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一般用ソフトを用いた3DCT及び3Dモデルの日常診療への応用

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Introducing a popular 3D-CT software and 3D anatomical models into clinical practice

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Abstract

Introductions：Three-dimensional computed tomography（3D-CT）and 3D anatomical models are commonly applied in medical settings, and are often used for facial bone reconstruction surgeries. Mostly doctors trust 3D-CT imaging than the traditional axial imaging viewed with CT, but there are several 3D-CT softwares available that can be downloaded（Not for medical purpose）.

Pre-operatively, We created a 3D model of patient's face with progressive hemifacial atrophy（Romberg disease）using a commonly used software.

Methods：A 19-year-old male patient, suffering from progressive hemifacial atrophy（Romberg disease）and his face presenting with left-right asymmetry.

For cosmetic improvement purpose, curing type bone reinforcing material was inserted to the depressed left cheek part of patient's face for facial contouring.

We made up 3D-CT of the patient's facial bone and facial surface before surgery and calculated how much volume is needed for the left cheek and made 3D model of the curing type bone reinforcing material.

Based on the created model, the curing type bone reinforcing material was used intra-operatively and the amount and shape of the material were formed.

Result：As a matter of fact, the curing type bone reinforcing material used required more volume than that of the model created, but it was very useful for determining the shape and place to insert.

Discussion：3D-CT and 3D models are easily created by using a popular software without consuming advanced techniques and knowledge, making it a convenient tool to be introduced into clinical practice.

Key words：3Dモデリング、3Dプリンター、術前シミュレーション、進行性顔面片側萎縮症

【はじめに】

術前にCTやMRIなどの3次元でのシミュレーションを行うことは実際の手術のイメージをより正確にし、円滑な手術をする手助けとなる。形成外科の領域では頭頸部手術において3次元シミュレーションが使われることが多い。

精度が高い医療用3Dモデリングソフトは開発が進んでおり大学病院などでは導入されつつある。しかしその一方、どこの医療機関でも簡単に導入できるものではないのが現状である。さらにそれを使いこなすには相当の修練が必要とされる。

医療用ではなく、趣味などで用いられる一般向けの3Dモデリングソフトは広く普及しており安価であり操作も簡便である。今回Windows10に付属している3Dモデリングソフトである3D Builder®（Microsoft®）を使用し、3次元の術前シミュレーションを行った。

【方　法】

患者は19歳男性、中学生ごろより左顔面の軟部組織萎縮を認め進行性顔面片側萎縮症と診断された。進行性顔面片側萎縮症は10代以降に発症することが多く、顔面の片側の一部もしくは全体に進行性の軟部組

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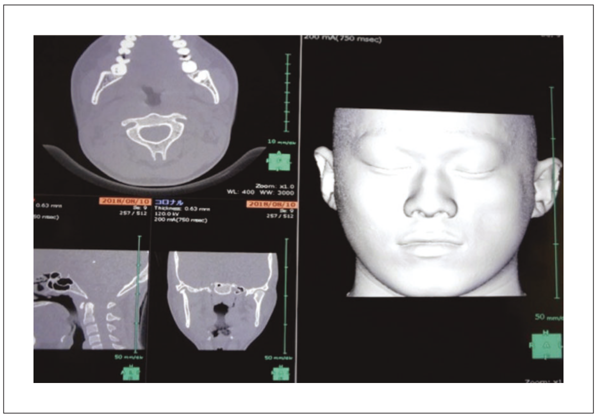


図１　３次元画像解析システムで顔面表面を描出した。左頬部が陥凹しているのが分かる。

織萎縮、骨萎縮を認める原因不明なまれな疾患である。顔面の知覚や運動障害を伴うことは通常ないため、手術は整容目的となる[1,2]。手術としては脂肪移植、筋膜移植や、遊離皮弁などが行われることが多い。また骨萎縮を認める場合は骨切り術が施行されることもある。

本症例は外来で保存的に経過をみていたが徐々に左頬部の萎縮が進行し、本人が整容目的に手術を希望した。軟部組織萎縮のみを認め骨萎縮がないこと、萎縮は左頬部中心に限局していること、遊離皮弁などの侵襲が大きい手術を患者が望まなかったことから、相談のうえで硬化型骨補強材による頬の形成手術を計画した。

硬化型骨補強材はペースト状であり、形状自由度に優れており、時間をおくと硬化する骨補強材である。整形外科、脳外科の手術において骨欠損部への充填などで使用されることが多い。また形成外科領域でも前頭骨陥没骨折などの骨欠損に対し使用されている[3,4]。

この硬化型骨補強材を左頬部中央の陥凹を認める頬骨上に充填し陥凹の改善をはかった。充填量と充填部位を決定するにあたり、3D モデリングソフトと 3D プリンターを用いて術前シミュレーションを行い検討した。

① 3 次元画像解析システム

：SYNAPSE VINCENT®（FUJIFILM®）

まず、術前の患者の顔面骨 CT を撮影し、その画像を院内に導入されている３次元画像解析システムへ転送した。この３次元画像解析システムは院内で撮影した CT や MRI などの断層画像から 3D 画像を描出し解析することができる。サーフェイス表示の設定を変えることで特定の臓器や血管、骨などを描出することができる。

今回は顔面骨 CT のサーフェイス表示を皮膚に対象を設定することで患者の顔面表面を描出した（図１）。

② 3D Builder®（Microsoft®）

3D Builder®は Windows10 に付属の無料 3D モデリングソフトであり、3D オブジェクトの作成、取り込んだ 3D ファイルの加工や装飾などができる。3D Builder®に３次元画像解析システムで作成した患者の顔面の画像を転送し、今回の手術の術前シミュレーションを行った。

まず、右頬部と左頬部を鼻の中央で２分割し、健常側である右頬部の鏡面像として左頬部を作成した。分かりやすいように元々の左頬部を黄色、ミラー像を青に着色した。

重ね合わせ不足している組織の容量、すなわち充填する硬化型骨補強材の 3D 画像を作成した。

作成した 3D 画像を STL から G-Code へ変換し 3D プリンターに転送し 3D モデルを作成した（図２、３）。

③術中所見

左口腔前庭切開からアプローチし頬骨を露出させた。頬骨はエレバラスパを用いて骨膜を剥離し、陥凹している部位に硬化型骨補強材が充填されるようにスペースを作成した。作成したモデルを参考に術中に硬化型骨補強材の使用量や形の形成を行った。左右の頬部を比較し硬化型骨補強材の量と位置の調節を行い粘膜縫合し、手術終了とした（図４、５）。

【結　果】

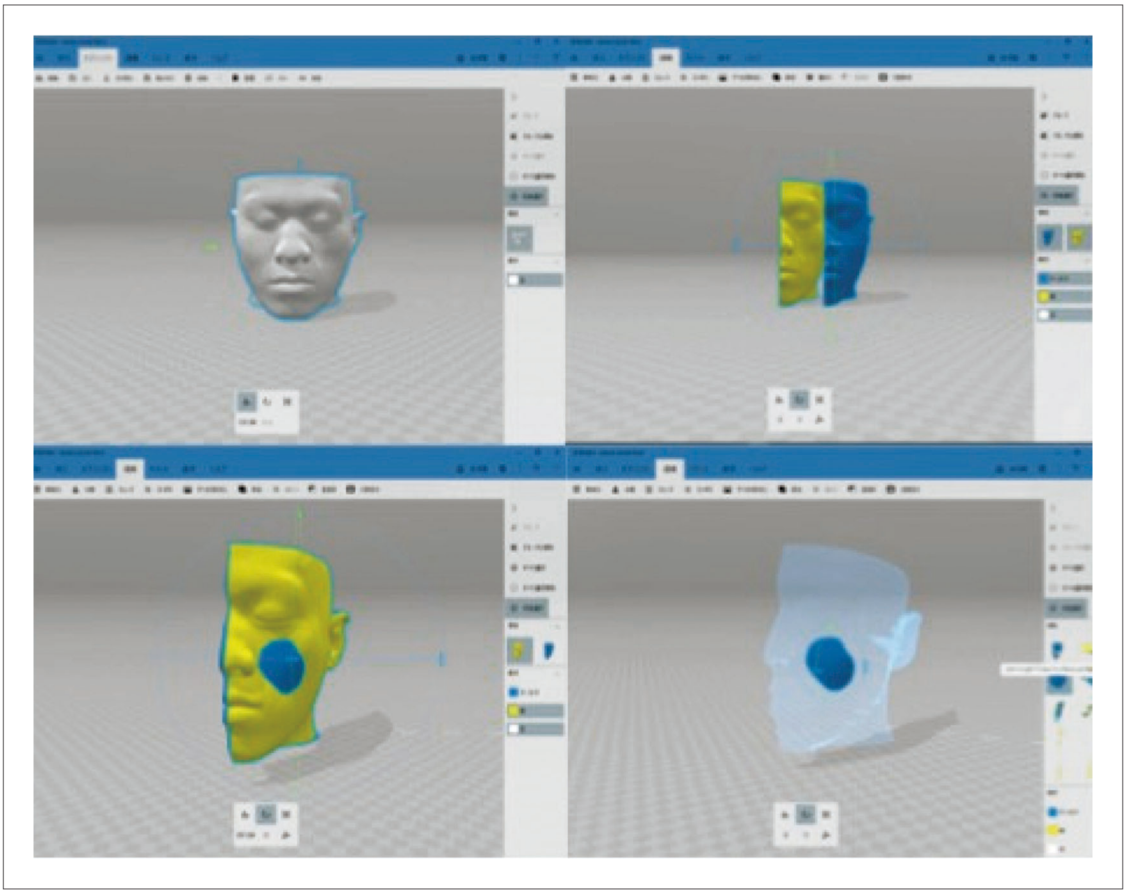
現在術後半年であるが、患者は違和感などの症状なく、また頬部変形なく経過良好である。

【考　察】

今回の手術では作成したモデルの容積より多く硬化型骨補強材を使用したが、その形状や挿入する場所などを決定するにあたり術前シミュレーション及びモデルの作成は非常に有用であった。また術後の患者の満足度は非常に高く、短時間、低侵襲で整容的に改善することができた手術と考えられる（図６）。

3D モデリングソフトや 3D プリンターの名前は広く知れ渡っているが、実際に使用している医療関係者は少数である。一部の医師は術前の 3D モデリングや、必要であれば 3D プリンターでのモデル作成を自ら行っているが、ほとんどの施設では業者に委託する場合が多くコストが高い。診療点数としては低いため（2,000 点、医科診療報酬点数表 K939 画像等手術支援加算２実物大臓器立体モデルによるもの）、顔面骨骨折であっても全症例に対して外部の委託で作成することは難しい。

医療用で使用する 3D モデリングソフトは操作が煩雑であり、使いこなすまでに修練が必要である。その分小児の先天性奇形に対する頭蓋形成術や骨切術など



a | b
c | d

図2 （a）取り込んだ顔面
（b）黄色：病側である左頬部　青：ミラー画像
（c）両者を重ね合わせた
（d）左頬部に不足している容量

図3 3D プリンターで作成したモデル
（a）術前の顔面モデル
（b）左頬部に不足している容量

a | b

の緻密な操作が要求される術前シミュレーションが可能であり、多種多様な高機能を備えている。しかし普及が遅い理由としては、コスト、時間、労力がかかることが主な理由と考える。また、モデリングソフトが院内の特定のパソコンでしか使用できないなど利便性にかける場合が多い。日本だけでなく海外の病院でも同様に低コスト、短時間、簡単にモデリングやプリントがでるようにする工夫が考えられており、安価で操作が簡単な3D モデリングソフトや3D プリンターの導入が試みられている[5-8]。

今回はWindoes10の付属品である3D Builder®を使用した。3D Builder®の特性を以下に簡単に列挙する。①GUI が他のソフトと比較し単純で分かりやすく、細かい説明などがなくとも操作方法が習得できる、②スムージングと単純化でオブジェクトをクリーンアップする、③印刷できるようにオブジェクトを自動修正する、④3D スキャンカメラで人物をフルカラーでスキャンすることができる、⑤3D ファイルをダウンロードして編集できる、⑥web カメラで写真を撮影し3D にすることもできる、またBMP、JPG、PNG、TGA ファイルを使用することもできる、⑦3D プリンターがなくとも、ネットで注文し宅配で受け取ることができる、⑧3D オブジェクトのイメージ画像を紙に印刷することができる、⑨3MF、STL、OBJ、PLY、WRL（VRML 2.0）、gLTF（v2.0）のファイルを開くことができる、⑩3MF、STL、PLY、OBJ のファイルとして保存できる。

これらの機能を使用すれば、例えば形成外科分野でいえば乳房再建や小耳症手術の術前シミュレーション

図 4　左上口腔前庭切開から硬化型骨補強材を充填した。

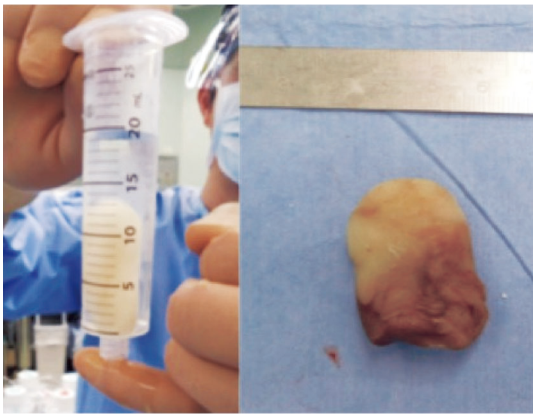


図 5　（a）使用し硬化型骨補強材の容積をシリンジで測定している、約 7 cc
（b）挿入した硬化型骨補強材

a｜b

a｜b
c｜d

図 6　（a）（c）術前　（b）（d）術後

など、他科でも脳外科、整形外科、歯科領域の術前シミュレーションで活用が期待される。さらに顔面骨骨折でいえば、骨折部の長さや欠損の面積・体積、プレートの形状や位置の決定などの術前シミュレーションであれば問題なく行うことができる。

今回硬化型骨補強材を充填させる場所や形は術前シミュレーションとほぼ同じであったが、誤差があった点は容積に関しては実際使用した量はモデルの約 1.5

倍となったことである。これに関しては実際使用した容積が7cc と少ない量であり微調節が難しかったこと、3D Builder®で左右の体積を測定するのではなく、ミラー画像と比較し肉眼的な差を手動で測ったことなどが原因と考える。(左右の体積を測定していたとしても顔面左右はまったく同じではないためある程度の差は生じたと考えるが)

【まとめ】

今回は3D Builder®を使用したが、他にもダウンロードできる無料または安価の3D モデリングソフトは多数ある。それらの一般向けの3D モデリングソフトは3D モデリングが未経験な医師であっても操作が簡単であり、また各自のパソコンへダウンロードしインストール可能である。時間も短時間で操作することがでるため、日常診療において活用が期待できる。

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眼窩骨折手術における3Dモデル導入の影響

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Experience of 3D printed model use in orbital floor reconstruction surgery using autologous bone

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Abstract

Recently, three-dimensional (3D) printed model use in orbital floor reconstruction surgery is popular and provides surgeons well-visualized field of orbital floor bone defect. Previous study mentioned the efficacy of 3D printed model only in orbital floor reconstruction surgery using artificial material (e.g., titanium plate) but not in surgery using autologous bone. We herein described our experience of 3D printed model in orbital floor reconstruction surgery using autologous bone. Fifteen patients with traumatic orbital floor fracture, operated from 2012 to 2018, were enrolled in this study and divided into 2 groups (group 1：9 patients, 3D printed model not used；group 2：6 patients, 3D printed model used). The 3D printed model of orbital floor was created from CT data of the ipsilateral orbital floor. The model was sterilized. Autologous bone was harvested and sculptured according to that 3D model. The time of surgery and the degree of eyeball deviation, which was measured from postoperative CT data, were compared between 2 groups. The time of surgery was not different between 2 groups even the average of years of experience of the surgeons was lower in the group 2. The degree of eyeball deviation was smaller in the group 2 ($p<0.05$). The use of 3D printed model allowed the surgeons to fashion autologous bone to so well-visualized bone defect model that the surgeons could accurately fashion autologous bone. Sculpturing in the well-visualized field of the defect also allowed young surgeons to reduce the time of surgery. According to this study, 3D printed model use in orbital floor reconstruction surgery using autologous bone may result in accurate reconstruction even in surgery performed by inexperienced surgeons.

