The Hybrid Arch Bar Is a Cost-Beneficial Alternative in the Open Treatment of Mandibular Fractures

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Abstract

Obtaining maxillomandibular fixation (MMF) to achieve fracture reduction and functional occlusion is essential in the management of maxillofacial trauma. The aims of this retrospective review were to compare the total time spent in the operating room (OR) when using the Erich arch bar (EAB) versus the bone anchored hybrid arch bar (HAB) as well as performing a cost–benefit analysis (CBA). The study sample comprised patients older than 18 years who underwent open reduction internal fixation of mandible fractures at two separate institutions over a 5-year period. The primary outcome variable was total surgical time in minutes, defined as the time from incision to the completion of closure. Average operative time was significantly longer for the EAB than for the HAB (186.74 ± 70.73 vs. 135.98 ± 2.69 minutes, $p < 0.001$). A significant amount of time was saved by using the HAB for unilateral (37.17 ± 13.19 minutes; $p = 0.007$) and bilateral fractures (55.83 ± 18.89 minutes; $p = 0.005$). In-depth CBA showed that, for average OR fees of \$60 per minute, the HAB produced savings of at least 4.01 and 11.63% of the total cost of surgery for unilateral and bilateral fractures. These results support the hypothesis that the HAB is a time-saving maneuver in the open treatment of mandible fractures. The HAB saves more time in bilateral fracture cases despite the longer overall operative times. This study shows the differential time-saving effect of the HAB regardless of fracture laterality as well as its cost minimization benefit compared with the EAB.

Keywords

- MMF
- surgical cost
- operating room time
- maxillofacial trauma

Obtaining maxillomandibular fixation (MMF) to achieve fracture reduction, dental occlusion, and osseous healing is essential in the management of maxillofacial trauma.¹ Numerous techniques have been utilized to establish MMF. A relatively new MMF technique, utilizing hybrid arch bars (HAB), directly anchors an arch bar to bone via screws placed into the alveolar process. The SMART Lock Hybrid MMF System from Stryker

(Stryker Craniomaxillofacial, Kalamazoo, MI) was the first commercial HAB which was released in 2013. Conceptually designed by Dr. Jeffrey Marcus, a Pediatric Craniofacial Plastic Surgeon, the SMART Lock system alleviates the issue associated with the creation of a posterior malocclusion seen with MMF screws by extending the vector of occlusal immobilization posteriorly to incorporate the entirety of the occlusal

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table. Because of the relatively simple application technique, and the elimination of circumdental wiring, there is a potential to reduce intraoperative time and puncture injuries.^{2,3} The favorable handling properties and low complication rates of the SMART Lock HAB have been reported.^{4,5} The average time saved during placement of the HAB, compared with Erich arch bar (EAB), has been found to range between 20 and 39.9 minutes in two retrospective studies.^{4,5} This was offset by the cost of the device. The SMART Lock system has an estimated cost of \$2,470 when the maximum number of 14 MMF screws are used.^{4,5} Prior studies have shown that despite the material cost, there is no difference with respect to total OR expenses when comparing traditional versus HAB use.^{4,5} However, these studies were based on small study samples, and time calculations were based on application time alone.

The aim of the study was to measure and compare the total time spent, from incision to closure, in the operating room (OR) when using the EAB versus HAB in two categories of mandible fractures. It is our hypothesis that open reduction internal fixation (ORIF) of both unilateral and bilateral mandible fractures via a transoral approach will take significantly less time owing to the use of the HAB. An additional aim of this study was to perform a cost-benefit analysis (CBA) using the present data for both MMF systems in unilateral and bilateral fracture groups.

Materials and Methods

Study Design

The investigators designed and implemented a retrospective case series from two academic medical centers (hospital A and hospital B) in different geographical locations (Bronx, NY; and Durham, NC) over a 5-year period. Due to the retrospective nature of this study, it was granted an exemption in writing by both the Institutional Review Boards of the Albert Einstein College of Medicine and the Duke University. None of the authors have any disclosures, stock options, or professional affiliations with Stryker.

