the deformity via an extracranial approach, mobilization of the entire medial orbital wall, orbital roof, and medial third of the orbital floor, thus resulting in a satisfactory outcome. However, the lateral orbital wall was not mobilized. Nevertheless, Schmid only performed this procedure in a single patient with hyperpneumatization of the frontal sinus, who successfully underwent osteotomy of the orbital roof without injury to the frontal lobe dura mater. Tessier acknowledged this good result, although he highlighted that it would be feasible only for sporadic cases. Tessier also added that dependency on the frontal sinus was not the key for OR.H correction because of its variable anatomy and inadequate depth.

> *"Schmid may have succeeded in treating a patient, but the procedure could not be used as a standard one (…) It was not radical enough. It was too exclusive." (English translation of Paul Tessier's comment* (Arnaud, 2010))

2.1.3. Tessier's B techniques

In the 1960s, Paul Tessier described extracephalic and infraethmoidal techniques for OR.H correction, conceptualizing several variations known as B techniques (Fig. 4). While procedures B1 and B2 involved the medial orbital wall and the medial third of the orbital floor, procedure B3 involved the medial and lateral orbital walls and the entire orbital floor.

Procedure B1 was directly inspired by Converse's method. It brought the medial canthi, a part of the medial orbital wall, and the inferomedial angle of the orbit, including the lacrimal apparatus, closer. Only the para-medio-nasal portions were resected, allowing preservation of the median nasal ridge. This procedure was performed only in two patients, with suboptimal outcomes partially associated with preservation of the median nasal ridge.

Procedure B2 was an extension of procedure B1. The intraorbital osteotomy was deeper, further away from the lacrimal crests, while nasal bone resection involved the medial and paramedian portions. Appropriate positioning of the nasal dorsum was ensured by the fixation of a median bone graft using steel wires. Like procedure B1, procedure B2 did not modify the position of the lateral canthi, resulting in a transverse increase in the orbital diameter. Tessier judged this procedure to be mediocre because of the lack of eyeball mobilization.

> *"This procedure is not completely efficacious; it cannot move the eyeball itself, for it does not move the peri-orbit or the orbital temporal wall." (Paul Tessier, 1972* (Tessier, 1972))

Procedure B3, which involved a U-shaped osteotomy, was conceptualized from this observation. It involved en bloc resection of the medial and lateral orbital walls, medial and lateral canthi, and the entire orbital floor. Although more radical, this technique could not be used for severe OR.H because it could lead to an "orbital chicane" (Fig. 4).

Although all B techniques could partially correct the centrofacial deformity, they did not modify the overall facial enlargement because of the lack of monobloc resection of the entire orbital frame. Thus, Tessier emphasized that extracranial techniques were insufficient for OR.H correction.

> *"As far as ocular hypertelorism is concerned, these three procedures, Converse, Tessier and Schmid, were all bound to fail since they only moved a small portion of the orbital rim and practically nothing either of the orbital walls or periorbitum, and therefore had little effect in moving the globe itself. They really only corrected the telecanthus by moving the medial canthi closer together." (Paul Tessier, 1972* (Tessier, 1972))