Key words：3Dプリンタ、眼窩骨折、自家骨再建、積層造形、手術シミュレーション

【はじめに】

近年CTデータから3Dモデルを作製し、眼窩底骨折の整復に利用する手法は3Dプリンタの低価格化に伴い広く普及しつつある。過去の報告においても、3Dモデルの導入により、手術時間の短縮や、再建形状の再現率向上が認められている[1-4]。しかしながら眼窩の自家骨再建における3Dモデルの有用性を評価した報告はまだ少なく[5]、導入前後での比較検討を行った報告はほとんどない。そこで当科での自家骨を用いた整復術における3Dモデルの影響に関して、導入前後での比較を行ったため報告する。

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【方　法】

当科にて3Dモデルを導入した2015年を起点にその前後3年間を対象期間とした。2012年1月から2017年12月までの期間に施行された眼窩骨折例84例中、眼窩下壁の単独骨折症例48例を抽出した。さらにこれらのうち自家骨を用いた15例を、当科にて3Dモデルを導入した2015年以降とそれ以前に分けた。最終的に3Dモデル導入前の対象群9例と3Dモデル導入後の対象群6例との比較検討を行った（図1）。

対象群患者背景

3Dモデル導入前群の男女比は男6女3、導入後群は男6女0で、両群間に有意差は認められなかった。3Dモデル導入前群の年齢平均値は31.9±15.6歳、導入後群の年齢平均値は37.8±11.2歳で、両群間に有意差は認められなかった。3Dモデル導入前群の受傷要因は、交通外傷2例、危害行為2例、転倒・事故5例、導入後群では交通外傷2例、危害行為2例、転

倒・事故 2 例で、両群間に有意差は認められなかった。3D モデル導入前群の既往歴はＣ型肝炎 1 例、髄膜炎 1 例、導入後群では高血圧 1 例、うつ病 1 例だった。3D モデル導入前群の術者卒後平均年数は 9.56±2.36 歳、導入後群の平均年数は 4.83±3.29 歳で、有意水準 5 %で有意差を認めた（表 1 ）。統計解析には Mann-Whitney の U 検定を用いた（統計ソフト SPSS）。

3D モデルを用いた自家骨再建

当科で行っている 3D モデルを用いた自家骨による整復術の概略を説明する。まず術前に患者の CT データから DICOM（Digital Imaging and COmmunications in Medicine）データを抽出し、CT 値から算出した閾値よりレンダリング処理 software（InVesalius 3.0：CTI、ブラジル）を用いて骨表面のレンダリングモデルを作製する。作製した骨表面レンダリングモデルから患側モデルと、健側の左右を反転させたミラーモデルを 3D プリンタ（Bellulo®：株式会社システムクリエイト、日本）にて出力し、滅菌処理を行う。次に術中で採取した腸骨等の自家骨をプリンタで出力した患側・健側ミラーの 3D モデルに合わせて加工する。最後に実際の欠損部へ加工した骨を挿入し整復する（図 2 ）。

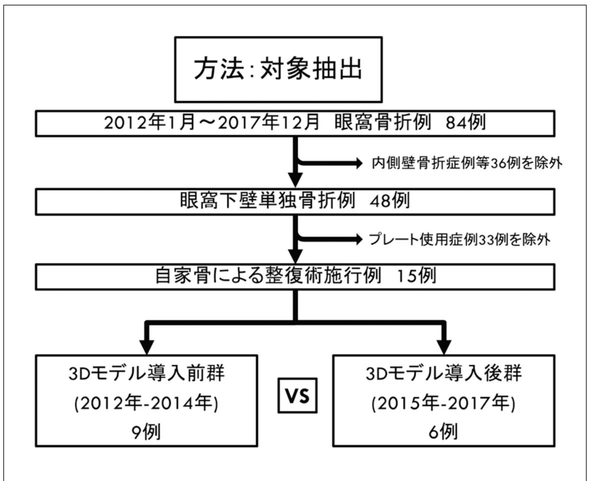


図 1 対象の抽出

眼球偏位量

術後半年での健側と比較した患側の眼球偏位量を CT 画像より求めた。術後半年の CT 水平断像を用いて、Ⅰ：まず眼軸と直交し、眼窩外側縁に接する直線を引く。Ⅱ：この直線と平行かつ、眼球赤道面と接する直線を引く。Ⅲ：この二本の直線間の距離を d とし、健側の d と患側の d との差を眼球偏位量とした（図 3 ）。

【結 果】

手術時間の比較

3D モデル導入前群の手術時間平均値は 172.2±34.8 分、導入後群の手術時間平均値は 156.3±28.6 分で、両群間に有意差は認められなかった（表 2 ）。

眼球偏位量の比較

3D モデル導入前群の眼球偏位量は+0.76±0.67 mm、導入後群の眼球偏位量は－0.19±0.72 mm で、両群間に有意水準 5 %で有意差を認めた（表 3 ）。

【考 察】

3D モデル導入後群において術者の卒後年数は低い傾向がみられた。これはモデル導入により比較的若年であっても、術者を任せられると指導医が判断した可能性がある。しかし 3D モデル導入前後で手術時間に有意な差は認められなかった。手術時間の平均値は導

表 1 患者背景

患者背景			
項目	3Dモデル導入前群(9例)	3Dモデル導入後群(6例)	U検定
男女比(男：女)	6：3	6：0	n.s.
年齢(歳)	31.9±15.6	37.8±11.2	n.s.
受傷要因			n.s.
交通外傷	2	2	n.s.
危害行為	2	2	n.s.
転倒・事故	5	2	n.s.
既往歴	C型肝炎、髄膜炎各々1例	高血圧、うつ病各々1例	
術者卒後年数(年)	9.6±2.4	4.8±3.3	※

U検定：Mann-WhitneyのU検定　n.s.：非有意　※：P=0.014＜0.05

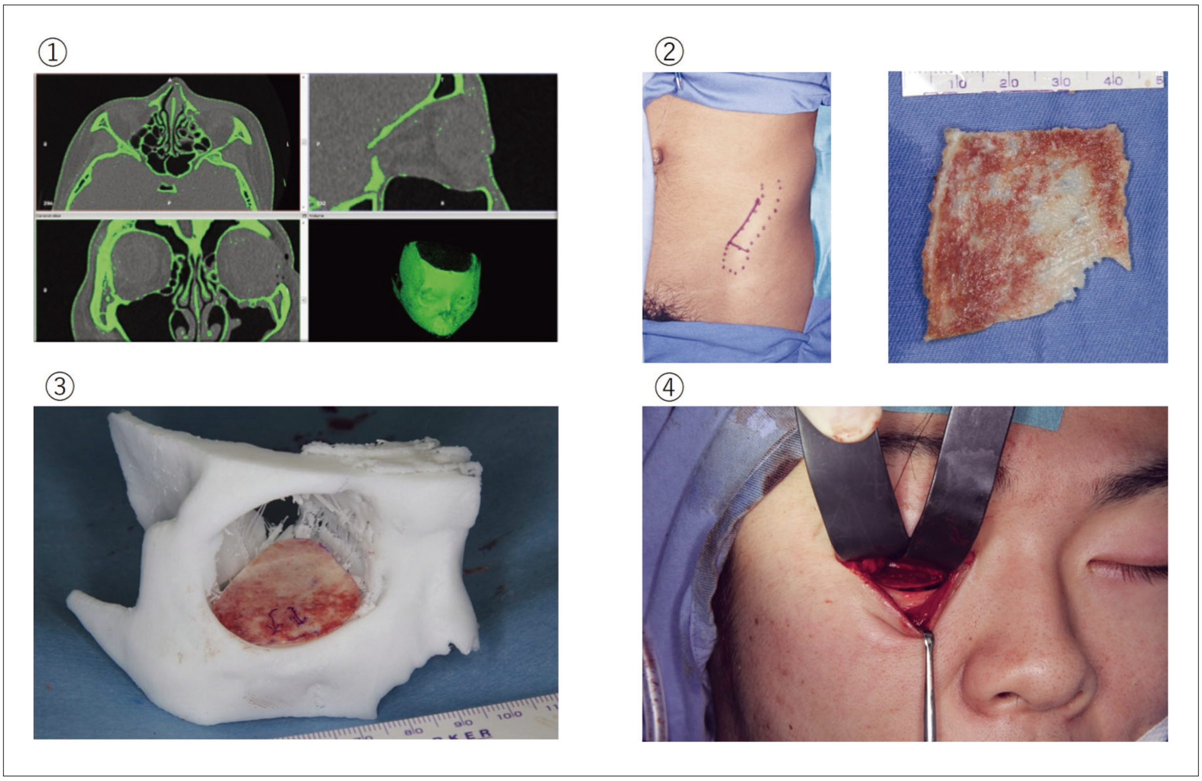


図２　3D モデルを用いた自家骨再建
①CT からモデルの作成　　②自家骨の採取
③モデルを用いたプレベンディング　④創部へ挿入

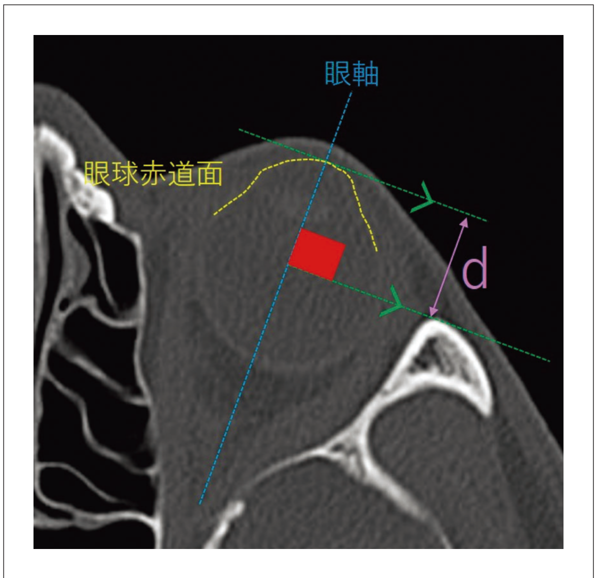


図３　眼球偏位量　－計測方法－
Ⅰ：眼窩外側縁と接し、眼軸と直交する直線を引く。
Ⅱ：Ⅰの線と平行かつ眼球赤道面に接する直線を引く。
Ⅲ：ⅠとⅡの直線間の距離をｄとする。
眼球偏位量＝健側のｄと患側のｄとの差とした。

入後群では 15.9 分短縮された。3D プリンタによるモデルが導入される以前では、眼窩底骨折の欠損範囲は、CT の二次元画像から推定し、小さな経結膜切開から覗き込んで確認するほかなかった。特に後方の欠損部の把握は難しく、場合によっては器具越しの感覚で形状を把握しなければならなかった。加えて自家骨の加工においても、形状把握の困難さは、精確な加工と良好なフィッティングを得るために何度も自家骨を創部に挿入しては取り出す調整作業を必要とした。これら手技の問題は結果として眼窩周囲組織の操作量を増やし、創部腫脹を生じさせ、手術時間を長引かせる。

3D モデルを実際の術野に持ち込むことで、欠損範囲はあらゆる角度から肉眼で確認することができる。また自家骨の加工はモデルに当てながらフィッティング・調整作業を行うことができるため、操作の制限や視野の制限なく行うことができるうえ、何度でも容易に当てなおしが可能である。

その結果、3D モデルの導入は、上記手技上の問題点の解消につながり、より少ない操作量、より創部負担の少ない手技で手術を完了することが可能である。今回の結果ではこれらの 3D モデル導入による利点が、ベテランの術者の経験と同等かそれを上回る可能性が示唆されたと考える。

眼窩底骨折の再建において重要なことは眼窩壁の精

表 2　手術時間の比較

手術時間比較(分)		
	3Dモデル導入前群(9例)	3Dモデル導入後群(6例)
	132	189
	202	176
	151	100
	206	147
	183	170
	120	156
	138	
	215	
	203	
平均	172.2	156.3
標準偏差	34.8	28.6

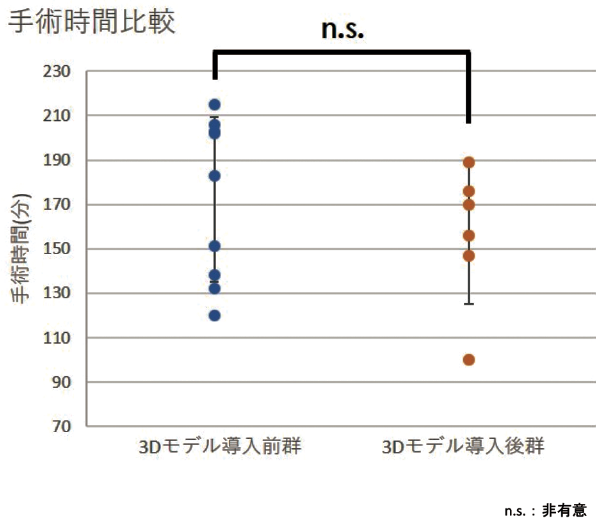
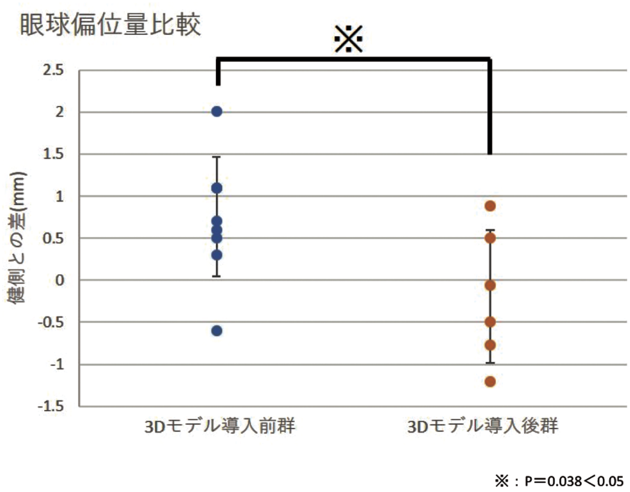


表 3　眼球偏位量の比較

眼球偏位量比較(mm)		
	3Dモデル導入前群(9例)	3Dモデル導入後群(6例)
	0.6	-0.06
	2.01	-1.21
	0.7	-0.5
	1.1	0.5
	0.3	0.88
	1.1	-0.77
	0.5	
	-0.6	
	1.1	
平均	0.76	-0.19
標準誤差	0.67	0.72



確な再現と眼窩内体積の復元である[6,7]．再建材料としてみた場合の自家骨は、生体適合性に優れた材料であるが、Siddique らの報告[8]や Iatrou らの報告[9]によれば自家骨は明確に吸収される材料であり、眼窩壁を精確かつ長期に維持する点では不利である。一方 Kontio らの眼窩底骨折 24 例に対し CT・MRI による術後評価を行った報告[10]では、5 例で骨量の増加を認めたにも関わらず術後の評価は良好であった。このような事実から 3D モデルを用いない手技においては、やや過剰な整復を術者が意識していた可能性が高い。また先述の Kontio らの報告[10]や Ellis らの報告[11]では自家骨を用いた再建では後方の眼窩体積量が増加する傾向にある。これらの影響により、我々の 3D モデル導入前群の眼球偏位量は、突出傾向を示したと考えられる。

眼窩内体積に対し、自家骨は主にその厚みから、メッシュプレート等と比して相当の体積を占める[11]。したがって自家骨を用いた再建では、必要十分な最小の体積での再建を目指すべきである。特に後方の整復精度が低下すると眼球は突出傾向となりうることは、眼窩が後方に向かって絞られる四角錐型の形状であるという解剖学的特徴から容易に了承される。3D モデルの導入により、植皮における濾紙での型取りのように、目標形状に直接自家骨を当てつつ、操作・視野の制限なく調整作業が可能である。この利点は欠損の輪郭にフィットした自家骨の加工を可能とした。その結果 3D モデル導入前群の自家骨と比して 3D モデル導入後群の自家骨の体積は減少していたと考えられる。この減少した体積に加え、眼窩内組織の委縮・骨吸収の影響が加わった結果 3D モデル導入後群の眼球偏位量はわずかに陥凹傾向を示したと考えられる。このことは自家骨再建において、欠損輪郭の精確なトレース

以外にこれら減少体積分の補正が必要である可能性を示している。

【まとめ】

眼窩下壁単独骨折症例に対する自家骨再建術における 3D モデル導入の影響を比較した。3D モデル導入により、経験の浅い術者であっても経験豊富な術者と同等の result が得られる可能性が示唆された。3D モデル導入により自家骨再建においても眼窩の整復精度が向上する可能性が示唆された。

一方でさらなる精度の向上には、欠損輪郭の単なるトレース以外になんらかの補正が必要である可能性が示唆された。今後さらなる症例蓄積と、眼窩容積測定などの三次元的評価が必要である。

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様々な下顎再建に対応可能なサージカルガイドの作成

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Creation of surgical guide applicable for various cases

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Abstract

Computer-assisted surgery has been actively conducted in the field of maxillofacial surgery in recent years. Simulation software is used for preoperative evaluation, surgical planning, prediction of results, simplification of the actual surgical process, and improvement of accuracy.

In our facility, simulation of reconstruction with the fibula and creation of three-dimensional entity models and surgical guides are conducted by ProPlan® software, which is a specialized software for craniomaxillofacial surgery. A surgical guide is very useful for benign tumors because the resection range of the mandible can be determined before surgery. However, surgical guides are difficult to use for patients with advanced malignant tumors or radiation osteomyelitis because the preoperatively planned resection range may change. Therefore, we devised guides that can respond when the resection range changes. One guide consists of a bridge and two atattchment entities which guide osteotomy, then maintains the positions of residual mandibular bones. And also, the guide indicates a reference point such as the mental tubercle or mandibular angle in space. The other is a fibula guide that can cut the fibular bone at a determined angle.

The postoperative evaluation of the deviation of condyle showed that the accurate reconstruction could be conducted by the surgical guides.

Key words：サージカルガイド、コンピュータ支援手術、下顎再建、腓骨皮弁

【はじめに】

腫瘍切除などによる区域切除後下顎骨欠損に対して、腓骨皮弁による下顎再建は1989年にhidalgoら[1]が最初に行って以来、現在では下顎再建において最も主要な再建方法である。下顎再建の達成すべき目標としては咀嚼機能、発語、気道の維持であり、精密な再建が必要となる。

コンピュータ支援手術（Computer-assisted surgery；CAS）を利用した下顎骨再建は近年では一般的な技術となっており、精密な手術のプランニングと正確な骨切りや固定を支持するサージカルガイドの作成により、従来の再建に比べて顔貌のよりよい改善を得られ[2]、さらに皮弁阻血時間を含めた手術時間の短縮[3-7]、そしてコスト削減に寄与するとされる。

一方で、進行癌などで切除範囲が手術中に変更になる症例や、骨のリモデリングや周囲組織の拘縮が起こる下顎骨切除後の二次再建においても有用なサージカルガイド作成の報告は少ない[8,9]。

我々が下顎骨再建用に作成しているサージカルガイドは多様な症例にも対応しうると考えており、その作成法と利用法を報告する。

【対象および方法】

使用したソフトウェアはProPlan CMF 3.0®（Materialize 社）で、3D プリンターは Form2®（Formlabs 社）である。作成したモデル、サージカルガイドは術前にガス滅菌を行った。CT 撮影は当院で行う場合、スライス厚1 mm以下で施行した。下記の3タイプにおいてそれぞれのサージカルガイドを説明する。

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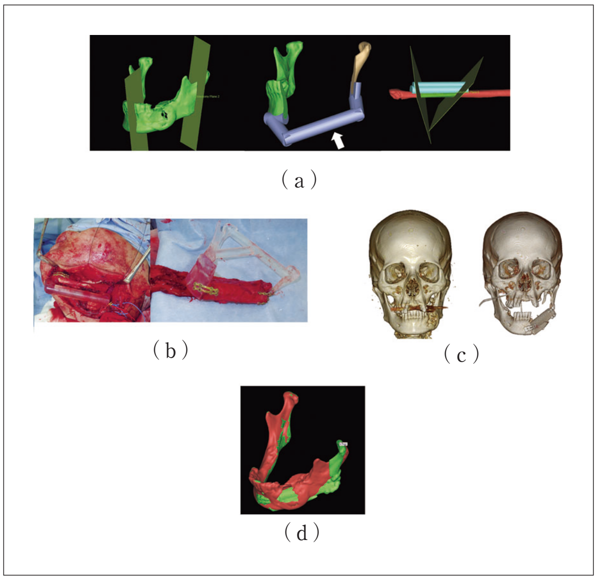

図 1　タイプ 1 症例、エナメル上皮腫
（a）サージカルガイド作成（白矢印：ブリッジ）
（b）手術時
（c）術前（左側）と術後（右側）CT
（d）術前（赤）と術後（緑）の下顎骨健側を重ね合わせし、関節突起先端の偏差を計測

タイプ 1：切除範囲が術前に決定している場合

まず術前に切除範囲を歯科口腔外科と相談して決定する。ソフトウェアの 3D オブジェクト作成ツールにあるシリンダー型の立体を組み合わせてサージカルガイドを下顎用と腓骨用にそれぞれ作成する。下顎用は骨切り面をシリンダーの断面に合わせるようにし、さらに下顎骨切除後の左右に残存する骨体に適合するようにガイドから下顎骨を差分し、ブリッジを作成して 1 個体とする（図 1a）。再建後の下顎骨モデルをプリントアウトし、チタンプレートを表面に当ててプリベンディングする。この際に、下顎骨モデルにチタンプレートの穴からスクリューでホールを開けておく。骨切り前にガイドを装着し、先に開けておいた穴にドリルを入れて、スクリューでガイドを下顎骨に固定する。アーチがあることにより下顎骨切除後も元々の形態を保つことができる（図 1b）。