Study Sample

The study sample was derived from adult patients older than 18 years who underwent ORIF of mandible fractures between November 1, 2011, and November 31, 2016. See ▶ **Table 1** for inclusion and exclusion criteria.

Study Variables

The primary predictor variable was the type of device used as either the EAB or HAB. All HABs were from the Stryker SMART Lock system. The primary outcome variable was total surgical time in minutes, defined as the time from surgical incision to the completion of closure. Secondary outcome variables included the anatomical site of fracture requiring ORIF, fracture type in terms of laterality, and study site.

Data Collection

Surgical case logs from each institution were used to identify cases that meet inclusion criteria (▶ **Table 1**). Operative start and end times were taken from the OR records. Operative

Table 1 Inclusion and exclusion criteria

Inclusion criteria
A single fracture of the hemimandible (unilateral or bilateral)
A transoral surgical approach
Closed treatment of any concomitant condylar process fracture
Application of MMF with the use of a single form of arch bar device—either an Erich or hybrid arch bar
Exclusion criteria
Mandible fractures were treated exclusively with closed reduction
Multiple ipsilateral fractures of the mandible were present
Trans-cervical or trans-facial approaches were performed
Different arch bar devices were used for the maxilla and mandible
Fractures were more than 2 wk old
Additional procedures other than dental extractions were performed at the same time as the mandible ORIF

Abbreviations: MMF, maxillomandibular fixation; ORIF, open reduction internal fixation.

reports were used to verify the diagnosis and procedures rendered.

Data Analysis

Analyses were conducted to test the hypothesis that operative time varied significantly according to the product used. Frequency distributions and summary statistics (e.g., means, standard deviations, and percentages) were inspected for all study variables. Pearson's chi-square tests were used to examine whether other measured characteristics, specifically study site, fracture laterality, and anatomic location of injury, were equivalent between the EAB and HAB groups. We then tested for bivariate associations between operative time and arch bar product, laterality, anatomic location, and study site using two-tailed *t*-tests and one-way analysis of variance (ANOVA) to compare operative time means by group. For the analysis by anatomic location, which had multiple categories of response, post hoc Student-Newman-Keuls tests were used to identify any pairwise differences in operative time. A two-sample *z*-test was used to compare the mean time saved using the EAB compared with the HAB for bilateral and unilateral fractures. Finally, we employed multivariable ordinary least squares regression to determine if operative time differed significantly by the arch bar product, controlling for potential confounding variables such as fracture type and study site.

A CBA was performed using various cost-per-minute rates of OR utilization that represent three conceivable tiers (low, middle, high) relative to all reported fees in the literature to date.^{6–8} The price of materials (EAB and wire: \$100; HAB and screw: \$325 and \$130) remained constant with prior studies.^{4,5} The present authors agreed that five MMF screws per

Table 2 Summary of study variables for the entire sample and covariate associations with arch bar product

Study variable	Erich N (%)	Hybrid N (%)	p-Value ^a
Sample size (n)	43 (42.2%)	59 (57.8%)	–
Laterality			
Unilateral	20 (46.5%)	33 (55.9%)	$p = 0.347$
Bilateral	23 (53.5%)	26 (44.1%)	
Study site			
Hospital A	36 (83.7%)	44 (74.6%)	$p = 0.267$
Hospital B	7 (16.3%)	15 (25.4%)	
Anatomic location of injury ^b			
Angle (A/O)	11 (25.6%)	15 (25.4%)	$p = 0.735$
Body (B/O)	1 (2.3%)	2 (3.4%)	
Symphysis (S/O)	8 (18.6%)	16 (27.1%)	
Angle, angle (A/A)	1 (2.3%)	4 (6.8%)	
Symphysis/ Symphysis (S/S)	1 (2.3%)	1 (1.7%)	
Angle/ Symphysis (A/S)	15 (34.9%)	14 (23.7%)	
Angle/Body (A/B)	5 (11.6%)	7 (11.9%)	
Body/ Symphysis (B/S)	1 (2.3%)	–	

^ap-Values were calculated from Pearson's chi-square tests of significance; α level 0.05.