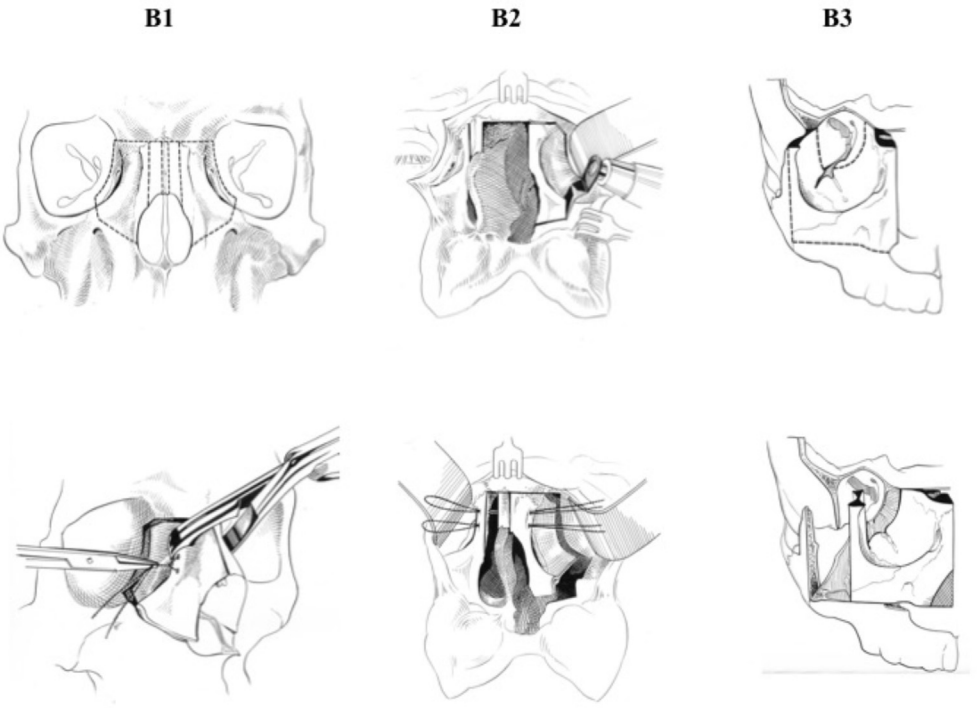

Fig. 4. B techniques: extracranial techniques for the correction of orbital hypertelorism. B1: This procedure was performed in two patients, but it was ineffective because the median nasal ridge was preserved. B2: Like procedure B1, procedure B2 did not modify the position of the lateral canthi, resulting in a transverse increase in the orbital diameter. B3: This procedure could not be used for corrections of >15 mm because of the risk of an orbital chicane (Collection Tessier). (Permission for use granted from the Association Française des Chirurgiens de la Face, AFCF).

2.2. Intracranial techniques

2.2.1. Tessier's A techniques: first box osteotomies

The unsatisfactory correction of OR.H by orbitofacial osteotomies using an extra-cranial approach and an encounter with a case of severe OR.H provoked the development of a bold and innovative idea by Tessier, which culminated in the inception of craniofacial surgery (Arnaud, 2010). The first case seen by Tessier during a consultation in 1960 involved a patient with extreme third degree OR.H (Fig. 5). This case will hereafter be referred to as Patient 0. By this time, Tessier was well aware that the preceding techniques were inadequate for OR.H correction.

> *"Because the first case of hypertelorism that had been entrusted to me was an extreme form, I told myself that canthoplasties do not mean anything. Removing a small piece of bone, in short, means nothing. We must see the problem differently." (English translation of Paul Tessier's comment* (Arnaud, 2010))

Tessier was accustomed to close collaborations with the neurosurgeons at Foch's Hospital, and he proposed an intracranial approach for Patient 0 to Guiot, who simply replied "why not?" Neither of them imagined that this response would lead to the inception of craniofacial surgery, a new discipline that ignored the dogmas of conventional plastic surgery and all a priori concepts.

> *"But when I saw this patient, I told myself that I needed to bring the orbits closer. We will not get rid of the main malformation, the excessive spacing of the orbits, if we do not use the cranium, which is already being used in surgeries for tumors and trauma." (English translation of Paul Tessier's comment* (Arnaud, 2010))

For correction of the severe hypertelorism presented by Patient 0, Tessier developed the A techniques (Fig. 6), which were intracranial techniques for OR.H correction based on the concept that extreme measures are required for extreme cases.

Initially, Tessier and Guiot decided to perform a two-stage surgery in order to limit the complications (notably meningitis) associated with a possible dura mater breach during orbital medialization via an intracranial approach. The first surgical step was to strengthen the anterior skull base via dermal grafting for dura mater reinforcement.