腓骨用のガイドは、2 本のシリンダーから作成する。1 本を腓骨に半分ほど当てて差分し表面に適合するようにし、8 mm の幅で骨切り面を差し引く。その上にもう 1 本のシリンダーを組み合わせる（図 1a, b）。血管を切り離す前にガイドを用いて骨切りを行い、事前に作成しておいた切除後の下顎モデルに当てはめて、プレートをベンディングして固定する。血管切離し、腓骨を下顎に固定する（図 1b）。代表症例患者の術前術後 CT（図 1c）と術前術後の下顎骨重ね合わせの像を示す（図 1d）。

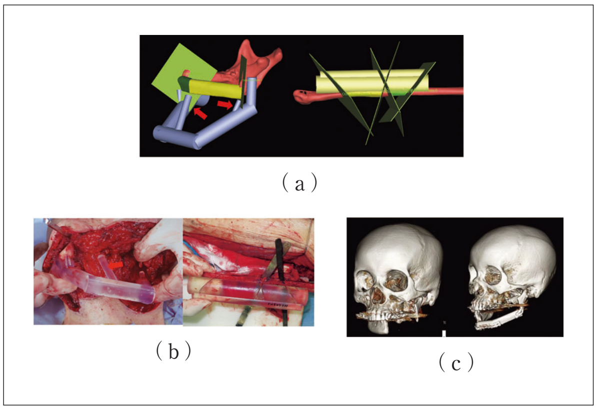

図 2　タイプ 2 症例、下顎歯肉癌術後の下顎骨欠損
（a）サージカルガイド作成（赤矢印：標識）
（b）手術時（赤矢印：標識）
（c）術前（左側）と術後（右側）CT

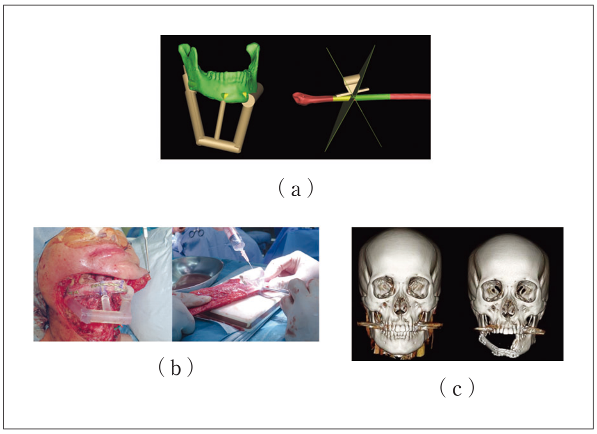

図 3　タイプ 3 症例、舌癌再発・放射線性骨髄炎
（a）サージカルガイド作成
（b）手術時
（c）術前（左側）と術後（右側）CT

タイプ 2：二期再建の場合

以前の下顎骨切除術よりさらに前に撮影した CT のデータから元来の下顎骨を STL ファイルとして取り込む。現在の切除後の偏位した下顎骨の残存骨体を元来の下顎骨に合わせるように移動させて、本来必要な骨欠損量を示す。骨体の断面はリモデリングされているため、再度骨切り面を設定し、タイプ 1 と同様に下顎と腓骨用のガイドを作成する（図 2a）。切除範囲に頤結節、下顎角部が含まれ、同部位の形態を腓骨内の骨切りで再現する場合は、その部位を示すような標識をガイド内に作成する（図 2a, b）。他の留意点としては、偏位した下顎骨の周囲を剝離して十分に整復位に戻すことと、側頭部切開から関節窩に到達し、関節突起周囲に固定したナイロン糸を牽引して、頬骨弓骨膜に縫合固定して整復を行うことである。タイプ 2 代表症例の術前後 CT を示す（図 2c）。

表１　タイプ別症例

タイプ	原疾患	年齢・性別	関節突起先端の偏差	
1	エナメル上皮腫	73・男	6.5mm	図1
1	ビスフォスフォネート製剤による顎骨壊死	73・女	6.1mm	
2	下顎歯肉癌	79・女	9.2mm	図2
2	下顎歯肉癌	53・女	10.9mm	
3	下顎歯肉癌	68・女	6.6mm	
3	舌癌再発、放射線性骨髄炎	67・男	7.7mm	図3

タイプ３：切除範囲が変更になる可能性がある場合

まず想定される切除範囲を歯科口腔外科と相談し、決定する。予定線より外側に離した場所に装着するように、タイプ１と同様にガイドを作成する。腓骨用のガイドは、頤結節や角部を形成する可能性がある場合に、予定した角度に骨切りを行えるようなガイドを作成する（図 3a, b）。切除後の残存下顎骨にガイドを装着し、ガイドから骨切りラインまでの長さを計測、また頤部と角部の位置を確認し、それに応じた骨切りを行う。代表症例の術前後 CT をしめす（図 3c）。

2018 年１月から 12 月までに、それぞれのタイプごとに２症例ずつ全６症例に対して、本サージカルガイドを使用して手術を行った。再建の評価法として、術前術後の患側関節突起先端部中心点の偏差を計測した（タイプ２の場合は下顎区域切除前の下顎を術前とした）（図 1d）。

【結　果】

全症例で良好な形態を再建できた（図 1c, 2c, 3c）。１例術後感染により皮弁壊死を認めた。その他は全例合併症なく、良好な咬合、開口を獲得できている。術前術後の患側関節突起先端部中心点の偏位距離はタイプ１が 6.1－6.5 mm で、タイプ２が 9.2－10.9 mm、タイプ３が 6.6－7.7 mm であった（表１）。

【考　察】

今回作成したサージカルガイドの特徴としては、骨切り両端のガイドをブリッジで結合することで、区域切除後も本来の位置を保つことができる。ガイド作成時の留意点としては、サージカルガイドの装着部位を固定性は維持しながらもなるべく小さくすることであり、剥離範囲を最小限にして残存骨の血流を維持し[10,11]、サージカルガイド装着したまま腓骨のプレート固定を可能にするためである。

切除範囲に関して、CAS によるプランニングが中止になる事前に十分な計画と綿密な打ち合わせを行うことは重要だが、それぞれの施設での頭頸部外科の方針の違いや、画像撮影から手術までの時間がやむなくかかってしまい、腫瘍が増大している場合などを考えると、手術中の変更に対応するようなサージカルガイドは有用であると考えている。切除範囲が変更になる場合のサージカルガイドについて、ガイドを通常用と変更になって切除範囲が広くなった用の２種類作成するといった報告がある[12]が、ガイド作成にかかる時間とコストを考えると、作成するガイドはシンプルに少ない方がよいと思われる。他に、ガイドに目盛りを記載することで切除範囲の変更に対応している方法[8]は我々の方法と類似している。

下顎再建における CAS に関する報告では、Proplan/Surgicase CMF は現在最も一般的に使用されているソフトウェアであり、また再建の評価方法として目印とする部位は関節突起が最も多く、その偏差は 0－12.5 mm であった[13]。我々の術後評価においては関節突起の偏差は 6.1－10.9 mm であり、過去の報告と比べてやや大きい印象があるが、報告の多数は目印となる部分を設定した自動重ね合わせツールによる計測であり、今回は手動で合わせているため、やや不正確な可能性がある。また、計測方法に関して、どの部位で行うか、どの時点での画像を比較するかなど、報告ではばらつきがあるため、今後は統一した評価法が望まれる[14]。当報告内の症例では、二期再建となるタイプ２の再建でやや偏差は大きい印象があるが、関節突起のリモデリングや周囲組織の癒着、瘢痕化によるもの、術前の CT データが他院で撮影したものであった

ことによると考えられる。今後症例数を増やして、正確な評価法による統計的検討を行っていきたいと考える。

【ま と め】

様々な下顎再建の症例に応用できるサージカルガイドの作成を考案した。術後の結果より、精密な再建を行うのに有用であると考えられた。

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Developing a real-time physically deformable neurosurgical virtual reality simulation system based on clinical case data

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Abstract

OBJECTIVE: It is important to understand the three-dimensional (3D) anatomical structure in neurosurgery. The approach to the lesion sometimes requires deformation of the brain by a retractor. Moreover, the surrounding anatomical structure is deformed by the lesion. Therefore, a model based on clinical case data with stereopsis and that is physically deformable and allows real-time, virtual reality (VR)-based operation of surgical instruments is useful for neurosurgical simulation. We are developing a real-time physically deformable neurosurgical VR simulation model based on clinical case data using state-of-the-art technology. We report on representative clinical cases using this VR system from our department of neurosurgery.

METHODS: We developed FBX data of the 3D mesh model by a modeling software using DICOM data generated using 3 Tesla MRI and 320 slice CT for clinical cases. The hand and head motion tracking for VR was performed using the Oculus Rift and Touch. A real-time physically deformable VR system was built by Unity using a laptop. This system was used to develop surgical strategy and for the training of neurosurgeons and medical students.

RESULTS: This system accurately simulated the anatomical structure in the clinical cases. The neurosurgeons and medical students reviewed this system favorably.

CONCLUSION: This system was useful for developing neurosurgical strategy and training of neurosurgeons and medical students.

Key words: Neurosurgery, surgical simulations, virtual reality

Introduction

It is very important in the field of neurosurgery to be able to grasp the three-dimensional (3D) anatomical structure of the brain. It is sometimes necessary to cause deformation of the brain with a retractor in order to reach a lesion. Moreover, the lesion itself causes deformation in surrounding structures in certain cases. Therefore, real-time virtual reality (VR)-based operation of surgical instruments in a 3D and physically deformable manner based on clinical case data is an effective means of surgical simulation in the field of neurosurgery. We used cutting-edge technology to develop a real-time physically deformable neurosurgical VR simulation system based on clinical case data that utilizes three-dimensional computer graphics (3DCG). We hereby report on our findings from representative clinical cases on which we used this system in our department.

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Methods

We used DICOM data generated using 3 Tesla MRI and 320 slice CT from clinical cases to develop 3D mesh model FBX data with a modeling software. For head and hand motion tracking during VR, we used the which are normally commercially sold for use with computer games (Figure 1). We constructed the real-time physically deformable VR simulation system with Unity, an integrated development environment used to support the development of software using a laptop. We used this system for developing surgical strategies and clinical training of neurosurgeons and medical students.

Results

This system accurately simulated the anatomical structures of clinical cases. Compared to other systems, such as 3DCG, 3D printer models and Freeform or leap motion, which use a geomagic haptic device, our system, which used Oculus Touch and

Figure 1　Oculus Rift and Oculus Touch
We used the Oculus Rift to monitor the operator's face position and direction while viewing a 3D VR space. The Oculus Touch can stably and accurately monitor hand position and direction, enabling the free operation of surgical instruments.

Table 1　Various surgical simulations
We performed the various types of surgical simulations shown and experienced the advantages and disadvantages of each system. Each system is currently being used at our facility, enabling comparative evaluation. We presented the detailed findings at an academic society meeting.

System	Advantages	Disadvantages
2017 prototype Oculus Touch, Oculus Rift, Unity, Blender, 3D Slicer, Brainlab iPlan(Not required)	Precise and stable hand motions. Physically deformable and can be used to simulate natural conditions such as gravity, elastic force, and liquidity. Offers three-dimensional view. Can reflect operator head and hand movements in real-time. Can be constructed at a relatively low cost (45,000 yen). Can simulate surgical instruments. Can easily re-use models. Easily portable.	Program and model construction are complicated and difficult. The system is not commercially available, meaning that the surgeon must construct it themselves.
2016 prototype Leap motion, Oculus Rift, Unity, Blender, 3D Slicer, Brainlab iPlan(Not required)	Physically deformable and can be used to simulate natural conditions such as gravity, elastic force, and liquidity. Offers three-dimensional view. Can reflect operator head and hand movements in real-time. Can be constructed at a relatively low cost (45,000 yen). Can simulate surgical instruments. Can easily re-use models. Easily portable.	Hand and finger movements are unstable. It is difficult to perform quick, detailed work. It is complicated and difficult to create the programs and models. The system is not commercially available, meaning that the surgeon must construct it themselves.
3D-CG SYNAPSE VINCENT, Brainlab iPlan, OsiriX	The application has been introduced at many hospital facilities. There are many free-of-charge applications. Can easily re-use models. Commercially available.	Soft deformation is difficult. Commercially-available applications are expensive.
haptic device Geomagic Sculp/Freeform/Freeform plus/Stylus	Model preparation and system operation are relatively easy. Tactile simulation is possible. Simple soft deformation possible similar to clay molding. Can easily re-use models. Commercially available.	Expensive (2 million yen or more). Physical deformation is not possible.
3D printing FLASHFORGE Creator Pro, XYZPRINTING da Vinci	Can use actual surgical instruments. Commercially available. Actual models can be picked up and observed.	Model preparation time is relatively long (one day to several days). Once the model is used for resection, it is difficult to use again. (Relatively high cost: Hundreds of thousands of yen or more). Soft model construction is relatively difficult.

Oculus Rift, had various advantages including low cost, and good surgical instrument operability, anatomical structure deformation, and high model preparation efficiency（Table 1）. Neurosurgeons and medical students evaluated the system highly for its practicality.

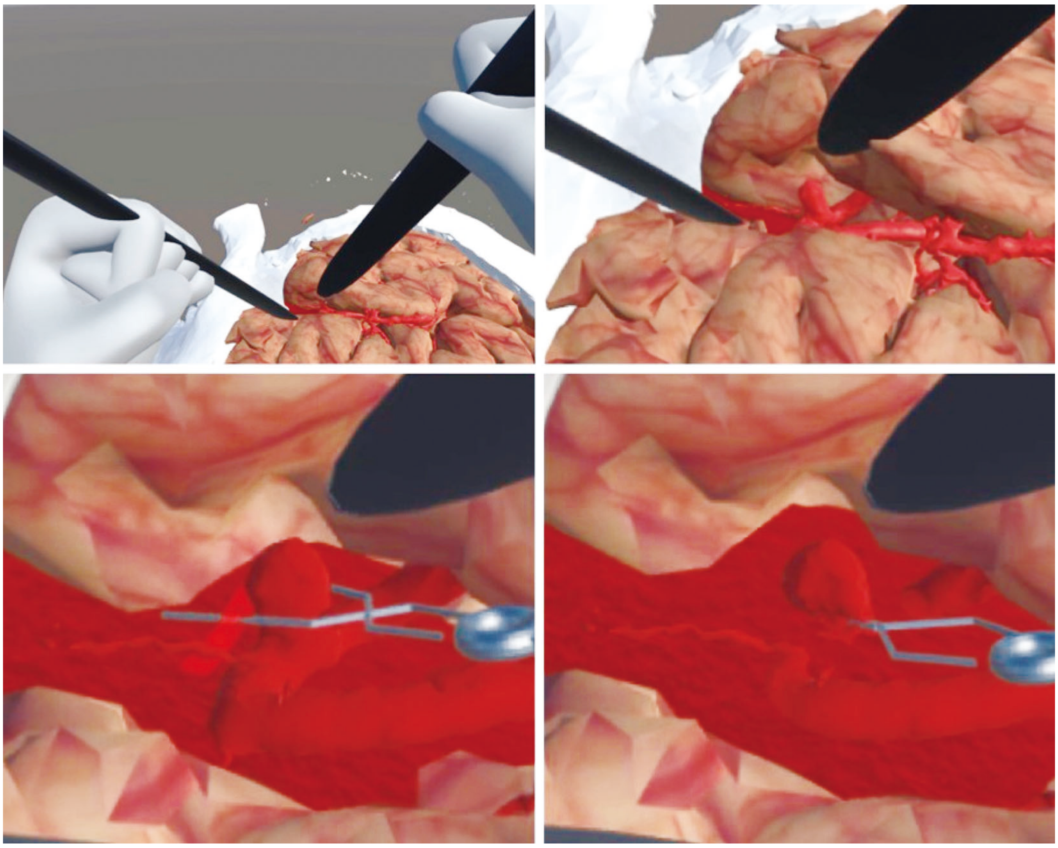

Figure 2 Cerebral aneurysm clipping surgery
A brain spatula is used to deform the brain so that the cerebral aneurysm can be exposed. If the surgical instrument touches a site on the cerebral aneurysm that is prone to bleeding, bleeding is simulated. Clip opening/closing angle can be freely adjusted with analogue input.

Figure 3 VR operating theater
The surgeon can freely walk around and even sit down, enabling them to carefully consider what position to put the patient in and where to place the surgical instruments.

Case Presentation

Case 1 : Cerebral aneurysm clipping. The aim of this surgery is to pinch the aneurysm with a clip in order to prevent the aneurysm from rupturing after deforming the brain with a brain spatula to expose the said aneurysm. Our system successfully achieved a practical simulation of this case (Figure 2).

Case 2 : Skull base tumor extraction. In neurosurgery, the patient's position and their positional relationship with the surgeon are important elements of the surgical strategy. With our system, the surgeon could freely walk around the VR operating theater and even sit down, enabling them to carefully consider what position to put the patient in and where to place the surgical instruments among other advantages. (Figure 3).

The skull could be opened with craniotomy instruments at a site freely selected by the surgeon and the tumor extraction percentage was also automatically displayed (Figure 4).

Discussion

The cost of surgical simulation systems that use neurosurgical computer-based data and are generally

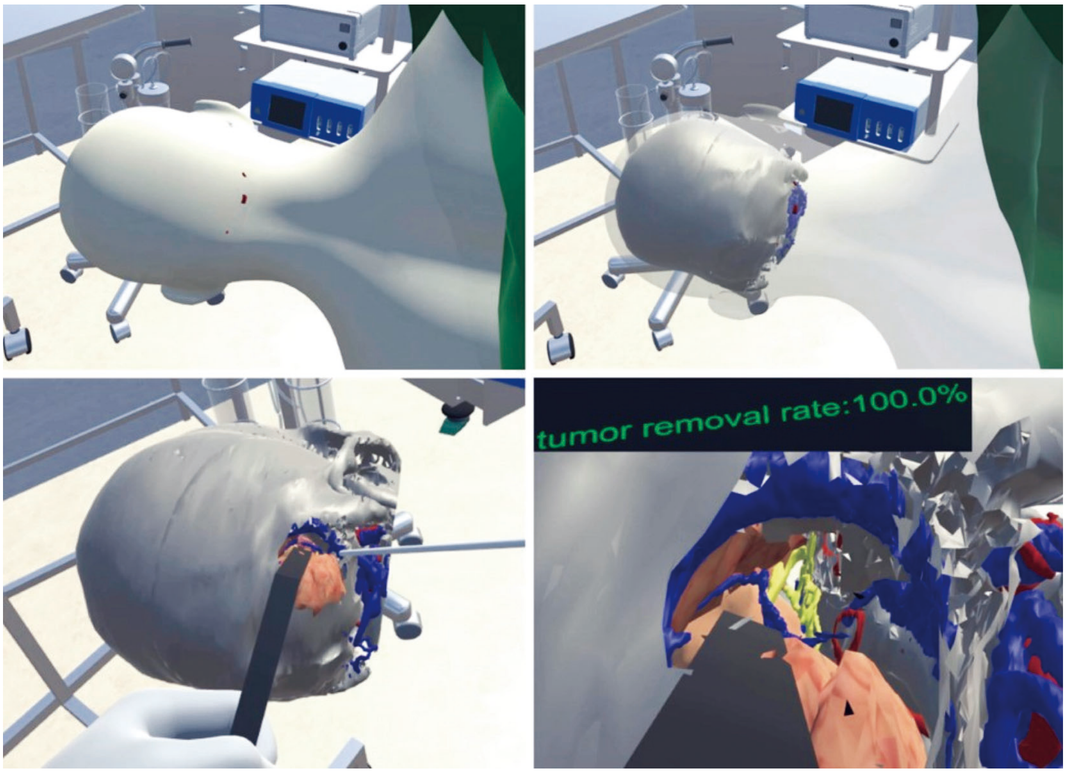

Figure 4 Skull base tumor extraction
The skull can be opened with craniotomy instruments at a site freely selected by the surgeon and the tumor extraction percentage is automatically displayed.

commercially available can range from millions to tens of millions of yen. Moreover, simulation models are created in a virtual manner, rather than based on data from patients actually scheduled for surgery[1,2]. As these systems are also relatively large in size, it can be difficult to transport them to actual clinics. Therefore, it is not easy for clinicians who want to utilize surgical simulations to introduce and use such systems. This has meant that simulation systems have not come into widespread use in medical settings and surgeons are unable to actually try using such systems. While VR simulations are considered to be beneficial in the field of neurosurgery, they have yet to come into widespread use and further development is anticipated going forward[3]. Our system can be constructed with a minimum cost of approximately 200,000 yen including that of the computer required. If a laptop is used, the system can be easily transported. We believe that publishing our method of construction of this system is significant as it could facilitate the spread of a practical surgical simulation system that can be generally used by many surgeons and aid in the achievement of safer surgery, which is highly anticipated by society at large.