^bThere were no cases of B/S mandible fractures that were treated with hybrid arch bars.

Table 3 Bivariate associations between time and arch bar product, fracture type, anatomic location, and study site

Study variable	Time (min) Mean ($\pm$ SD)	p-Value ^a
Arch bar		
Erich	186.74 $\pm$ 70.73	$p < 0.001$
Hybrid	135.98 $\pm$ 52.69	
Fracture type	133.15 $\pm$ 49.57	
Unilateral	183.59 $\pm$ 71.10	$p < 0.001$
Bilateral	127.12 $\pm$ 56.65	
Anatomic location ^b	112.33 $\pm$ 44.84	
Angle (A/O)	142.29 $\pm$ 41.31	$p = 0.429$
Body (B/O)	176.40 $\pm$ 46.18	
Symphysis (S/O)	217.00 $\pm$ 96.17	
Angle, angle (A/A)	175.72 $\pm$ 60.91	
Symphysis/Symphysis (S/S)	182.83 $\pm$ 82.10	$p = 0.857$
Angle/Symphysis (A/S)	Excluded ^c	
Angle/Body (A/B)		
Body/Symphysis (B/S)		
Study site		
Hospital A	158.92 $\pm$ 67.27	$p = 0.653$
Hospital B	151.77 $\pm$ 60.49	

^aAll analyses were t-tests, except for anatomic location, which was an analysis of variance (ANOVA).

^bBased on post hoc Student–Newman–Keuls tests, there were significant pairwise differences at $p < 0.05$ only between B/O and all other locations and between S/S and all other locations.

^cExcluded on criteria of having fewer than two cases in B/S group.

arch, rather than seven, maintain adequate rigidity and more accurately represent current clinical practice at our institutions. This point was well accepted by Kendrick et al, and for this reason we performed our cost calculations at 10 MMF screws per case.⁵ Potential cost reductions for items due to negotiated discounts between hospitals and vendors were not incorporated into this analysis. Data for total operative times were used to calculate and plot the total cost of surgery with product at various OR fees per minute. The slope of each line and y-intercept were calculated to determine the intersection between x- and y-coordinates for unilateral and bilateral fracture datasets.

Results

A total of 102 cases were included in the study. The HAB was used in more than half of unilateral fracture cases (55.9%), but the EAB was used in the majority of bilateral cases (53.5%). No significant relationships between fracture locations, laterality of injury, study site, and EAB and HAB were observed (see ►Table 2).

The average operative time was statistically significant ($p < 0.001$), longer for the EAB (186.74 minutes; SD = 70.73)

compared with the HAB (135.98 minutes; SD = 52.69). Significantly longer operative times were also observed for bilateral fractures (183.59 minutes; SD = 71.10) compared with unilateral fractures (133.15 minutes; SD = 49.57; $p < 0.001$). There was no significance according to anatomic fracture location among the three unilateral fracture patterns ($p = 0.429$) or the four bilateral fracture patterns ($p = 0.857$). However, pairwise comparisons showed significantly shorter operative times for unilateral body fractures compared with all other locations ($p < 0.05$), and longer times for bilateral symphysis/symphysis fractures compared with all other locations ($p < 0.05$). With respect to study site, no significant differences in operative time were observed ($p = 0.653$; see ►Table 3).

Results from the multivariable ordinary least squares regression model testing the relationship between arch bar product and time, adjusted for fracture type and study site, are provided in ►Table 4. The model was constructed according to several factors. Given that laterality and anatomic location of injury are highly related and inherently dependent, and because anatomic location was not a significant variable in pooled bivariate analyses within the unilateral and bilateral groups, the anatomic location of injury was

Table 4 Multivariable ordinary least squares regression model testing the relationship between arch bar product and time, controlling for fracture type and study site

Variable	Beta coefficient (95% CI)	p-Value
Arch bar product		
Erich	Referent	p < 0.001
Hybrid	−0.35 (−69.54 to −23.83)	
Fracture type		
Unilateral	Referent	p < 0.001
Bilateral	0.35 (23.82 to 68.86)	
Study site		
Hospital B	Referent	p = 0.816
Hospital A	0.02 (−30.62 to 24.19)	

omitted from the final regression model. The HAB was associated with a significant reduction in OR time ($b = -0.35$; $p < 0.001$), after controlling for fracture type and study site. Regardless of the device used or study site, bilateral fracture type was significantly associated with greater operative time ($b = 0.35$; $p < 0.001$). Study site was not associated with operative time when controlling for arch bar product and fracture type ($b = 0.02$; $p = 0.816$).