> *"For a negligible risk of meningitis, prior neurosurgery was necessary to ensure that the dura mater was perfectly sealed when I performed the cranio- orbito-facial procedure. The dura mater had to be reinforced during the first exploration phase. To achieve this, I proposed dermal grafting." (English translation of Paul Tessier's comment* (Arnaud, 2010))

The second stage of surgery corresponded to correction of OR.H itself.

The preparatory neurosurgery for shielding the anterior skull base was performed in 1962 without any complication. The outcomes indicated that all patients undergoing A techniques for OR.H correction would benefit from this unavoidable preliminary procedure performed 6 months before the second step.

The second part of the surgery, procedure A1, was performed for the first time in a patient with second degree OR.H in 1962. It was never reproduced because of the same limitations observed with procedures B1 and B2. Three years passed before procedure A2 was introduced.

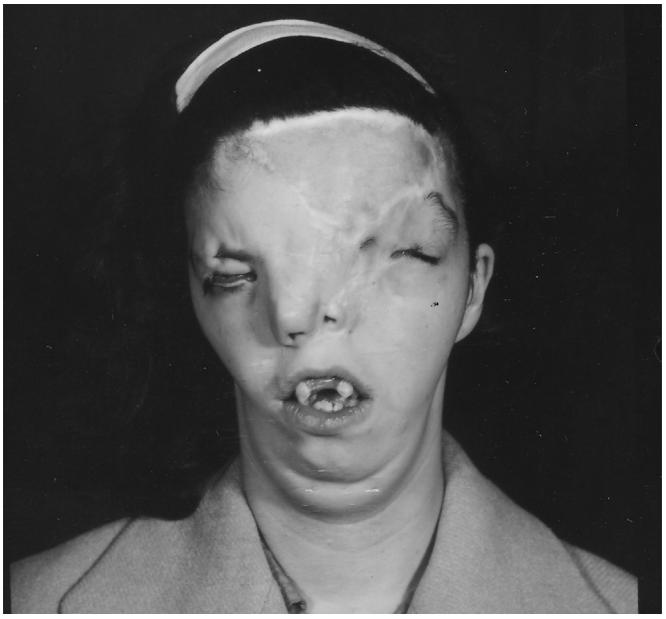

Fig. 5. The first case of orbital hypertelorism, which was severe, seen by Tessier (Collection Tessier) (Permission for use granted from the Association Française des Chirurgiens de la Face, AFCF).

"I waited for other cases … I felt that I was not ready … That there was something that I did not understand about the skull base (…) I also had other cases … I still waited, I think, for three or four years … (…) Then, we treated three cases. After the initial dermal grafting procedure, we treated the three cases in three weeks, with one surgery per week. We started with the simplest one (…) I had not distributed the cases according to severity of the malformation; I was gradually moving ahead so I could observe the outcomes of the procedures." (English translation of Paul Tessier's comment (Arnaud, 2010))

In 1965, procedure A2 was performed in two cases of third degree OR.H. Noting that he did not mobilize the entire orbital frame, Tessier used procedure A3 for Patient 0 in the following week. This approach involved osteotomy of the medial, lateral, superior, and inferior orbital walls. For efficient orbital mobilization and eyeball displacement, the intraorbital osteotomies were performed behind the equator of the eyeball ("useful orbits" concept). Tessier was the first to mobilize the four orbital walls and medialize them like boxes. This technique was subsequently used for 22 patients until the end of 1969.

This major breakthrough, presented at the Rome Congress in 1967, was based on a simultaneous and complementary approach toward the skull and face. It facilitated the introduction of surgical concepts that are still relevant for the treatment of craniofacial malformations and skull base tumors. The intracranial approach became indispensable for cases of second and third degree OR.H that could not be treated with the extracranial approach. Tessier's box osteotomies were reproduced by several surgeons worldwide.