As our system only underwent limited, subjective evaluation by users, we believe that objective evaluation data need to be collected going forward, including precise anatomical comparisons with actual surgical findings and the investigation of shortened operation time and reductions in the number of complications.

Conclusions

Altogether, our results suggested that our real-time physically deformable neurosurgery VR simulation system based on clinical case data is practically useful for formulating surgical strategies and for clinical training.

Conflicts of interest：There are no conflicts of interest to declare with regard to this study.

An outline of this manuscript was presented at the 10th congress of the World Society for Simulation Surgery (September 30, 2018, Chicago), the 77th

Annual Meeting of the Japan Neurosurgical Society (October 12, 2018, Sendai), and the 28th Japan Society for Simulation Surgery General Meeting (November 10, 2018, Tokyo).

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10th Biennial World Society for Simulation Surgery Meeting (WSSS Chicago)

In Conjunction with 96th American Society of Plastic Surgery (PSTM 2018)

President Elect: Arun Gosain MD. (Chief & Professor of Surgery, Northwestern University, USA)

Secretary General: Akira Yamada MD. (Professor of Surgery, Northwestern University, USA)

Board of Directors: Jong Woo Choi MD (South Korea), Gaby Doumit MD (Canada) , Tomohisa Nagasao MD (Japan) , Howard Levinson MD (USA) , John VanAalst MD (USA)

Founder: Toyomi Fujino MD.FACS

Date: September 30 (Sun) , 2018

Place: McCormick Place West W 180, Chicago , Illinois, USA

Inaugural Congress of the International Society for Simulation Surgery
Data : December 9-11, 1992 / Venue : Tokyo, Japan / President : Toyomi Fujino

2nd Congress of International Society for Computer Aided Surgery (CAS'95)
Data : June 21-24, 1993 / Venue : Berlin, Germany / President : Jeffrey L Marsh and Toyomi Fujino

3rd Congress of International Society for Computer Aided Surgery (CAS'96)
Data : June 26-29, 1996 / Venue : Paris, France / President : J Th Lambrech

4th Congress of the International Society for Simulation Surgery
Data : November 6, 2004 / Venue : Tokyo, Japan / President : Yu Maruyama

5th Congress of the International Society for Simulation Surgery
Data : October 15-18, 2006 / Venue : Chiang Mai, Thailand / President : Charan Mahatumurat

6th Congress of the International Society for Simulation Surgery
Data : October 27-29, 2008 / Venue : Taipei, Taiwan / President : Lun-Jou Lo

7th Congress of the International Society for Simulation Surgery
Data : January 12, 2010 / Venue : Waikiki, Hawaii, USA / President : F Donald Parsa

8th Congress of the International Society for Simulation Surgery
Data : June 14-15, 2012 / Venue : Seoul, South Korea / President : Yong-Oock Kim

9th Congress of the International Society for Simulation Surgery
Data : December 3, 2016 / Venue : Nara Centennial Hall, Nara city, Japan / President : Keisuke Imai

Welcome message of WSSS President Elect

Dear Colleagues and Friends,

It is a great honor for us to host the 10th congress of the Society for Simulation Surgery. There are several exciting developments for our organization. First and foremost, we have renamed the society from the International Society for Simulation Surgery (ISSiS) to the World Society for Simulation Surgery (WSSS). We feel this will help us to serve our mission to advance simulation surgery without being sidetracked by the implications of our previous initials. The next exciting development is that the congress will be held outside of Asia for the first time in its history, as we will join the 88th Annual Meeting of the American Society of Plastic Surgeons/Plastic Surgery Foundation (ASPS/PSF). The meeting is to be held in Chicago, Illinois from Sept. 29 through October 1. The WSSS meetings will be held on Sep. 30. When registering for the ASPS, please indicate that you are a WSSS member so that we may track the registration process. You will find that the ASPS meeting offers a plethora of educational offerings that will excite and inspire all WSSS members. Participants are welcome to join the instructional courses of the ASPS at no extra charge. You will also find a host of activities to welcome international guests to the ASPS, including an International Reception to be held in the Museum of Science and Industry, hosted by the Plastic Surgery Foundation (PSF). We would encourage all of you to consider joining the ASPS as International members so that you may enjoy their many educational offerings and member benefits on an ongoing basis. The benefits of membership are outlined in the Membership section of the ASPS website:
https://www.plasticsurgery.org/for-medical-professionals/join-asps

The WSSS congress provides a forum in which international leading experts from all over the Asian Pacific region and the world can present and discuss the latest topics regarding simulation surgery, giving a great opportunity for them to share their knowledge and experience. The scientific arena of this congress is of fundamental importance to foster innovation in simulation surgery and move these concepts from the planning and design phase to implementation in clinical practice. By holding this event in conjunction with the annual meeting of the American Society of Plastic Surgeons, we feel it will further stimulate a mutual exchange of ideas well beyond the Asian Pacific region.

Not only is Chicago one of the most popular attractions for tourism in the United States, it is also one of the best-recognized locations for hosting professional conferences. Venues for the meeting will include Navy Pier, the Museum of Science and Industry, with host hotels located on or near Chicago’s famous Miracle Mile. The commute from Chicago O’Hare International Airport to the hotels in downtown Chicago is a 30 minute cab ride, but could take longer depending on the traffic conditions. There are also trains that travel directly from the O’Hare airport to downtown (CTA Blue Line) if one wishes to avoid heavy traffic conditions.

We encourage colleagues from all over the Asian Pacific region and the world to attend and make this an unforgettable important and enjoyable meeting. We look forward to gathering with you to enjoy a pleasant autumn in the beautiful city of Chicago, located on the shore of Lake Michigan.

With Regards,

Arun K. Gosain MD, President-Elect

Akira Yamada MD, Secretary

World Society for Simulation Surgery

Program Overview

8:00 AM **WSSS Welcome & Introductions**

8:15 AM **"Recent Advances in Simulation Surgery: Current and Future Applications." - Howard Levinson, MD, John Van Aalst, MD, Sue Jordan, MD, Jong-Woo (JW) Choi, MD, Derek Steinbacher MD**

This Panel will feature current pioneers in surgical simulation and explore all aspects of the field to include bioprinting, virtual surgical planning for craniofacial surgery, and the use of surgical simulation in training surgeons

9:45 AM **Break**

10:00 AM **Keynote Lecture: "Prediction of Body Shape with Biomechanical Techniques" - Tomohisa Nagasao, MD**

Dr. Nagasao comes from Japan, and is an expert in the field of surgical simulation.

11:00 AM **WSSS Panel 2 - "Pioneering Craniofacial Surgery and the Role of Simulation Surgery" - Arun Gosain, MD, Kenneth E. Salyer, MD, Joseph McCarthy, MD**

This is a special feature of the meeting in which two giants of craniofacial surgery, Drs. Salyer and McCarthy, will present the evolution of surgical simulation through their personal cases. The panel will end with a discussion of how they anticipate such cases will be handled in the future given the increasing application of surgical simulation.

12:00 PM **WSSS Business Meeting**

4:00 PM **Free Paper Session 1**

This session will feature scientific papers on surgical simulation. Each paper will be presented by the author and be followed by two minutes of discussion. The first session will be co-moderated by John VanAalst, MD & Akira Yamada, MD.

5:10 PM **Free Paper Session 2**

This session will feature scientific papers on surgical simulation. Each paper will be presented by the author and be followed by two minutes of discussion. The second session will be co-moderated by Howard Levinson, MD & Akira Yamada, MD.

6:13 PM **Closing Comments**

WSSS Chicago Program : 9/30/2018 (McCormick Place West W 180)

8:00 – 9:45am:	**WSSS Panel 1 | "Recent Advances in Simulation Surgery: Current and Future Applications."** *Moderator: Howard Levinson, MD | Panelists: John Van Aalst, MD, Sue Jordan, MD, Jong-Woo (JW) Choi, MD, Derek Steinbacher, DMD, MD*
9:45 – 10:00am:	Break
10:00 – 11:00am:	**Keynote Lecture | "Prediction of Body Shape with Biomechanical Techniques"** *Tomohisa Nagasao, MD*
11:00am – 12:00pm:	**WSSS Panel 2 | "Pioneering Craniofacial Surgery and the Role of Simulation Surgery"** *Moderator: Arun Gosain, MD | Panelists: Kenneth E. Salyer, MD, Joseph G. McCarthy, MD*
12:00 – 1:30pm:	**WSSS Business Meeting (Invitation Only)** Lunch Break (Exhibit Hall)
1:30 – 3:00pm:	**PSF President's Panel | "The Role of Plastic Surgeons in the Delivery of Global Health Care: Assessing the needs and finding the optimal model to meet these needs."** *Moderator: Arun Gosain, MD | Panelists: Christopher (Alex) Campbell, MD, James Chang, MD, Scott Corlew, MD, Goran Jovic, MD*
3:00 – 4:00pm:	Afternoon Break/Exhibits

4:00 – 5:10 pm: **Free Paper Session 1: 4:00 – 5:10 pm | Co-Moderators: John VanAalst, MD & Akira Yamada, MD**

4:00PM-4:07 PM Development and evaluation of high fidelity surgical simulators | Dale Podolsky,MD

4:07 PM-4:14 PM Photoacoustic Imaging for the Planning of Lymphaticovenular Anastomosis: A Case Report | Anna Oh, MD

4:14 PM-4:21PM Development of a novel template for the planning and facilitation of fronto-orbital remodeling | Eisuke Watanabe, MD

4:21 PM-4:28 PM Airway volume Simulation in Virtual Surgical Mandibular Distraction: A Cohort Study | Laura Humphries, MD

4:28 PM-4:35 PM Touch Surgery: A 21st century platform for surgical training | Ari Mandler, MD

4:35 PM- 4:42 PM Analysis of cranial morphology of Japanese healthy infants using homologous modeling | Makoto Hikosaka, MD

4:42 PM- 4:49 PM Microsoft Kinect V2 as an alternative grading system for facial paralysis | Yohei Sotsuka, MD

4:49 PM- 4:56 PM The use of Computer-Aided Design and Manufacturing in Acute Mandibular Trauma Reconstruction | Thomas Xu

4:56 PM- 5:03 PM Conformity of the Actual to Planning Result in Orthognathic Surgery | Kyle Gabrick, MD

5:03 PM- 5:10 PM Virtual Surgical Planning in Craniofacial Reconstruction: an Evidence-based Update and Workflow Analysis | Kristopher Day MD

Session 2: 5:10 – 6:20pm | Co-Moderators: Sue Jordan MD & Akira Yamada, MD

5:10 PM- 5:17 PM Virtual Surgical Planning for Correction of Delayed Presentation Scaphocephaly Using a Modified Melbourne Technique | Thomas Xu

5:17 PM- 5:24 PM A New Colored Solid Model for Simulation Surgery: It is made of salt | Yoshiaki Sakamoto MD

5:24 PM-5:31 PM Is the sphenosquamosal suture related to the cranial deformity in Plagiocephaly? | Masashi Takemaru MD

5:31 PM-5:38 PM Teaching Breast Aesthetics Using A Sculpture-Based Simulation Workshop | Lauren Nigro, MD

5:38 PM-5:45 PM Application of Finite Element Analysis to Predict Skin | Sergey Turin, MD

5:45 PM-5:52 PM Virtual Reality and Augmented Reality Technology in Neurosurger Tomohisa Miyagi, MD

5:52 PM- 5:59 PM Increasing Opportunities for Active Experimentation in Residency Using Simulation: A revised cleft lip education curriculum | Francesca Saldanha, MD

5:59 PM-6:09 PM Reconstruction of a Hemirhinectomy Defect Using a 3D Printed Custom Soft Tissue Cutting Guide | Jonathan Brower, MD

6:09 PM-6:16 PM Advanced Microsurgical Trainer for Breast Reconstruction | Morgan Yacoe, MD

WSSS Panel 1 Abstract

WSSS Panel 1 | "Recent Advances in Simulation Surgery: Current and Future Applications."
Moderator: Howard Levinson, MD | Panelists: John Van Aalst, MD, Sue Jordan, MD, Jong-Woo (JW) Choi, MD, Derek Steinbacher, DMD, MD

Title: Finite Element Modeling to Guide Stem Cell-Scaffold Craniofacial Constructs

John Van Aalst, MD
Professor, University of Cincinnati Department of Surgery
Director, Division of Plastic Surgery
Surgical Director, Craniofacial Center

We have created a juvenile swine alveolar cleft model and treated the defect with several scaffold types, including both nanoscaffolds and 3D printed polycaprolactone scaffolds. Embedded within these scaffolds are primed mesenchymal stem cells. The goal of this work is to determine best practice for bone formation within the cleft defect. In order to better understand the forces exerted on the stem cell-scaffold constructs, we have additionally developed finite element models to study the sets of scaffold characteristics that lead to best bone formation. This talk will focus on the capacity of FEM to create simulations that improve our ability to treat craniofacial defects with stem cell-scaffold constructs.

WSSS Panel 1 Abstract

WSSS Panel 1 | "Recent Advances in Simulation Surgery: Current and Future Applications."
Moderator: Howard Levinson, MD | Panelists: John Van Aalst, MD, Sue Jordan, MD, Jong-Woo (JW) Choi, MD, Derek Steinbacher DMD, MD

Title: The next generation of 3D printed implants

Sumanas W. Jordan, MD, PhD
Assistant Professor of Surgery
Northwestern University Feinberg School of Medicine

Plastic surgeons have developed significant expertise in virtual 3D planning and have long used stereolithography to develop surgical models and guides. As 3D imaging and additive manufacturing have advanced side-by-side, customized patient-specific implants are making an impact on craniofacial reconstruction with increasing accessibility and popularity. This talk will look to the next generation of 3D printed implants, beyond inert metals and polymers, to bioactive materials with complex 3D structures. Hyperelastic bone, decellularized tissue inks, and electroconductive material inks will be introduced. The potential for future point-of-care 3D printing will be briefly discussed.

WSSS Panel 1 | "Recent Advances in Simulation Surgery: Current and Future Applications."
Moderator: Howard Levinson, MD | Panelists: John Van Aalst, MD, Sue Jordan, MD, Jong-Woo (JW) Choi, MD, Derek Steinbacher, DMD, MD

Title: Clinical applications of 3D computer simulation & 3D printing technology in Craniofacial surgery

Jong-Woo Choi, MD, PhD, MMM
Professor, Department of Plastic surgery, Asan Medical Center, Seoul, South Korea

Recent advances in 3D computer simulation allows the surgeons to simulate the surgery preoperatively. In addition, as the brand new 3D printing technology becomes popular, the clinical applications onto the various aspects became a reality.

Craniofacial surgery would be the one of the best special areas for these new technologies because it mostly deals with the skeletal tissues which would be good candidate for simulation based on CT dicom data.

Moreover, the recent advances in 3D photogrammetry enable the craniofacial surgeons not only to evaluate the surgical outcomes but also to simulate the soft tissue changes as well as the hard tissue.

This presentation will discuss my clinical applications in terms of the craniofacial surgery such as orthognathic surgery, craniosynostosis and rhinoplasty.

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Title: 3D Applications in Orthognathic and Craniomaxilofacial Surgery. (D. Steinbacher, DMD, MD, FACS)

Derek M. Steinbacher DMD, MD, FACS
Yale University School of Medicine
Associate Professor Plastic Surgery, Cranio-maxillofacial Surgery

PURPOSE: Three-dimensional (3D) analysis and planning are powerful tools in craniofacial, orthognathic, and reconstructive surgery.
The elements include 1) analysis, 2) planning, 3) virtual surgery, 4) 3D printouts of guides or implants, and 5) verification of actual to planned results. The purpose of this presentation is to review applications of 3D planning in craniomaxillofacial and orthognathic surgery.

MATERIALS AND METHODS: Case examples involving 3D analysis and planning were reviewed. Work-flow and optimization for orthognathic surgery is highlighted. Future potential is addressed with unique aspects specific to new applications in craniomaxillofacial surgery.

RESULTS: Examples of 3D planning are described, with focus on work-flow, planning pearls, and aesthetic optimization in orthognathic surgery.

CONCLUSIONS: Planning in craniomaxillofacial and orthognathic surgery is useful and has applicability across different procedures and reconstructions. Three-dimensional planning and virtual surgery enhance efficiency, accuracy, creativity, and reproducibility in craniomaxillofacial surgery.

WSSS Key Note Lecture Abstract 10:00 AM – 11:00 AM

Prediction of Body Shape by Biomechanical Calculation

Chair and Professor
Department of Plastic and Aesthetic Surgery
Kagawa National University, Takamatsu, Japan
Tomohisa NAGASAO MD.

Many treatments in plastic surgery aim to transform patients' body shapes. In order to achieve optimal results in such treatments, we need to predict how body shapes transform in response to external forces. A biomechanical technique called "structural analysis" enables the prediction. The basic principles of structural analysis is divided the object into small elements, evaluate the dynamic behavior of each element by dynamic calculation, and accumulate the results with each element to predict the deformity of the whole entity of the object.

By using structural analysis, we clarified the following clinical problems.

(1) Development of prediction system of postoperative shape of the thorax in the treatment of chest deformities
(2) Mechanisms of orbital floor fractures
(3) Appropriate fixation methods of zygoma fracture
(4) Why keloids tend to present so-called "crab-like shapes"
(5) Effective way to perform scar revisions for interrupted scars
(6) How to perform Le Fort 3 Osteotomy safely
(7) How to achieve optimal results if the correction of protruding ears

This presentation introduces the usefulness of structural analysis for the practices in plastic surgery.