The mean operative times for each of the two primary interventions, along with a measure of the minutes saved attributable to HAB, are provided in ►Table 5. On average, a significant number of minutes were saved by using the HAB for unilateral fractures (37.17 minutes, SD = 13.19; $p = 0.007$) and bilateral fractures (55.83 minutes, SD = 18.89; $p = 0.005$). The mean time saved was significantly greater in bilateral fractures than in unilateral fractures ($Z = 5.74$; $p < 0.001$). This time-saving effect of HAB was maintained overall when assessing all included mandible fractures (50.76 minutes, SD = 12.78; $p < 0.001$).

The CBA for the use of the HAB versus the EAB at three selected rates of OR utilization (\$20/min, \$60/min, \$100/min) is provided in ►Table 6. At OR utilization fees of \$20/min or less, HAB is time-saving but cost-prohibitive for all fractures. At OR utilization fees at or above \$60/min, HAB is both time-saving and cost-beneficial in all cases. For unilateral fractures at \$60/min, HAB saves \$380.80, or 4.01% of the total cost of surgery, which increases to \$1,868.00, or

11.87% of the total cost at \$100 per minute. For bilateral fractures, at \$60/min, HAB saves \$1,500.40, or 11.63% of the total cost of surgery, which increases to \$3734.00, or 17.43% of the total cost at \$100/min. The percentage product cost contribution (%PCC) decreases as the OR time-dependent fee increases for any given surgery and is further reduced in the longer duration bilateral procedures. At the three selected OR dollar per minute values, the lowest and highest %PCC for the HAB is 11.0 and 21.4%, respectively.

►Fig. 1 illustrates the graphic trend of total cost of OR plus the cost of product (EAB or HAB) against variable OR utilization fees per minute. Line graphs were constructed using the data for length of operative times for both categories of fractures. The intersection of two lines represents the point at which the total cost of surgery using the EAB or HAB is the same, or the economic break-even point. For unilateral fractures, the break-even point occurs at an OR fee of \$49.76/min when total cost is \$7,877.17. For bilateral fractures, the break-even point occurs at an OR fee of \$33.13/min when total cost is \$7,163.98.

Discussion

The purpose of this study is to investigate whether HAB is a time-saving and economical alternative to the EAB when looking at total operative time for open treatment of unilateral and bilateral mandible fractures. The hypothesis is that the HAB leads to a significant reduction in operative time, leading to a saving in OR utilization costs after adjusting for its fixed cost. The specific aims of the study are to compare the total operative time when using either the EAB or HAB and to perform a thorough CBA for HAB using time-dependent variables.

We present the largest retrospective review of 102 cases for any HAB to date, with the correlating results that support our hypothesis. As one may expect, bilateral fractures had increased operative time when compared with unilateral fractures, even after controlling for all other study variables in our regression model. However, this effect was independent of the time-saving effect of HAB. The time-saving benefit of the HAB was observed regardless of fracture laterality and the institution. Compared with the EAB, the HAB showed an average time-saving of 37.17 minutes in unilateral cases and 55.83 minutes in bilateral cases. It is expected that total operating time increases in bilateral cases

Table 5 Absolute time-savings attributable to the hybrid arch bar compared with the Erich arch bar, stratified by laterality

Variable	Erich Mean ($\pm$ SD)	Hybrid Mean ($\pm$ SD)	Minutes saved ^a Mean ($\pm$ SD)	p-Value
Fracture type				
Bilateral	213.22 (75.41)	157.38 (56.41)	55.83 (18.89)	$p = 0.005$
Unilateral	156.30 (51.47)	119.12 (43.37)	37.17 (13.19)	$p = 0.007$
Overall	186.74 (70.73)	135.98 (52.69)	50.76 (12.78)	$p < 0.001$

^aA two-sample z-test compared mean time saved using the Erich compared with the hybrid device for bilateral and unilateral fractures, and confirmed that average time saved was significantly greater in bilateral fractures than in unilateral fractures ($z = 5.74$; $p < 0.001$).