"In patients with true hypertelorism, in whom medial displacement of the orbital cavities is essential to correct the deformity, a combined intracranial and extracranial osteotomy is the only effective operation that will ensure safety and freedom from intracranial complications." (John M. Converse, 1970 (Converse et al., 1970))

2.2.2. Tessier's heritage

In 1970, inspired by Tessier's work, Converse developed a single-step procedure for OR.H correction using the intracranial approach while preserving olfaction (Converse et al., 1970). Noting that the cribriform plate is not or slightly enlarged, unlike the anterior

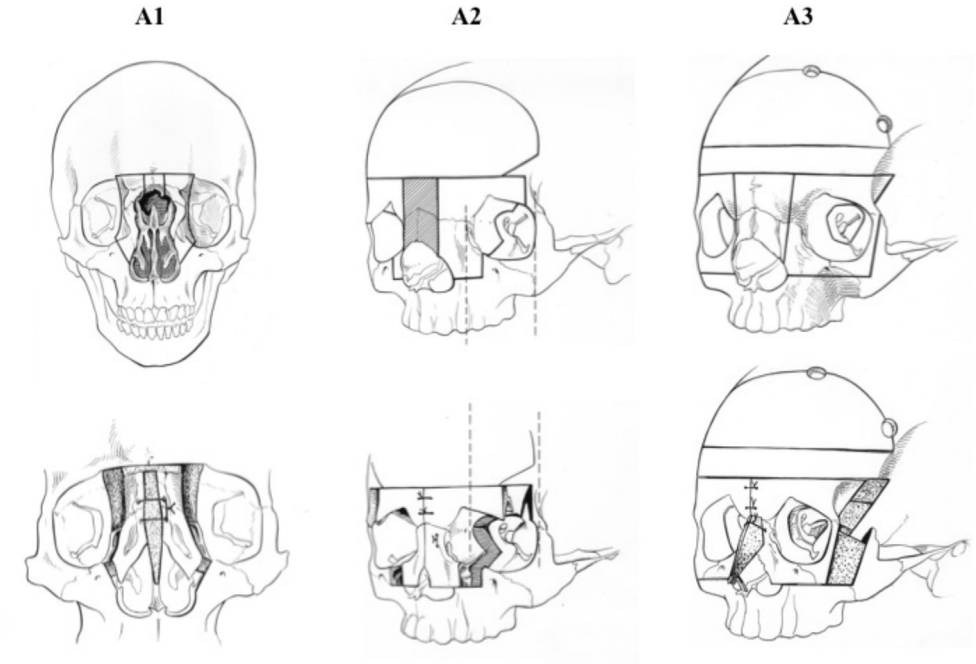

Fig. 6. A techniques: intracranial techniques for the correction of orbital hypertelorism A1: This procedure was only performed once in 1962 because of inadequate outcomes. A2: This procedure was performed twice in 1965, following which it was abandoned because it resulted in incomplete mobilization of the orbital frame. A3: This procedure corresponded to en bloc orbital mobilization and was used by Tessier for several patients (Collection Tessier). (Permission for use granted from the Association Française des Chirurgiens de la Face, AFCF).

portion of the ethmoid, Converse performed ethmoidal cell resection on either side of the cribriform plate, thus allowing its preservation (Fig. 7). This also limited the risk of meningitis and precluded the requirement of initial dermal grafting for sealing of the anterior skull base. This surgery sparing the olfactory grooves was successfully performed for four of his patients.

To summarize, treatment involving box osteotomies via combined intra and extracranial approaches (Tessier) with preservation of the cribriform plate (Converse) is safe and effective and represents the gold standard method for moderate to severe OR.H correction. Since its description, this technique has been employed by several craniofacial surgeons, even today.

> *"The intracranial technique of Tessier with Converse's modification is the most useful in that the majority of the orbit is mobilized as a box. Although in some ways it is the most difficult and dangerous, it is also the most useful and, paradoxically, can be considered the safest because total control of the orbits is gained, as well as control of the frequent intracranial anomalies." (Munro, 1979* (Munro and Das, 1979))

Several surgeons have subsequently introduced minor variants of the initial technique (Psillakis et al., 1981; Shen et al., 2015; Marchac et al., 2012; Sailer and Landolt, 1987).