WSSS Panel 2: 11:00 AM-12:00 PM

“Pioneering Craniofacial Surgery and the Role of Simulation Surgery”

Moderator: Arun Gosain MD

WSSS President Elect

Panelist:

Kenneth E. Salyer MD

Founder and Chairman
World Craniofacial Foundation, Dallas, Texas, USA

Joseph G. McCarthy MD

Clinical Professor, Hansjorg Wyss Department of Plastic Surgery
Professor Emeritus of Plastic Surgery, Hansjorg Wyss Department of Plastic Surgery, NYU Langone Health, New York, USA

This is a special feature of the meeting in which two giants of craniofacial surgery, Drs. Salyer and McCarthy, will present the evolution of surgical simulation through their personal cases. The panel will end with a discussion of how they anticipate such cases will be handled in the future given the increasing application of surgical simulation.

Free Paper Session 1. 4:00 PM- 5:10 PM(Chairs: VanAalst MD, Yamada MD)

4:00PM-4:07PM

Title: **Development and evaluation of high fidelity surgical simulators**

Dale J Podolsky[1,2], David M Fisher[3], Karen W Wong Riff[3], James M Drake[2,4], Christopher R Forrest[3]

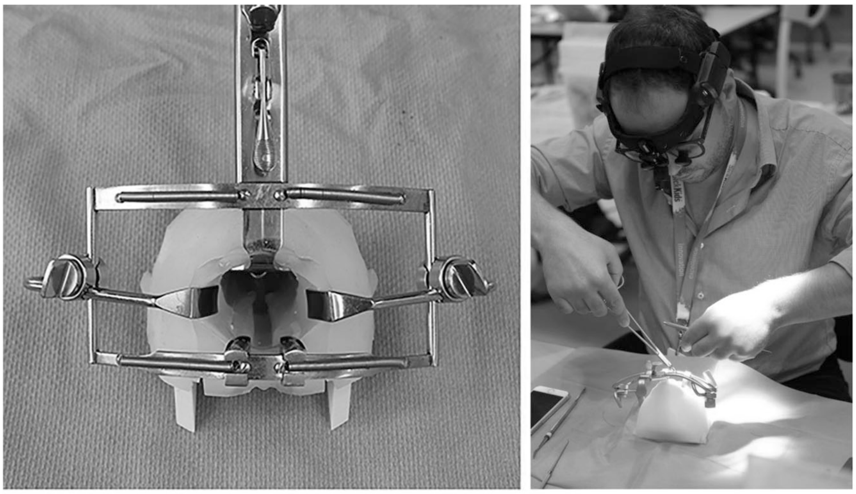
1:Division of Plastic & Reconstructive Surgery, University of Toronto, Toronto, Ontario, Canada 2:Center for Image Guided Innovation and Therapeutic Intervention (CIGITI), Toronto, Ontario, Canada 3:Division of Plastic & Reconstructive Surgery, The Hospital for Sick Children, Toronto, Ontario, Canada 4:Division of Neurosurgery, The Hospital for Sick Children, Toronto, Ontario, Canada

Introduction: Surgical simulators provide a platform to gain experience before operating on real patients.

Methods: Using patient imaging, 3D printing, adhesive, polymer and material techniques a high-fidelity physical cleft palate (Figure 1), cleft lip (Figure 2) and adult rhinoplasty (Figure 3) simulator were developed. The cleft palate simulator was evaluated using electromagnetic sensors to test economy of hand motion, a confidence scale, assessment of realism and perceived value using questionnaires as well as knowledge tests. A newly developed technical assessment scale was used to assess whether performance improves with repeated use. The cleft lip simulator was assessed for realism and perceived value. The rhinoplasty simulator was assessed qualitatively for realism and anatomic accuracy.

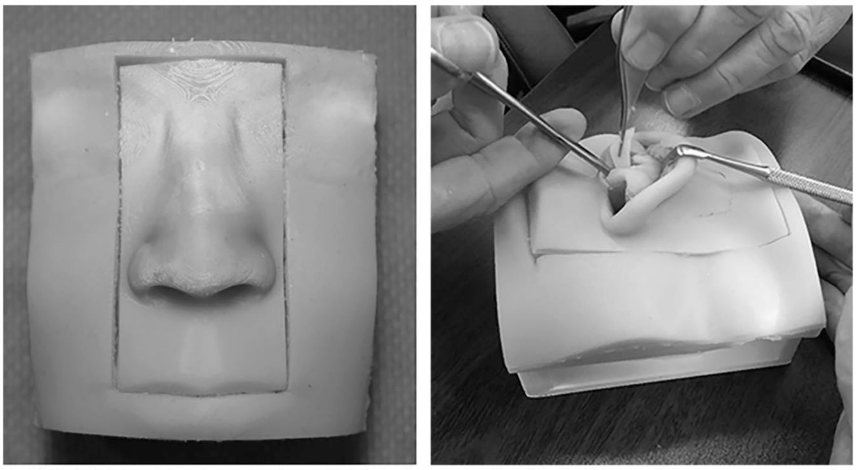
Results: The cleft palate simulator was shown to improve confidence as well as knowledge of cleft palate anatomy and repair procedures. The cleft palate simulator distinguished between skill level using economy of hand motion, the technical assessment scale, confidence scale, and was shown to improve performance through repeated use. The cleft lip simulator was found to be highly realistic and anatomically accurate allowing performance of all steps of a cleft lip repair and primary cleft rhinoplasty procedure. The adult rhinoplasty simulator allowed performance of critical steps of rhinoplasty in a highly realistic and anatomically accurate physical environment.

Conclusions: High-fidelity physical surgical simulators for cleft and rhinoplasty procedures were successfully developed and evaluated. The simulators provide an effective platform to gain hands-on experience of complex procedures prior to operating on real patients.



Left) Perspective view of the cleft palate simulator. Right) Plastic surgery fellow performing a cleft palate repair on the simulator during a comprehensive cleft palate training workshop

Perspective view of the cleft lip simulator removing marginal lip tissue demonstrating the multilayered tissues including muscle, subcutaneous fat as well as dissection planes.



Left) High-fidelity rhinoplasty simulator. Right) Performance of grafting technique demonstrating some of the internal components of the simulator.

4:07PM-4:14PM

Title: **Photoacoustic Imaging for the Planning of Lymphaticovenular Anastomosis: A Case Report**

Anna Oh[1], Hiroki Kajita[2], Eri Matoba[1], Nobuaki Imanishi[3], Yoshifumi Takatsume[3], Hiroyuki Sekiguchi[4], Yasufumi Asao[5], Takayuki Yagi[5], Sadakazu Aiso[3], Kazuo Kishi[2]

[1] Department of Plastic and Reconstructive Surgery, Tachikawa Hospital, Tokyo, Japan
[2]Department of Plastic and Reconstructive Surgery, Keio University School of Medicine, Tokyo, Japan
[3]Department of Anatomy, Keio University School of Medicine, Tokyo, Japan
[4]Department of Diagnostic Imaging and Nuclear Medicine, Kyoto University
[5]Japan Science and Technology Agency, ImPACT Program, Cabinet Office, Japan

Background: Photoacoustic imaging (PAI) technique can visualize the distribution of light absorbing molecules, such as hemoglobin or indocyanine green (ICG), with high spatial resolution. After ICG administration, PAI can provide the three-dimensional images of superficial lymphatic vessels as well as venules. Recently, we planned lymphaticovenular anastomosis (LVA) surgery based on PAI, and achieved good outcome.
Methods: The patient is a woman in her 60s with the surgical history of cervical cancer and had left lower extremity lymphedema over 10 years. With ICG fluorescence lymphography, a linear pattern below the knee and diffuse-pattern dermal backflow was observed in the affected limb. Before the surgery, PAI lymphangiography was performed using the PAI-05 system, made by Canon Inc. (Japan), Hitachi, Ltd. (Japan), and Japan Probe Co, Ltd.(Japan). With the PAI images (Fig.1), we determined an incision site where lymphatic vessels were adjacent to venules just below the knee.
Results: During the surgery, we found the lymphatic vessels and venules at the place shown by PAI (Fig.2). After the surgery, the circumferences were reduced at the all sites proximal to the anastomosis site.
Conclusion: PAI showed the actual anatomical course of each lymphatic vessel and venule, which was useful in finding them during the surgery. Next, we are planning a clinical trial of the PAI-based LVA surgery to compare the duration of the surgery, number of anastomoses, and the clinical outcomes.
Acknowledgement: This work was funded by ImPACT Program of the Council for Science, Technology, and Innovation (Cabinet Office, Government of Japan).

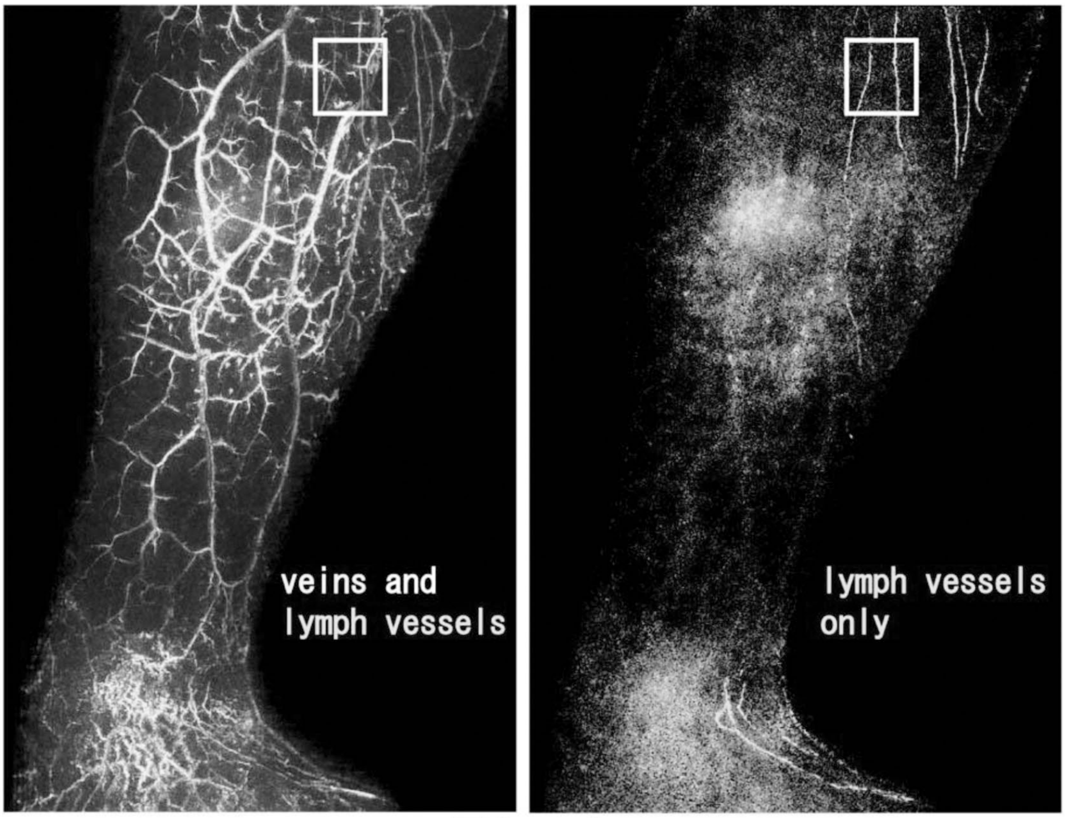

veins and
lymph vessels
lymph vessels
only

Fig. 1

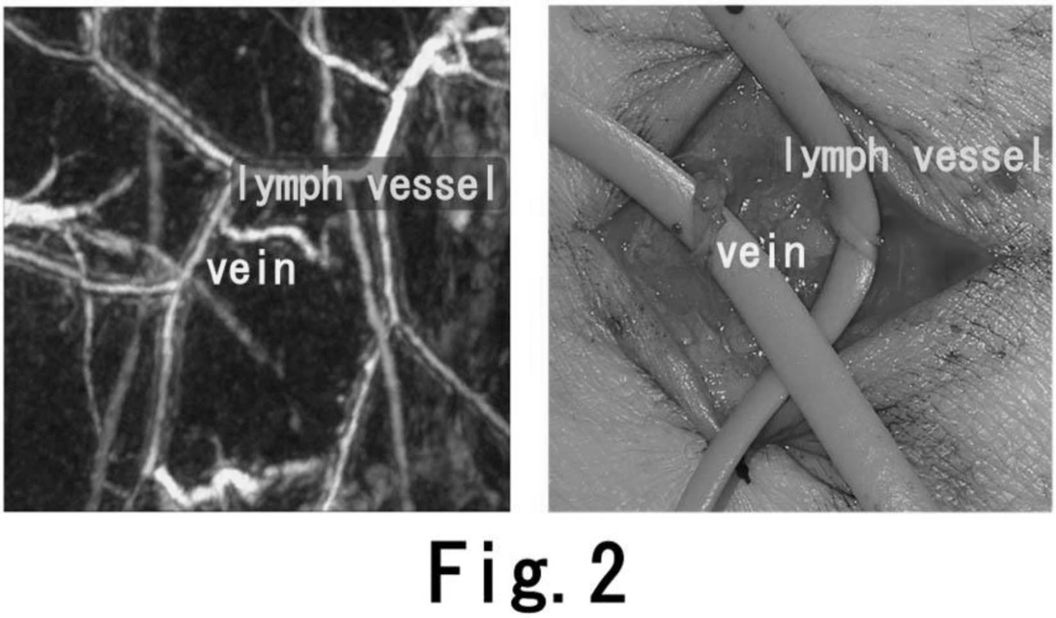

lymph vessel
vein
lymph vessel
vein

Fig. 2

4:14 PM-4:21PM

Title: **Development of a novel template for the planning and facilitation of fronts-orbital remodeling**

Eisuke Watanabe MD[1], Keisuke Imai MD[1], Koji Kawamoto MD[1], Daisuke Sakahara MD[1], and Hiroshi Nishikawa MD[2]

1 Department of Plastic and Reconstructive Surgery, Osaka City General Hospital, Osaka, Japan

2 Department of Plastic Surgery, Birmingham Children's Hospital NHS Foundation Trust, Birmingham, United Kingdom

In recent years, the use of preoperative templates employing three-dimensional [3-D] preoperative planning software has been reported in cranial remodeling for patients with craniosynostosis. We have created 3-D solid templates for operative simulation to facilitate fronto-orbital remodeling. A 3-D template of the fronto orbital bar would be expected to enhance the accuracy, shorten the duration of surgery, and improve the outcome of fronto-orbital remodeling. Therefore, we have constructed preoperative templates using a combination of 3-D planning software for craniofacial surgery (ProPlan CMF, Materialise, Leuven, Belgium). A 3-D printer was used to verify the accuracy of the predictive template with the postoperative models of the actual clinical fronto-orbital remodeling carried out

Subjects and methods

The study subjects were patients with trigonocephaly (n = 5) and unicoronal plagiocephaly (n = 1.). These cases met the following criteria; Firstly fronto-orbital remodeling had been completed. Secondly post-operative computed tomography (CT) data that could be used to

create postoperative 3-D material models was also available. Thirdly, preoperative data that could be used to construct a predictive model was available. With this data a comparison between the predictive model and the actual clinical postoperative model could be made. We used the ProPlan˙ software to construct the template preoperatively. The templates were created from normative data of the crania that we generally encounter intraoperatively (Eur. J. Plast. Surg.14: 80, 1991). Subsequently, we created 3-D solid models based on the preoperative simulation data and compared them to postoperative CT data of the actual fronto-orbital bars constructed during surgery

Results

In all six cases, the shapes of the fronto-orbital remodeling created operatively correlated well with the predictive solid models. The 3-D material models created based on the data from the software closely corresponded to those based on the actual postoperative CT data. We believe that the templates created in this study could be applicable and useful for reshaping of the fronto-supra-orbital bar clinically.

Conclusion

This study demonstrated the validity of template models constructed from appropriate software. We have concluded that the combination of 3-D planning software for craniofacial surgery with a 3-D material template to be a potentially useful clinical application.

4:21 PM-4:28PM

Title: **Airway volume Simulation in Virtual Surgical Mandibular Distraction: A Cohort Study**

Laura S. Humphries, MD[1] Essie K. Yates, MD[5]
Julie M. Mhlaba, MD[4] John M. Collins, MD, PhD[2] Fuad M. Baroody, MD[3] Russell R. Reid MD, PhD[1]

[1] Department of Surgery, Section of Plastic Surgery, University of Chicago Medical Center
[2] Department of Radiology, University of Chicago Medical Center
[3] Department of Surgery, Section of Otolaryngology-Head and Neck Surgery, University of Chicago Medical Center

[4] University of Chicago Pritzker School of Medicine
[5] Atlantic Center of Aesthetic and Reconstructive Surgery

Background: We investigated the accuracy of virtual surgical planning (VSP) in predicting airway volume (AV) changes after mandibular distraction in patients with Pierre Robin Sequence (PRS) and associated tongue-based airway obstruction (TBAO).

Methods: We completed a retrospective review of patients for whom VSP was used during MDO for treatment of TBAO at a single institution. Pre-operative AV, VSP-predicted AV, and post-operative AV were calculated from 3-D CT scans using industry software. A blinded institutional radiologist also calculated pre- and post-operative AVs using one of two software programs. Pre- and post-operative polysomnography (PSG) was used to titrate end-point of mandibular lengthening.

Results: Data were available for 11 patients, who were included in the study. Mean apnea-hypopnea index (AHI) (5.42 ± 4.53 vs 44.96 ± 20.57, $p<0.001$) and mean nadir oxygen saturation (70.3% ± 9.72 vs 82.9% ± 9.62, $p=0.003$) improved with mandibular distraction. There was moderate correlation between VSP-predicted and actual mandibular distraction lengths ($R^2=0.65$, $p=0.003$). There was a strong correlation between VSP-predicted and industry-calculated actual post-MDO AV ($R^2=0.99$, $p<0.001$). There was no significant correlation between actual mandibular distraction length and industry-calculated actual post-MDO airway volume for the entire cohort ($R^2=0.05$, $p=0.49$), but correlation approached significance by institutional calculations. No significant correlation existed between industry and institutional-calculated percent change in post-MDO AV ($R^2=0.06$, $p=0.57$).