Table 6 Cost-benefit analysis (CBA) of the time saved with the hybrid arch bar at various OR utilization fees for unilateral and bilateral mandible fractures

Unilateral						Bilateral				
	Erich	SMART Lock ^a	Savings	Total cost saved (%)	PCC(%) ^b	Erich	SMART Lock	Savings	Total cost saved (%)	PCC (%)
Total case time (min)	156.3	119.12	37.17	–	–	213.22	157.38	55.83	–	–
Cost material	\$100.00 ^c	\$1,950.00 ^d	–\$1,850.00	–	–	\$100.00	\$1,950.00	–\$1,850.00	–	–
Total OR cost ^e										
\$20/min	\$3,126.00	\$2,382.40	\$743.60	–	–	\$4,264.40	\$3,147.60	\$1,116.80	–	–
\$60/min	\$9,378.00	\$7,147.20	\$2,230.80	–	–	\$12,793.20	\$9,442.80	\$3,350.40	–	–
\$100/min	\$15,630.00	\$11,912.00	\$3,718.00	–	–	\$21,322.00	\$15,738.00	\$5,584.00	–	–
Total OR cost + product										
\$20/min	\$3,226.00	\$4,332.40	–\$1,106.40	N/A	N/A	\$4,364.40	\$5,097.60	–\$733.20	N/A	N/A
\$60/min	\$9,478.00	\$9,097.20	\$380.80	4.01%	21.4%	\$12,893.20	\$11,392.80	\$1,500.40	11.63%	17.1%
\$100/min	\$15,730.00	\$13,862.00	\$1,868.00	11.87%	14.1%	\$21,422.00	\$17,688.00	\$3,734.00	17.43%	11.0%

^aStryker SMART Lock Hybrid MMF system represented all “hybrid” arch bars in the present study.
^bProduct cost contribution (PCC), calculated as the contribution of the hybrid arch bar cost to the total cost of surgery.
^cBased on reported average values.
^dBased on the use of 2 arch bars and 10 screws in total, or 5 screws per arch (US \$325 and \$130 each, respectively).¹⁶
^eThree time-dependent operating room (OR) fees selected as fair examples of low, middle, and high rates based on all reported values in the literature.^{17–19}

due to the nature of a more extensive surgical procedure; however, these two time-saving values were statistically different, confirming that the HAB conserved time to a greater effect in bilateral than unilateral cases. The cause of this is unknown.

Note, this finding would have been missed if the study assessed only application time alone, as technical aspects of different portions of the surgery are not entirely independent of one another.^{4,5} Evaluation of the effect in regards to specific anatomic location of the fracture(s) was not feasible because the subcohorts were too small to achieve significance.

Fig. 1 Economic break-even point for the hybrid arch bar at variable operating room (OR) utilization fees for unilateral and bilateral mandible fractures. For unilateral fractures, the break-even point occurs at an OR fee of \$49.76/min (total cost is \$7,877.17 with each product). For bilateral fractures, the break-even point occurs at an OR fee of \$33.13/min (total cost is \$7,163.98 with each product).

Open treatment of mandible fractures with HAB saved an average of 55.83 minutes with bilateral fractures and 37.17 minutes with unilateral fractures. Our data are comparable to those published by Kendrick et al, which showed a mean saving of 39.9 minutes with the HAB.⁵ In another review of 50 cases, substantially longer values for HAB application were found (42 minutes), with a mean time-saving of 20 minutes over traditional arch bars. Interestingly, in this study, the time data were gathered from closed reduction cases with the majority (21 out of 25 cases) of HABs placed on complex mandible fractures (2–3 fractures).³ In other studies, times as long as 95.06 and 100.8 minutes have been reported for application of EAB.^{9,10} These data reflect differences in study designs but does support the idea that HAB is a time-saving device when compared with the EAB despite intersurgeon variability.