2.2.3. Facial bipartition surgery

OR.H. causes significant transverse, vertical, and sagittal deformities in the middle third of the face, involving not only the ethmoid sinus and orbits but also the maxilla. Box osteotomies are used to correct orbital deformities in the transverse direction; however, they do not improve anterior open bites frequently associated with transverse and vertical maxillary insufficiencies.

In 1976, Van Der Meulen (Van Der Meulen, 1976) mentioned the possibility of simultaneous correction of maxillary and craniofacial deformities.

> *" All of the craniofacial deformities described were associated with deformities of the upper jaw, caused apparently by a growth arrest in the craniocaudal axis of the face (…) all these skeletal deformities should be corrected in one operation by a combination of orbital and maxillary osteotomies. In other words a midline "faciotomy."* (Van Der Meulen, 1976)

Using a facial bipartition technique, Van Der Meulen corrected OR.H and the occlusal disorders presented by a patient with a facial cleft (Van Der Meulen, 1979). This procedure allowed approximation of the orbits, lowering of the hard palate, and transverse maxillary expansion (Fig. 8).

Ortiz-Monasterio proposed preoperative geometric planning for increasing the intraoperative surgical precision and decreasing the surgical duration (Ortiz Monasterio et al., 1990; Ortiz-Monasterio and Molina, 1994). This method is based on the precise identification of points and facial planes on posteroanterior cephalograms, which will subsequently guide osteotomies and aid in the achievement of postoperative results consistent with preoperative calculations.

2.3. Soft tissue management

As mentioned above, surgeries for OR.H correction were introduced in the mid-twentieth century and involved the treatment of soft tissue deformities associated with an increased IOD6–8 (Converse and Smith, 1966). Despite the major advances in craniofacial (osseous) surgery that were subsequently introduced, soft tissue management has always been a major concern of surgeons dealing with cases of OR.H. Paradoxically, soft tissue abnormalities are considered the most challenging part of surgery for OR.H.

> "We cannot overstress that OR.H has its real difficulties. Not so much in reducing an exaggerated IOD as in correcting the other malformations which increase it or are associated with it: these may give rise to an infinite variety of aspects or effects or sequelae when the OR.H itself has been corrected." (Paul Tessier, 1973 (Tessier et al., 1973))

Thus, surgeons should pay extra attention to the correction of extraorbital anomalies, which are numerous and varied (encéphalocèle, bifid nose, lacrimal fissure or coloboma, ala nasi fissure, epicanthal folds, median cutaneous skin excess, Widow's peak, etc.) (Munro and Das, 1979; Tessier, 1974; Urrego et al., 2005; del Campo, 1984; McCarthy, 2012; Mulliken et al., 1986). More recently, a team classified the soft tissue anomalies associated with

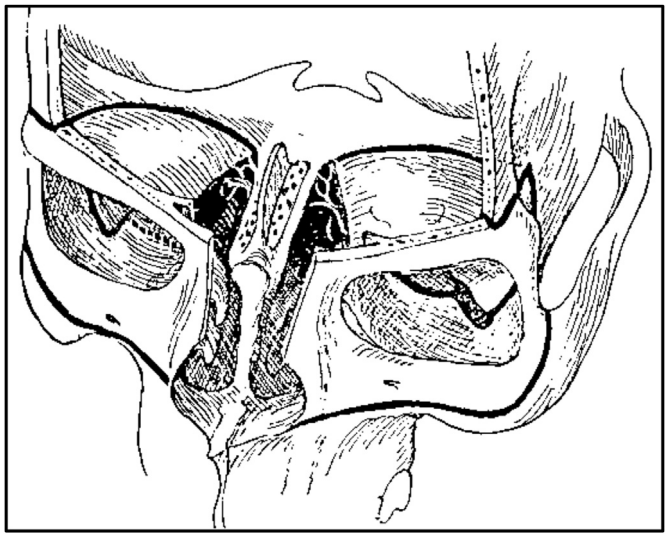

Fig. 7. Outline of subtotal orbital osteotomy with preservation of the cribriform plate for the correction of orbital hypertelorism (Converse JM, Ransohoff J, Mathews ES, Smith B, Molenaar A. Ocular hypertelorism and pseudohypertelorism. Advances in surgical treatment. *Plast Reconstr Surg.* 1970; 45:1-13 (Converse et al., 1970)) (Permission for use granted from Wolters Kluwer Health, Inc., *Plastic and Reconstructive Surgery.*).