Conclusions: Predictive airway volume calculation may be an effective adjunct to determine anatomic end-point of mandibular distraction but small sample size, operator and software variability, and patient airway morphology may confound firm conclusions. Further studies are warranted

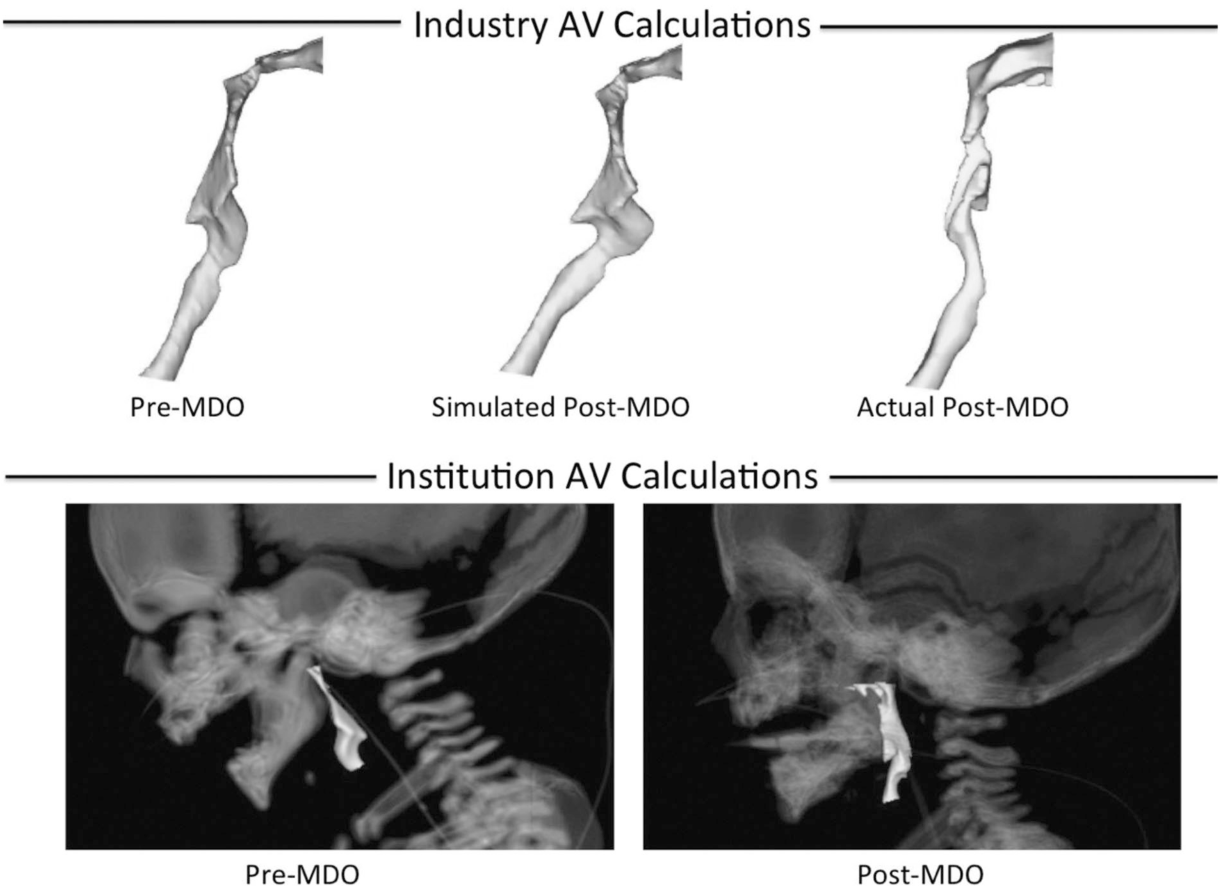


Figure. Patient 4 Clinical Outcomes and Airway Volume Calculation. Patient 4 was a full-term African-American male with Pierre Robin Sequence who underwent MDO at age 3.8 weeks, weight 4.225kg. He was born with a Veau Type 2 cleft palate. The patient demonstrated obstructive sleep apnea on PSG, with an AHI of 43.8. Flexible laryngoscopy revealed base of tongue prolapse into the pharynx, resulting in retroflexed epiglottis. He underwent placement of a 30mm radius internal curvilinear distractor. Post-operative AHI was 3.6, reflecting a 91.78% reduction in AHI. The patient's course was complicated by superficial infection of the left cheek requiring incision and drainage and wound VAC placement at about 2 weeks into the consolidation phase. Industry-calculated airway volumes (top): Pre-MDO 1199 mm^3; Simulated Post-MDO 1303 mm^3 with planned mandibular distraction of 10.47mm on the right and 9.69mm on the left; Actual Post-MDO 1303 mm^3. Institutional-calculated airway volumes (bottom), with actual mandibular distraction of 11.5mm; Pre-MDO 488.13 mm^3 and Post-MDO 722.29 mm^3. In this case, pre- and post-operative AV increased with mandibular distraction with both industry and institutional calculations.

4:28 PM-4:35 PM

Title: Touch Surgery: **A 21st century platform for surgical training**

Ari G. Mandler MD

The George Washington School of Medicine and Health Science

TouchSurgery is a novel online platform (iOS, Google Play) that is geared towards innovating professional training for surgical procedures. In other industries, such as aviation, simulation has already been shown to reduce costs and improve outcomes in
crisis. Studies involving simulation-based learning in healthcare similarly indicate the potential for reducing errors through skill acquisition and cognitive retention. Cohort studies have shown improved performance among simulator-trained medical students in comparison to those with traditional ward training. With this front in mind, TouchSurgery is paving its way for implementation within the surgical realm. Operations can be completed in one of two settings: learn or test. The learning feature provides step wise instruction, prompting the user to complete tasks like debridement and incising with the drag of a finger. The test feature, on the other hand, allows one to complete operations without guided instructions. Currently, the simulations within the application are numerous and cover over 14 different specialties, providing use for more than 100 residency programs across the United States. Given the revolutionary shift to simulation-based learning, platforms like TouchSurgery will need to meet the demands of surgical training in the 21st century.

4:35 PM- 4:42 PM

Title: **Analysis of Cranial morphology of Japanese Healthy infants using homologous modeling**

Makoto Hikosaka MD 1, Tsuyoshi Kaneko MD 1, Kosuke Kuwahara MD1, Ako Takamatsu MD1, Yuki Miyanori MD 1, Osamu Miyazaki MD2, Shunsuke Nosaka MD 2, and Rei Ogawa MD 3

1: Department of Plastic and Reconstructive Surgery, National Center for Child Health and Development

2: Department of Radiology, National Center for Child Health and Development

3: Department of Plastic and Reconstructive Surgery, Nippon Medical School

Objective: There are many reports analyzing the cranial morphology of healthy children in the past. But most of them are limited to two-dimensional analysis, and there are only a few reports which focused on Japanese healthy infants. We report a novel method that enables comprehensive analysis of cranial morphology in 3D using homologous modeling, and our achievements so far.
Methods: Craniofacial CT data of 20 healthy infants (9 males, 11 females) ranging in age from 1 to 11 months were collected. We created 20 homologous models of cranium using software specifically designed to support homologous modeling. We averaged vertex coordinates of the homologous models to create an average model. We further performed principal component analysis to elucidate the elements that characterize the morphological variety of the cranium, and created virtual models based on each principal component. The contribution rate was calculated, and the features described by each principal component were interpreted.
Results: We created the average cranial model of 20 Japanese healthy infants. Seven principal components (cumulative contribution rate: 89.218%) were interpreted as to which part of the cranial shape each component was related to. The elements were extracted that may characterize the cranial morphology of some of the clinical conditions such as dolico/brachycephaly and deformational plagiocephaly. Some of these elements have not been mentioned in the past literature.
Conclusion: Homologous modeling was considered to be a valid and strong tool for comprehensive analysis of cranial morphology. We are currently working on the project to increase the number of cases.

4:42 PM- 4:49 PM

Title: Microsoft Kinect V2 as an alternative grading system for facial paralysis

Yohei Sotsuka MD, Kenichiro Kawai MD, Hisako Ishise MD, Soh Nishimoto MD, and Masao Kakibuchi MD

Hyogo College of Medicine Department of Plastic Surgery

Introduction and Objective

Grading system for evaluating facial movements in facial paralysis can be classified into traditional and computer-based grading systems. Computer-grading system provided quantitative repeatable results, they required significant time for manually using software and required high cost which limited their widespread clinical use. Recently, three-dimensional depth cameras in commercial gaming systems have been common, and reduced their cost. A few studies have used depth sensors for face detection. One of the three-dimensional depth cameras in commercial gaming systems is Microsoft Kinect V2 sensor. We present the results of using Microsoft Kinect V2 sensor for grading facial paralysis.

Methods

The facial grading system software was implemented using Kinect for Windows SDK 2.0, and was written by the author in Visual C#. The software can display the 17 animation units automatically in real time once the face has been tracked. First, facial emotions of two healthy subjects were captured by Kinect V2 and were graded by the software described. Second, facial emotions of one facial paralysis patient were captured by Kinect V2 and were graded by the soft ware before and after the botulinum toxin injections for treatment of synkinesis.

Results

Facial emotions of two healthy subjects were able to grade by Kinect V2. For facial paralysis patient with synkinesis, after botulinum toxin injections, the synkinesis eye closure movements improved both clinically and also in our facial grading system software.

Conclusion

Microdoft Kinect V2 can be an alternating grading system for facial paralysis.

4:49 PM- 4:56 PM

Title: The Use if Computer-Aided Design and Manufacturing in Acute Mandibular Trauma Reconstruction

George Kokosis MD, Edward H. Davisdon MA(Cantab), MBBS 2, Rachel Pedreira BS 3, Alexandra Macmillan MA(Cantab) MBBS 3, Amir H. Dorafshar MBChB 4

1. Department of Plastic and Reconstructive Surgery, Johns Hospkins Hospital, Baltimore
2. Division of Plastic and Reconstructive Surgery, Albert Einstein College of Medicine, Montefiore Medical Center, Bronx, NY
3. Johns Hospkins School of Medicine, Baltimore
4. Division of Plastic and Reconstructive Surgery, Rush University Medical Center, Chicago, IL

Purpose: Virtual surgical planning (VSP) with subsequent computer- aided design and manufacturing have proved efficacious in improving the efficiency and outcomes of a plethora of surgical modalities, including mandibular reconstruction and orthognathic surgery.

Patients and Methods: Five patients underwent complex mandibular reconstruction after traumatic injury using VSP from July 2016 to August 2017 at our institution. The Johns Hopkins University Hospital institutional review board approved the present study. The patient's occlusion was restored virtually, and a milled 2.0-mm plate was created that would bridge the defect with the patient in occlusion.

Results: Appropriate occlusion was confirmed using postoperative computed tomography. No patient developed any adverse outcomes, except for a minor dehiscence of the intraoral incision in 1 patient that was treated with local wound care. The average interval from the injury to custom plate availability was approximately 7 days.

Conclusions: The utility of this technology in acute complex mandibular trauma can overcome the challenges of traditional treatment. Custom patient-specific prebent and milled plates permit the use of a lower profile and therefore less palpable hardware, can guide reduction, avoid the need for plate bending, and obviate the need for an extraoral incision.

FIGURE 1. *A,* Clinical and intraoperative photographs of a 34-year-old man who suffered a blast injury that resulted in an open right comminuted hemimandibular fracture with significant soft tissue loss. *B,* Virtual surgical planning used to analyze the nature of the fracture to be reduced. **(Fig 1 continued on next page.)**

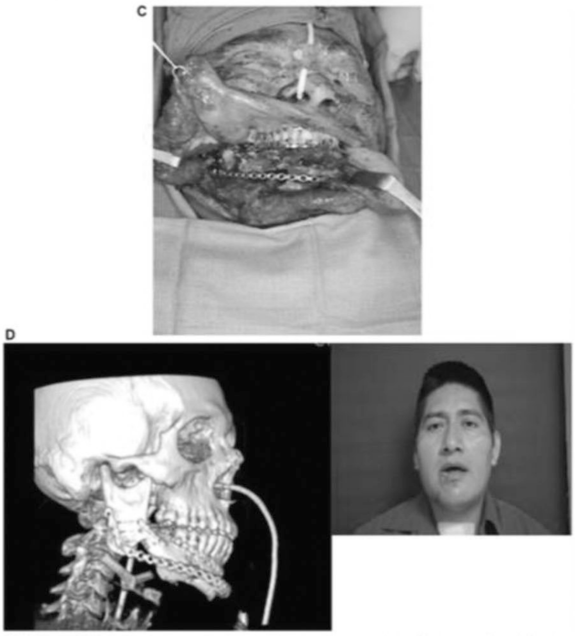


FIGURE 1 (cont'd). *C,* Intraoperative photograph showing the milled plate used to restore occlusion. *D,* Postoperative CT scan *(Left)* and clinical photography *(Right)* confirmed the occlusion.

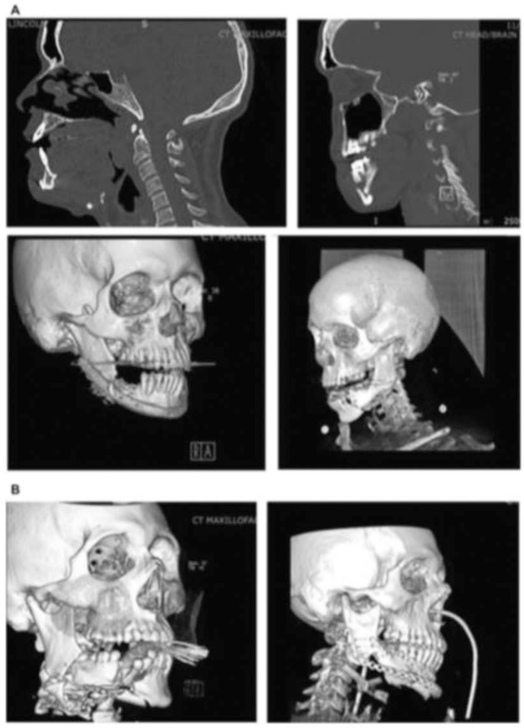


FIGURE 2. *A,* Preoperative *(Upper left)* and postoperative *(Upper right)* computed tomography (CT) and preoperative *(Lower left)* and postoperative *(Lower right)* 3-dimensional (3D) scans of patient 1, confirming postoperative occlusion. *B,* Preoperative *(Left)* and postoperative *(Right)* 3D scans of patient 2. **(Fig 2 continued on next page.)**

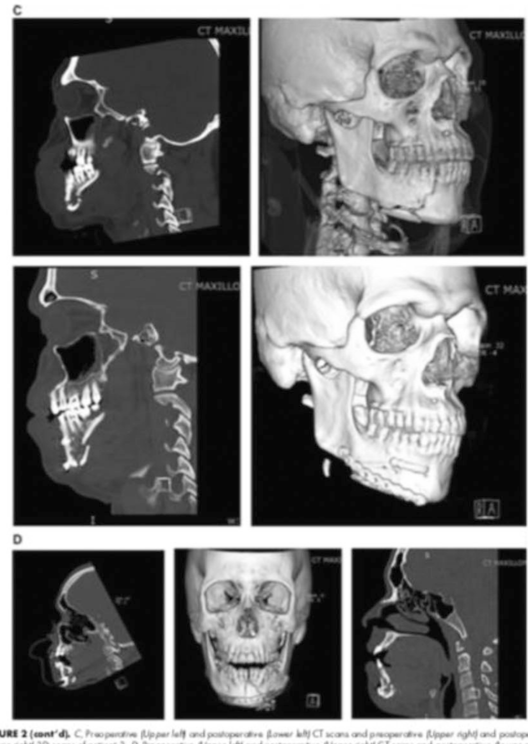


FIGURE 2 (cont'd). *C,* Preoperative *(Upper left)* and postoperative *(Lower left)* CT scans and preoperative *(Upper right)* and postoperative *(Lower right)* 3D scans of patient 3. *D,* Preoperative *(Upper left)* and postoperative *(Upper right)* CT scans and postoperative *(Lower middle)* 3D scan of patient 4. **(Fig 2 continued on next page.)**

4:56 PM- 5:03 PM

Title: Conformity of the Actual to Planned Result in Orthognathic Surgery

Kyle Gabrick MD (1); Alexander Wilson BS (1); Rajendra Sawh-Martinez MD (1) Derek Steinbacher MD, DMD (1)

(1) Yale School of Medicine Section of Plastic and Reconstructive Surgery

Abstract

Purpose: Virtual surgical planning (VSP) has facilitated pre-operative planning, splint accuracy, and intra-operative efficiency in orthognathic surgery. The translation of the VSP to the actual result has not been adequately examined. Our chief aim was to examine the conformity of VSP to the post-operative result. We hypothesize the greatest conformity exists in the anteroposterior dimensions.

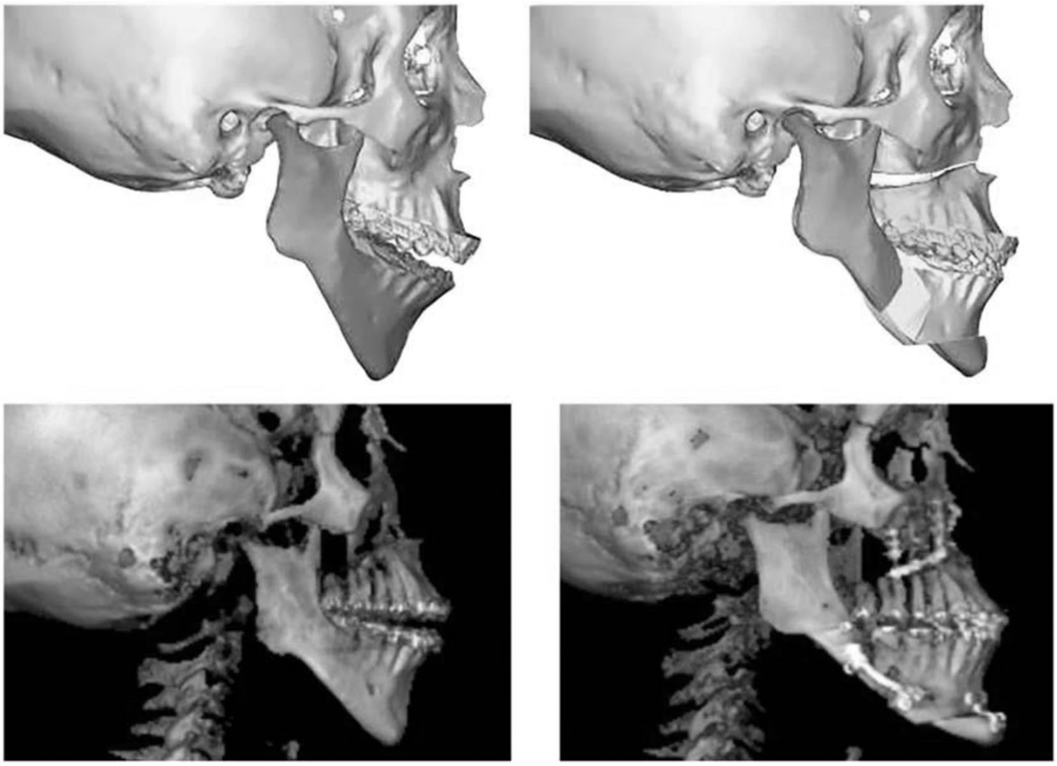
Methods:

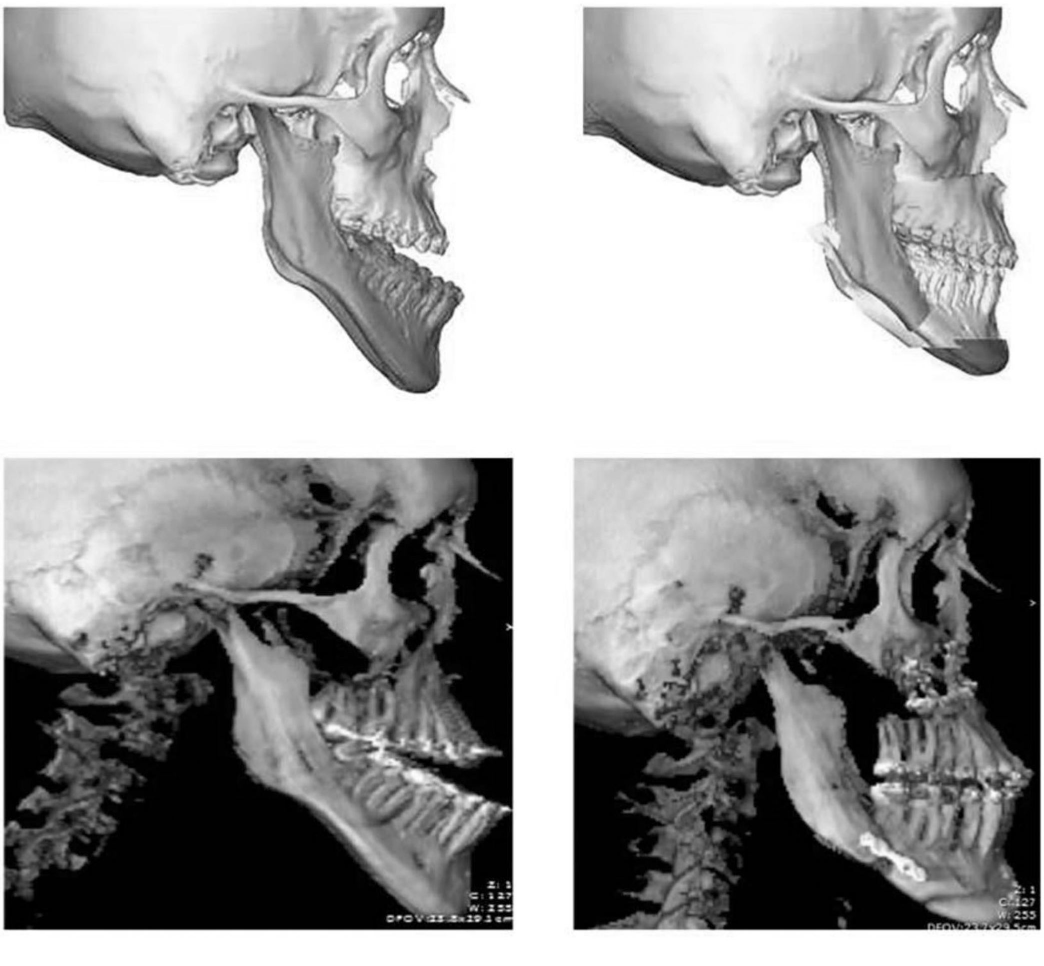
We examined patients who underwent Le Fort I maxillary advancement, bilateral sagittal split osteotomies, and genioplasty. The pre-operative VSP file and post-operative cone beam CT were registered in Mimics utilizing unchanged landmarks. We quantified the conformity to the VSP utilizing linear and angular measurements between bone surface landmarks. Results were compared utilizing t-tests with $p < 0.05$ considered statistically significant

Results: 100 patients who underwent Le Fort I, bilateral sagittal split osteotomies, and genioplasty were included. Three-dimensional analysis showed significant differences between the plan and outcome for the following landmarks: A point (y, p=0.04; z, p=0.04), B point (y, p=0.02; z, p=0.02), Pg (y, p=0.04), Me (x, p=0.02; y, p=0.01; z, p=0.03), and ANS (x, p=0.04; y, p=0.04; z, p=0.01). Angular measurements SNA, SNB, and ANB were not statistically different.

Conclusion:

There is a high degree of conformity comparing orthognathic VSP to the actual post-operative result. However, some incongruency is seen: vertically (maxilla), and sagittally (mandible, chin). Departures of the actual position compared to the plan could be the result of: condylar position changes, osteotomy locations, aesthetic intraoperative decisions, and/or play in the system.





5:03 PM- 5:10 PM

Title: VIRTUAL SURGICAL PLANNING IN CRANIOFACIAL RECONSTRUCTION: AN EVIDENCE-BASED UPDATE AND WORKFLOW ANALYSIS

Day KM,[1] Kelley PK,[1] Dorafshar AH,[2] Combs PD,[1] Casmedes HP,
Henry SL, [1] George TM, [1] Harshbarger RJ[1]

[1] University of Texas Medical Branch-Austin; Dell Seton Medical Center; Seton Medical Center at the University of Texas
[2] Rush University; Rush University Medical Center

Background: The value of Virtual Surgical Planning (VSP) is increasingly cited in craniofacial (CF) surgery articles. Controversy persists regarding the level of evidence for VSP, calling for a quality assessment of existing literature. We summarize the evidence-basis for VSP in CF surgery with cases highlighting established clinical workflow protocols.

Methods: A Medical Subject Headings (MeSH®) keyword search for all MEDLINE® publications on VSP in CF surgery was conducted. Trend lines were tested for best fit to the rate of change in the number of CF VSP publications per year. Articles‘ conclusions were tabulated for common data points. Key steps in the VSP workflow are described and illustrated with case examples.

Results: Clinical workflow analysis is provided based on experience with 564 CF cases employing VSP. Publications on VSP in CF surgery have increased exponentially ($y = 16.84e^{0.12x}$, $R^2 = 0.97$) over the last two decades, totaling 1728 articles. Common sub-topics include: image analysis, surgical planning, surgical simulation, custom guides or implants, and verification of results. Clinical settings include: acute, elective, acquired, and congenital conditions. Authors suggest that VSP may improve results, increase safety, enhance efficiency, augment surgical education, and aid surgeons‘ ability to execute complex CF operations. The majority of VSP publications in CF surgery are level four or five evidence.

Conclusion: While the literature suggests that VSP may improve many aspects of CF surgical care, the level of evidence is low. Higher quality studies are needed to advance beyond proof of concept for VSP in CF surgery.

Figure 1. MEDLINE® Trend of Virtual Surgical Planning Publications Over Time

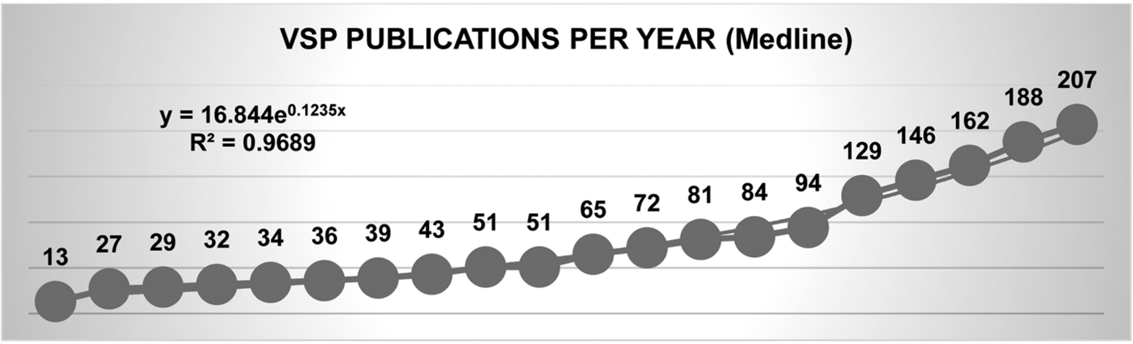
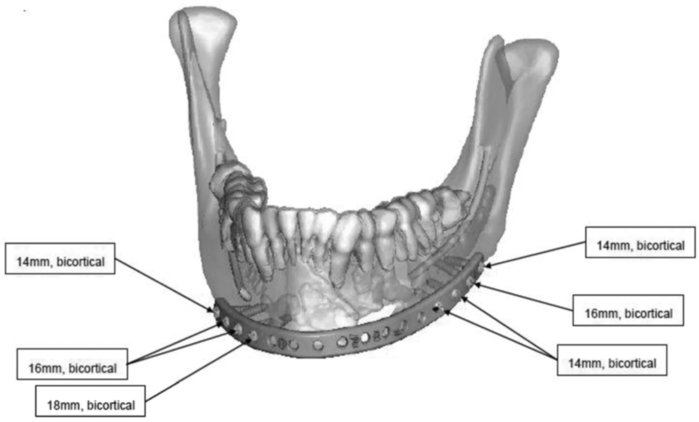


Figure 2. Acute Mandibular Trauma Reconstruction Using Virtual Surgical Planning and Pre-Bent Custom Implant



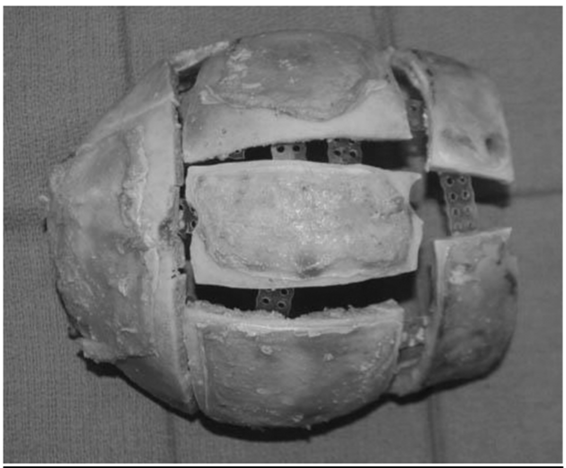


Figure 3. Elective Cranioplasty in Late-Presentation Craniosynostosis Patient Undergoing Cranial Vault Remodeling with Virtual Surgical Planning

Free Paper Session 2 5:10 PM- 6: 13 PM (Chairs: Sue Jordan MD, Yamada MD)

5:10 PM- 5:17 PM

Title: Virtual Surgical Planning for Correction of Delayed Presentation Scaphocephaly Using a Modified Melbourne Technique

George Kokosis MD, Edward H. Davisdon MA(Cantab), MBBS 2, Rachel Pedreira BS 3, Alexandra Macmillan MA(Cantab) MBBS 3, Amir H. Dorafshar MBChB 4

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2. Department of Craniofacial, Plastic and Reconstructive Surgery, Louisiana State University Health Science Center, Children's Hospital of New Orleans, New Orleans, LA
3. Department of Plastic and Reconstructive Surgery, Miami Cancer Center Institute, Baptist Health, Miami, FL
4. Division of Plastic and Reconstructive Surgery, Rush University Medical Center, Chicago, IL

Background: Late treatment of scaphocephaly presents challenges including need for more complex surgery to achieve desired head shape. Virtual surgical planning for total vault reconstruction may mitigate some of these challenges, but has not been studied in this unique and complex clinical setting.

Methods: A retrospective chart review was conducted for patients with scaphocephaly who presented to our institution between 2000 and 2014. Patients presenting aged 12 months or older who underwent virtual surgical planning-assisted cranial vault reconstruction were included. Patient demographic, intraoperative data, and postoperative outcomes were recorded. Pre- and postoperative anthropometric measurements were obtained to document the fronto-occipital (FO) and biparietal (BP) distance and calculate cephalic index (CI). Virtual surgical planning predicted, and actual postoperative anthropometric measurements were compared.

Results: Five patients were identified who fulfilled inclusion criteria. The mean age was 50.6 months. One patient demonstrated signs of elevated intracranial pressure preoperatively. Postoperatively, all but one needed no revisional surgery (Whitaker score of 1). No patient demonstrated postoperative evidence of bony defects, bossing, or suture restenosis. The mean preoperative, simulated, and actual postoperative FO length was 190.3, 182, and 184.3 mm, respectively. The mean preoperative, simulated, and actual postoperative BP length was 129, 130.7, and 131 mm, respectively. The mean preoperative, simulated, and actual postoperative CI was 66, 72, and 71.3, respectively.

Conclusions: Based on our early experience, virtual surgical planning using a modified Melbourne technique for total vault remodeling achieves good results in the management of late presenting scaphocephaly.

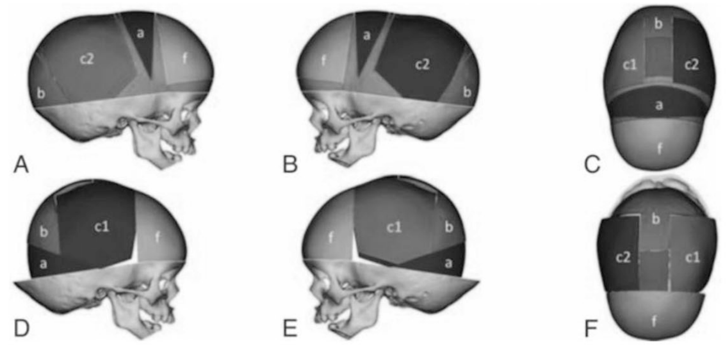

FIGURE 1. Preoperative (A–C) and postoperative (D–F) positioning of segments A, B, C, and F is shown from lateral and superior views. The posterior ridge of the cranial base is burred intraoperatively, although this is not shown on the surgical plan.

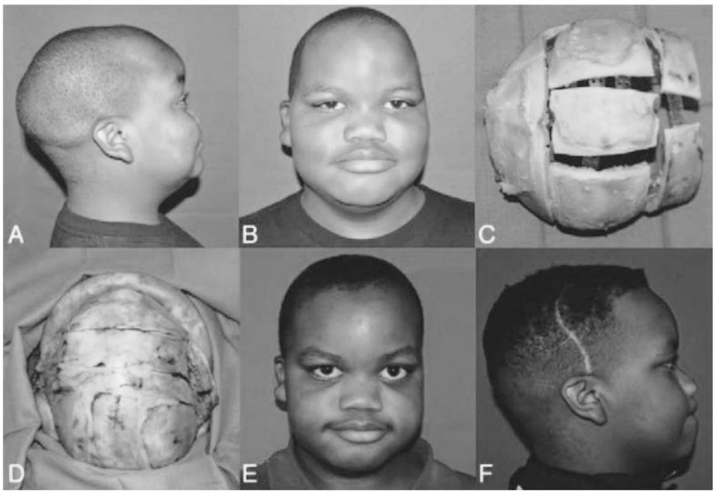

FIGURE 2. (A, B) Child with nonsyndromic sagittal craniosynostosis who presented at 12 years of age. A subtotal cranial vault reconstruction was performed at 14 years of age. (C) Cranial ostomy splint markings at time of operation. (D) Final construct of cranial vault reconstruction on table. (E) Follow-up at 3 weeks postoperatively. (F) Follow-up at 15 months postoperatively demonstrating good results.

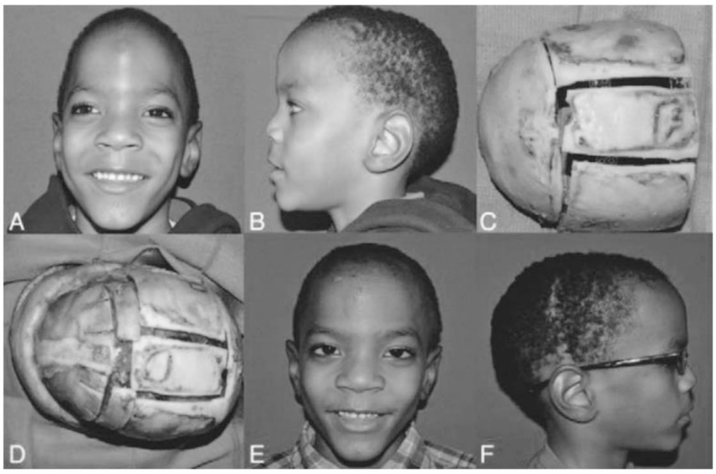

FIGURE 3. (A, B) Child with nonsyndromic sagittal craniosynostosis who presented at 5 years of age. A subtotal cranial vault reconstruction was performed at 6 years of age. (C) Final cranial construct at time of operation on table. (D) Final cranial vault reconstruction. (E) Follow-up at 3 months postoperatively. (F) Follow-up at 1 year postoperatively demonstrating good results.

5:17 PM- 5:24 PM

Title:A new colored solid model for simulation surgery: it is made of salt

Yoshiaki Sakamoto [1], Hisao Ogata [1], Teruo Sakamoto, D.D.S [2], Takenori Ishii, D.D.S. [2]Kazuo Kishi [1]

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[2] Department of Orthodontics, Tokyo Dental College, 1-2-2 Masago, Mihama-ward, Chiba 261-8502, Japan

Background: Simulated craniomaxillofacial surgery is critical for planning the procedure, shortening operative time, and practicing the procedure. However, typical models are expensive, given their solid materials, and the surgical sensations do not accurately reflect the procedure performed using human bone. To solve these problems, a new solid salt model has been developed.

Method: Stereolithography data was generated using computed tomography data, and a salt model created using a 3D inkjet printer. By extracting specific data for elements such as the teeth and mandibular canal, these elements were highlighted in the solid model using different colored material. As well, we compared the maximum load and plastic deformation of the salt model, a stereolithographic resin model, and a pig limb.

Result: The salt model had similar tenacity to bone, and the risk of damage to the teeth and inferior alveolar nerve was easily confirmed.

Conclusion: The material cost of the salt model is extremely low, and the salt model may provide a more accurate sensation of cutting human bone. Thus, this model is useful for both simulated operation and practice for inexperienced surgeons.

5:24 PM- 5:31 PM

Title:Is the sphenosquamosal suture related to the cranial deformity in Plagiocephaly?

Masashi Takemaru [1], Yoshiaki Sakamoto [1], Junpei Miyamoto [2], Tomohisa Nagasao [3], Kazuo Kishi [1]

[1] Department of Plastic and Reconstructive Surgery, Keio University School of Medicine
[2] Miyamoto Plastic & Reconstructive Surgery Hospital.
[3] Department of Plastic and Reconstructive Surgery, Kagawa University School of Medicine

【Purpose】The coronal ring of patients with unilateral coronal synostosis (UCS) presents premature fusion. This study aims to elucidate the causes of the symptom of UCS including asymmmetry of the frontal region of the skull and deformity of the orbital region.

【Method】On the basis of computed tomography data of neonatal dry skull, computer-aided design models; involving only frontoparietal suture (FP), involving frontoparietal and frontosphenoid sutures (FP+FS), and involving frontoparietal, frontosphenoid and sphenosquamosal sutures (FP+FS+SS) were produced. Pressure of 15 mm Hg was applied to the neurocranium of each skull model to simulate ICP. Using the finite element method, the displacements presented by each model's orbits were calculated.

【Results】In FP model, high stress was generated at only the frontal region. In contrast, FP+FS and FP+FS+SS models which involves skull base generated high stress not only frontal, but also orbital region. In addition, the high stress also generated at skull base in FP+FS+SS model. The simulated deformation in FP+FS+SS models is similar to UCS.

【Conclusion】Despite the progress of molecular biology and genetics, many things are still not understood about the suture biology and the exact causative pathways remain yet to be completely understood in craniosynostosis. Biomechanical study is useful to reveal the cranial deformation in craniosynostosis.

5:31 PM- 5:38 PM

Title: Teaching Breast Aesthetics Using A Sculpture- based Simulation Workshop

Lauren Nigro MD, Morgan Yacoe MD, Jennifer L. Rhodes MD

Virginia Commonwealth University

Background: With over 106,000 patients undergoing breast reconstruction each year and a growing interest in aesthetic outcomes, it is critical trainees develop an eye for breast aesthetics. To enhance learning, we developed a simulation-based approach to teaching breast aesthetics, including form, symmetry, perspective, and observational skills.