Time-saving effects are sought by hospitals to decrease cost, but the time variable is difficult to calculate, and rarely reported.¹¹ Time-dependent OR fees excluding anesthesia were reported to have increased from an average of \$20/min in 1991 to \$62/min in 2004. A 2009 study from an academic medical center in Ohio reported at about \$21/min.⁷ A 2016 study estimates the value as \$60/min.⁸ Personal communication/unreported data obtained from the senior authors’ (D.P. and M.T.) current and prior hospital affiliations estimated the average value of operating room time as approximately \$62/min exclusive of anesthesia, nursing, and technician support. We applied these data points to a CBA that converts the benefits of a given intervention (HAB) to dollar values, as opposed to a cost-effectiveness analysis that measures outcomes in nonmonetary terms, such as health status and life-years gained. The senior authors (D.P. and M.T.) emphasize that these terms are not interchangeable, limiting the methodology

of our study to a traditional CBA. To the extent that we can assume the HAB produces satisfactory outcomes with respect to reducing and fixating mandible fractures, our conclusions approach a cost-minimization analysis that by definition compares overall costs in situations where alternative options have similar outcomes.

Our data reveal that HAB is a cost-minimizing intervention over the EAB except when OR fees are low, as shown by the negative value of total % savings in both unilateral and bilateral groups (► **Table 6**). The significance of this analysis is that the HAB is “efficient” at minimizing cost only when the total accumulated costs of the surgery are sufficient to offset the product investment. For unilateral fractures, the break-even point occurs at a higher OR fee (\$49/min) than for bilateral fractures (\$33/min). HAB’s contribution to the total cost of surgery is a tangible figure for budget allocation, and we demonstrate how this value decreases with increases in OR fees and surgical duration.

We propose that the HAB’s contribution to the total cost of surgery, or %PCC, can serve as a more tangible figure for allocating budget dollars, and we demonstrate how this value decreases substantially with increases in OR fees and surgical duration. Finally, given that economic efficiency relates to the number of inputs (dollars) converted into final products (surgical services), we also predict that the HAB may be cost-efficient by allowing additional surgeries to be provided in a fixed allocated OR time, provided that these services generate revenue.¹²

The idea of reducing surgical time has gained recent attention. Mathematically, it has been shown that over-utilized OR time is more expensive than regular or unused time due to the higher compensation for personnel during undesirable hours.¹³ Therefore, longer-than-average surgical case times cannot be ignored, particularly with the added fact that teaching residents significantly increases OR time.^{14,15} A recent study from the NYU Hospital for Joint Diseases demonstrated the benefits of lowering surgical case times. Between 2014 and 2016, a dedicated task force implemented multiple intraoperative time-saving interventions. Case times decreased by 11 to 15%, affording additional procedures to be scheduled during the service’s allotted OR time. The cumulative impact was a 9% growth in volume and added revenue. This outcome serves as a prime example of how motivated leaders can apply rigorous data to accelerate OR efficiency and drive change.⁸

There are several limitations to the present study. First, there are an insufficient number of cases, which prevented the evaluation of whether the particular fracture pattern increases or decreases operative time. This may help clarify further the significance of the time-savings between unilateral and bilateral fractures. Second, measuring the intraoperative application portion with each device will provide more support for the findings of this study if we can show correlation with total case times.^{4,5}

In summary, our data show that HAB is a time-saving and cost-beneficial alternative to the EAB in the open treatment of both unilateral and bilateral mandible fractures. More specifically, HAB generates a larger surplus of saved time in bilateral

fracture cases despite the longer overall operative times. In-depth CBA shows that HAB produces a saving of at least 4.01% of the total cost of surgery at average OR fees of \$60/min. This saving increases to at least 11.63% of the total cost of surgery for bilateral fractures. Interpreting this efficiency in terms of actual patient outcomes deserves future investigation.

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