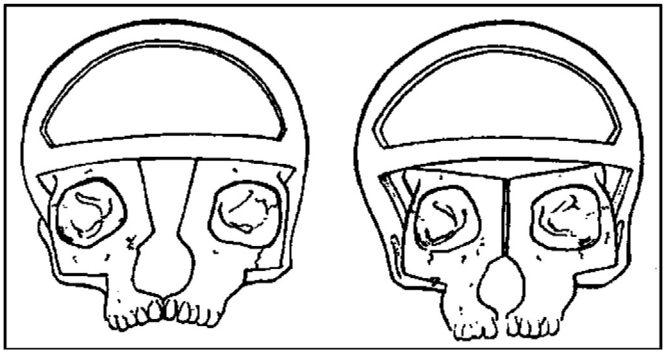

Fig. 8. Medial faciotomy. Diagram to show the sites of the various osteotomies and the rotation of the facial segments (J.C. Van Der Meulen. Medial faciotomy. *Br J Plast Surg.* 1979; 32:339-342 (Van Der Meulen, 1979)). Permission for use granted from Elsevier, Inc., *Journal of Plastic, Reconstructive & Aesthetic Surgery.*).

OR.H into three categories, namely soft tissue excess of the midline, medial canthus folds and dystopias, and nasal malformations, and described their surgical correction strategies on the basis of their experience (Raposo-Amaral et al., 2017). These concomitant anomalies should not be underestimated and, as far as possible, corrected simultaneously with medialization of the orbits (bony correction).

3. Perspectives: modern surgical techniques for OR.H correction

Several present-day surgeons have taken advantage of the technological advances made in the early 2000s and attempted to improve box osteotomies and facial bipartition procedures. They did not alter the surgical procedure itself; rather, they refined the preparatory procedures. Munro demonstrated that the amount of interorbital bone that should be resected in cases of OR.H was greater than that calculated by simple mathematical subtraction (Munro and Das, 1979). Therefore, preoperative planning appeared to be a useful and promising approach for the prevention of inaccurate bone resection, with accurate prediction of the bone-related outcome being fundamental to ensure sufficient eyeball movement and an adequate postoperative IOD.

The increased use of efficient imaging techniques has enabled teleradiographs and 3D visualization of craniofacial deformities in individual patients. Several teams have shown that 3D surgical planning is a valuable tool for the successful completion of a box osteotomy (Fadda et al., 1996; Xie et al., 2011) or facial bipartition procedure(De Ponte et al., 1997; Gonzalez et al., 2005).

The use of preoperative 3D printing (Engel et al., 2015) and stereolithographic models (Hidalgo et al., 2009; Sailer et al., 1998) has been shown to be useful for accurate planning of craniofacial osteotomies and decreasing the surgical duration. The acquisition of 3D models has allowed surgeons to simulate their surgery and train on prototypes until achievement of the desired results; moreover, they can preform their osteosynthesis plates, which can save considerable time during the subsequent surgery.

With the advent of computer-assisted surgery (CAS) using increasingly powerful and reliable software, simulations and virtual planning can be directly implemented on the computer by the surgeon. This makes stereolithographic models, which only simulate a single surgical technique and do not allow backtracking, almost obsolete. On the other hand, simulation software opens infinite planning possibilities for surgeons. Similarly, prebent osteosynthesis plates can now be directly obtained by 3D printing or direct machining from the virtual simulation files of the patient.

More recently, a Chinese team developed an augmented reality-based surgical navigation system for this indication (Zhu et al., 2016). This burgeoning technique, which directly superimposes the preoperative plan over the surgical site, has already proved itself in various surgical fields, including laparoscopy, neurosurgery, and orthopedic surgery. During osteotomies, it optimizes surgical precision by reliably guiding the operator throughout the procedure.

Since the mid-1990s, computer-assisted surgery (CAS) has continued to develop, particularly in the field of craniofacial surgery (Scolozzi, 2017; Chang et al., 2016; Haas et al., 2014; Atanasiu et al., 2018; Queiros et al., 2017). On one hand, it enables preoperative planning of the osteotomies and bone resections using a 3D scanner, while on the other hand, it enables simulation of the outcomes of orbital approximation and osteosynthesis. Although this technology facilitates the surgical procedure and its postoperative effects, CAS using cutting guides has only been described for a few cases of box osteotomies (Scolozzi, 2017; Tahiri and Taylor, 2015; Adolphs et al., 2014) and one case of facial bipartition surgery (Schlund et al., 2018). Cutting guides and custom-made osteosynthesis plates seem to guide the surgeon during each stage of the procedure, resulting in outcomes that correspond to the preoperative predictions (Schlund et al., 2018) (Fig. 9). At this time, however, there is a lack of objective data concerning the accuracy of CAS using cutting guides for OR.H correction. Most studies using CAS for OR.H correction have not used cutting guides, and those using them included single cases or case series and did not involve comparisons with conventional instruments. Moreover, the majority of these studies did not perform objective measurements of the accuracy of cutting guides. In this context, our craniofacial team is currently working on a study about the surgical correction of OR.H using cutting guides in order to evaluate the accuracy of these tools. The purpose of this study, which includes ten patients who underwent surgical correction of OR.H, is to compare orbital measurements between planning scans and postoperative scans for objective evaluation of the accuracy of cutting guides.

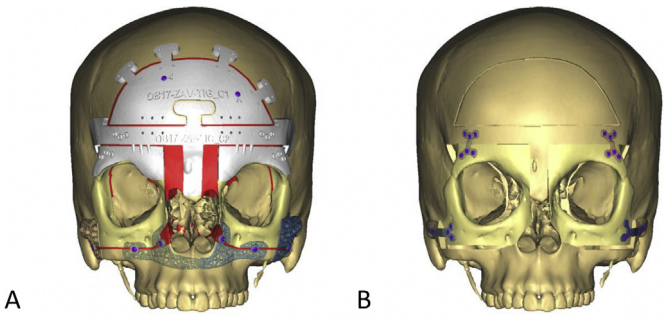

Fig. 9. Planned box osteotomy for the correction of orbital hypertelorism. A. Preoperative simulation showing the bone to be removed (red) and the design of the cutting guides. B. Virtual final result.

We would also like to add that developments in surgical techniques for the correction of OR.H are primarily focused on bony corrections, with not much emphasis on improvements in soft tissue management. However, a satisfactory outcome cannot be obtained without the meticulous correction of soft tissue deformities along with accurate bony correction. The management of soft tissue malformations associated with OR.H using new technologies is poorly described in the literature and does not seem to be the focus of current research projects. In the future, perhaps, CAS will be refined and become a reliable tool to simulate and plan the surgical correction of soft tissues.

4. Conclusions

In summary, OR.H correction is a great surgical challenge that fascinates surgeons even today. Tessier was the first to achieve an intracranial route, which was modified by Converse for olfaction preservation. Then, Van Der Meulen further improvised by innovating a technique that enabled the correction of maxillary deformities, which are frequently associated with OR.H, during the same surgery. All this work led to the development of two efficient techniques for OR.H correction: box osteotomies and facial bipartition. Currently, augmented reality-based surgical navigation and CAS using cutting guides are rapidly developing and expected to refine and standardize the surgical correction of OR.H in the future, provided their reliability is proven with solid evidence. The use of such technologies is also expected to ensure better management of concomitant soft tissues anomalies in the future.

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