Methods: With the collaborative efforts of a sculptor, we desig a workshop using resin casts of a female torso after unilateral mastectomy. Subjects included plastic surgery residents and students. Using clay and sculpting tools, each subject was tas with re-creating the absent breast, requiring careful observatic critical examination, and translating the conception into a multidimensional creation. The torso was designed to allow subjects to look over the clavicles to understand the patient's perception of the reconstructed breast. Subjects were surveye evaluate the experience.

Results: Twelve subjects participated in the workshop; seven completed the survey. Subjects honed observational and analytical skills to understand and recreate symmetry, volume contour, and texture of the breast from clay. On a scale of 0-1 (10 being the most useful), subjects ranked the effectiveness the workshop at 9.4 (Table 1). They strongly felt the workshop improved their understanding of breast aesthetics (9.4/10). Subjects reported a greater appreciation of the breast's comp nuanced shape, pitfalls of light and shadow's effect on perspective, and different vantage points of observation.

Conclusion: Using sculpture as a hands on medium, the simulation workshop provided subjects a greater understandir three-dimensional breast aesthetics. Subjects sharpened skill crucial for surgical practice.

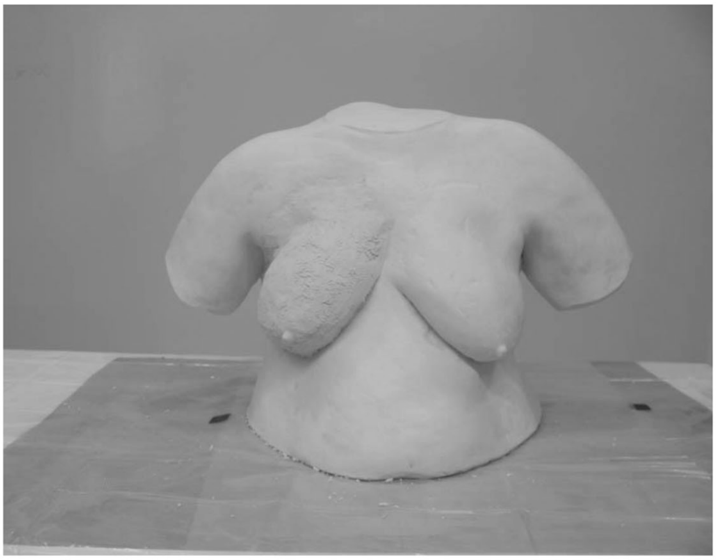
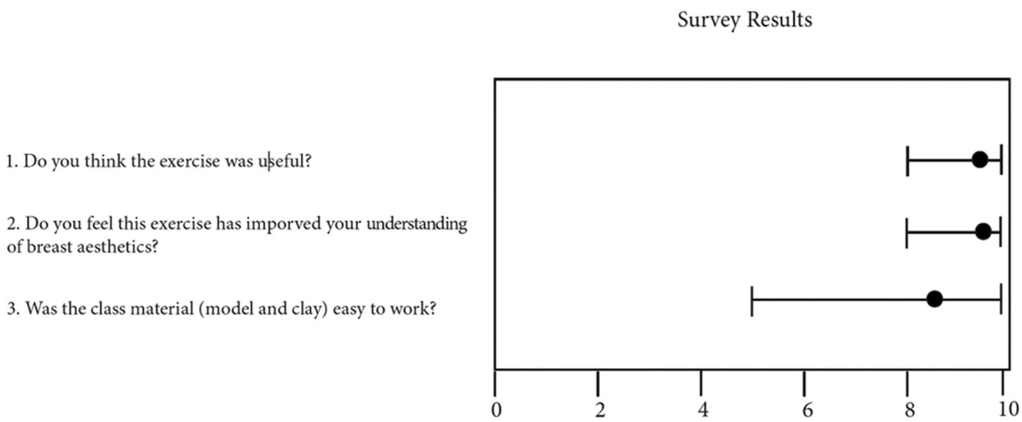


Table 1.


Survey Results
1. Do you think the exercise was useful?
2. Do you feel this exercise has imporved your understanding of breast aesthetics?
3. Was the class material (model and clay) easy to work?
0
2
4
6
8
10

5:38 PM- 5:45 PM

Title: Application of Finite Element Analysis to Predict Skin Mechanical Stress on A Patient-Specific Model of Complex Local Tissue Rearrangement

Sergey Y Turin, MD, Northwestern University Feinberg School of Medicine, Chicago, IL
Taeksang Lee, MS *co-first author, Purdue University, West Lafayette, IN;
Paul Berg, BA, Lurie Children's Hospital of Chicago, Chicago, IL;
Arun K Gosain, MD, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, IL; Adrian Buganza Tepole, PhD, Purdue University, West Lafayette, IN

Excessive mechanical tension following flap advancement and transposition has been associated with complications including hypertrophic scarring and delayed healing. Yet, there is still a lack of tools to measure tissue stress in the operating room and anticipating stress distributions in complicated tissue rearrangement cases remains challenging. A patient-specific three-dimensional (3D) geometry of the skin and skull of a 7 year-old patient was built with computer tomography (CT) scan data and multi-view stereo (MVS). The patient was treated to correct a cranial contour deformity and resect two large areas of scalp scarring. The surgery was simulated on the 3D models using finite element analysis (FEA) to compute the mechanical stress contours. Overall stress was highest at specific areas near the suture lines. For the temporal scar, the stress concentration occurred at the distal end of the flap. The occipital scar excision was Y-shaped and showed peak tension along one limb up to the T-junction of the sutures. This region of high stress identified in the simulation did show partial flap tip necrosis and delayed healing one month after surgery. In conclusion, MVS and FEA allow prediction of mechanical stress contours on patient-specific models that can help during preoperative planning to minimize skin tension, as well as help anticipate regions at risk of wound healing complications.

Fig. 1. 7-year-old female with a history of scalp and calvarium resection, with unstable scar and residual pigmented nevus after completing tissue expansion (*left*); Patient at the 3-day follow up, a small region of partial flap necrosis and delayed healing developed at the T junction of the occipital scar (*right*).

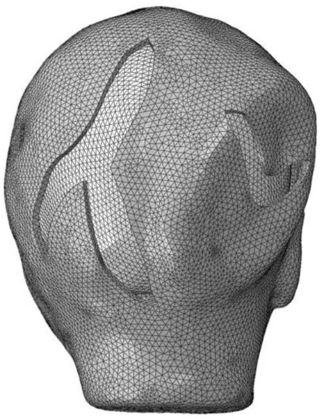


Fig. 2. The 3D model of the skull with the calvarial defect from the CT scan was corrected to simulate the cranioplasty procedure and merged with the multi-view stereo (MVS) model of the skin after tissue expansion. The two scars were removed from the skin model according to the MVS geometries obtained intraoperatively.

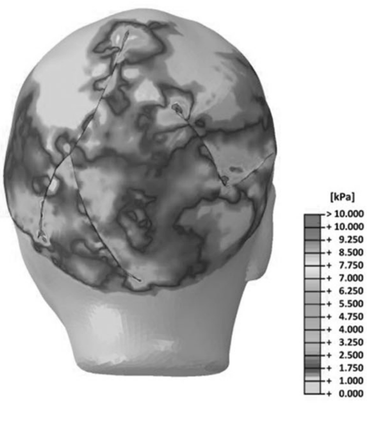


Fig. 3. von Mises stress distribution at the end of the virtual surgery simulation: A region of high stress in the occipital suture extended over a large are including the T junction of the flaps.

5:45 PM- 5:52 PM

Title: Virtual Reality and Augmented Reality Technology in Neurosurgery

Tomohisa Miyagi, Kuninaka Tomomi, Yuki Kinjo, Shigetaka Kobayashi, Hideki Nagamine, Yohei Hokama, Ryuichi Usugi, Yukio Tsuchida, Chiaki Katagiri, Masahiko Nishimura, Kenichi Sugarawa, Hiroshi Takagi, Shogo Ishiuchi

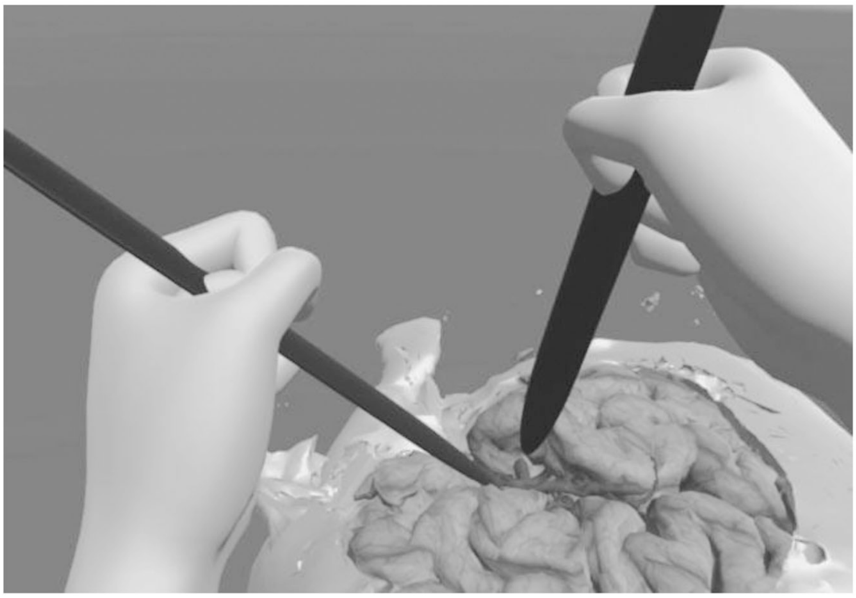
Department of Neurosurgery, University of the Ryukyus

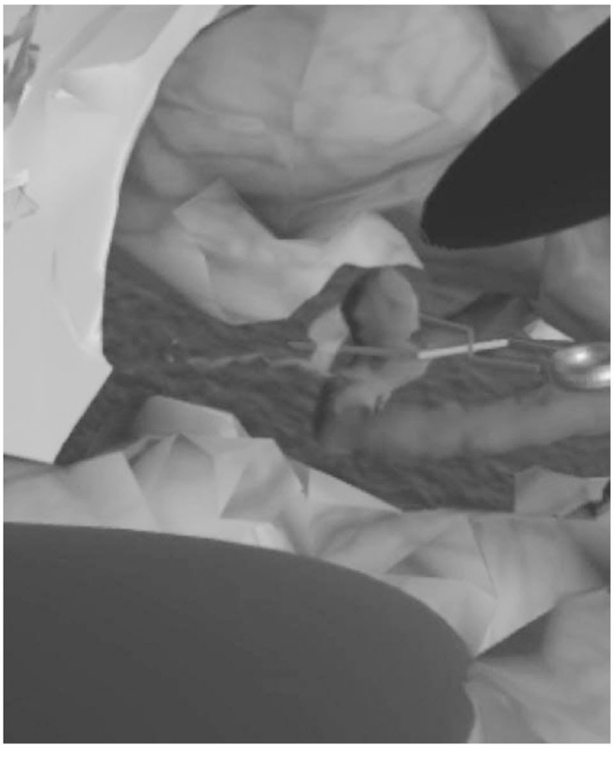
OBJECTIVE: We are to report on representative clinical cases using virtual reality and augmented reality technology in our department of neurosurgery.

METHODS: We created three-dimensional computer graphics (3DCG) by SYNAPASE VINCENT of FUJIFILM and iPlan of Brainlab with using DICOM data of 3T MRI and 320 slice CT. Hand and head motion tracking system was used for Virtual reality. The motion tracking was performed using Oculus Rift and Touch of Oculus VR. Real-time physical deformation virtual reality system was built by Unity of Unity Technologies which is a software application to computer programmers for software development.The virtual reality system is used to training of neurosurgeons and medical students.

RESULTS: It was beneficial for the confirmation of the approach to use 3DCG augmented reality(blood vessel,tumor, language area, association fiber and so on) projection to the surgical microscope field. The virtual reality technology was effective for neurosurgical training of neurosurgeons and medical students.

CONCLUSION: The virtual reality and augmented reality technology were useful for the selection of the neurosurgical approach and neurosurgical trainning.





5:52 PM- 5:59 PM

Title: Increasing opportunities for Active Experimentation in residency using simulation: a revised cleft lip education curriculum.

Francesca Y. L. Saldanha [1], Carolyn R. Rogers-Vizena [1,2]

1. Department of Plastic and Oral Surgery, Boston Children's Hospital, Boston, MA.

2. Harvard Medical School, Boston, MA, USA.

Increasing healthcare safety and quality mandates, coupled with duty-hour restrictions and diminishing opportunities for resident operative autonomy, have prompted recruitment of advances in simulation to cater to the hands-on learning preferences of surgical residents.

Revisiting the principles of Kolb's Learning Cycle (Figure 1), the authors created a revised cleft lip educational program that sought to 1) maximize educational impact by traversing the full learning cycle in a single educational encounter and 2) pilot a high-fidelity procedural skills trainer that captured the importance of submillimeter detail whilst permitting resident operative autonomy.

Eleven residents participated in small group-educational sessions comprising a standard cleft didactic lecture, augmented by an instructional video. Participants immediately processed knowledge from the lecture/video by "operating" on the simulator allowing opportunities for questions and self-reflection, completing the learning cycle (Figure 2). A self-assessment survey (Figure 3) was taken prior to and after each component of the session, including a self-confidence survey to conclude the session.

Preliminary analysis using the Wilcoxon signed-ranked test indicates a statistically significant increase in learning across all aspects of the self-assessment by the end of the session ($p<0.02$). In particular, simulation contributed a significant increase in understanding of cleft rhinoplasty post-simulation compared to post-lecture ($p<0.014$ versus $p<0.2$, respectively). 100% ($n=11$) of the cohort strongly agreed that simulation helped them actively engage in learning and should be a required aspect of training, whilst 91% ($n=10$) thought simulation was a highly effective adjunct, granting trainees the Active Experimentation required to efficiently process knowledge less-experienced stages of training.

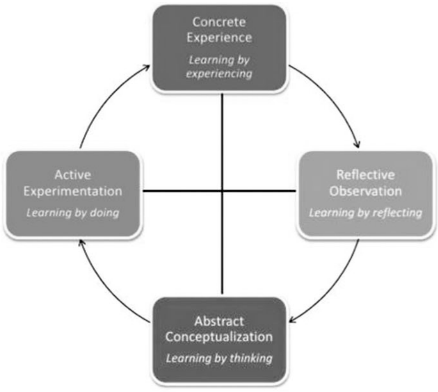


Figure 1. The Kolb Experiential learning cycle describes the process of taking in and consolidating new experience into retained knowledge as a cycle of four distinct phases: Concrete Experience (CE), and Reflective Observation (RO), Active Experimentation (AE), Abstract Conceptualization (AC). *(Adapted from Kolb DA, Kolb A. The Kolb Learning Style Inventory—Version 3.1 2005 Technical Specifications. Boston, MA: Hay- group; 2005.)*

SELF-ASSESSMENT			
*On a scale of **1 to 4**, please rate your confidence for the following statements.*			
I understand the anatomy of the unilateral cleft lip/nasal deformity			
1 Not at all Confident	2 Little Confidence	3 Somewhat Confident	4 Very Confident
I can independently formulate a treatment plan for a patient with unilateral cleft lip			
1 Not at all Confident	2 Little Confidence	3 Somewhat Confident	4 Very Confident
I can independently mark a unilateral cleft lip repair			
1 Not at all Confident	2 Little Confidence	3 Somewhat Confident	4 Very Confident
I can independently perform a unilateral cleft lip repair			
1 Not at all Confident	2 Little Confidence	3 Somewhat Confident	4 Very Confident
I can independently perform primary cleft rhinoplasty			
1 Not at all Confident	2 Little Confidence	3 Somewhat Confident	4 Very Confident
I can troubleshoot intra-operative problems (eg. short medial lip) during cleft lip repair			
1 Not at all Confident	2 Little Confidence	3 Somewhat Confident	4 Very Confident

Figure 3. The self-assessment survey for the pilot curriculum was used to gauge learning with respect to important aspects and principles of the unilateral cleft lip repair. It was filled out three times by residents throughout the session (pre-lecture, post-lecture and post-simulation.

Figure 2. The unilateral cleft lip pilot curriculum is an example of how training in residency can be developed
to better target the full experiential learning cycle, promoting early autonomous trainee operative experience
without risking patient safety.

5:59 PM- 6: 09PM

Reconstruction of a Hemirhinectomy Defect Using a 3D Printed Custom Soft Tissue Cutting Guide

Jonathan Brower MD, Joseph Crozier MA, Damon McIntire BA, Michael Boyajian BA, Albert S Woo MD, FACS

The Department of Plastic Surgery, Rhode Island Hospital and The Warren Alpert Medical School of Brown University, Providence, RI

Introduction
The forehead flap serves as a workhorse flap for subtotal nasal defects.[1] A three-stage technique is commonly employed for these full-thickness wounds in which reconstruction of skin, support, and nasal lining is required. An optimal aesthetic result, however, depends on surgeon artistry to craft the detailed three-dimensional topography of the nose from a two-dimensional flap.[2] Results are therefore inconsistent and unpredictable.[3] To address this reconstructive challenge, we sought to use 3D printing technology for the creation of a customized soft tissue cutting guide for reconstruction of a hemirhinectomy defect with a forehead flap.

Methods
The Canfield VECTRA® M5 3D imaging system was used to capture a 3D photo of the patient with the hemirhinectomy defect. Blender® software was used to create a mirror image of the unaffected side. The guide was printed using the Stratasys® J750 with "Tango" Polyjet Material.

The guide was sterilized for use in the first stage of reconstruction. It was placed on the defect intraoperatively to confirm the desired result. The guide was manually flattened and a 2D representation was traced onto the forehead, incorporating it into the flap design. The forehead flap was then elevated and inset with a skin graft for nasal lining. The patient subsequently returned to the operating room for cartilage grafting and pedicle division.

Results
Please see attached photos.

Conclusion
A 3D printed cutting guide for soft tissue can be used to provide customized reconstruction of a hemirhinectomy defect with a forehead flap.

1. Rohrich RJ, Griffin JR, Ansari M, Beran SJ, Potter JK. Nasal Reconstruction – Beyond Aesthetic Subunits: A 15-Year Review of 1334 Cases. 2004. *Plast Reconstr Surg*. 114:1405-16.
2. Menick FJ. Nasal Reconstruction with a Forehead Flap. 2009. *Clin Plastic Surg*. 36:443-59.
3. Jacobs CA, Lin AY. A New Classification of Three-Dimensional Printing Technologies: Systematic Review of Three-Dimensional Printing for Patient-Specific Craniomaxillofacial Surgery. 2017. *Plast Reconstr Surg*. 139:1211-20.

Figure 1: Creation of mirror image from unaffected anatomy obtained from 3D camera. The mirror image was then 3D printed as the cutting guide.

Figure 2: The cutting guide is laid over the hemirhinectomy defect to confirm size and shape.

Figure 3: Immediate post op results of forehead flap fabricated with assistance of cutting guide for symmetry.

6:06 PM- 6: 13PM

Title: **Advanced Microsurgical Trainer for Breast Reconstruction**

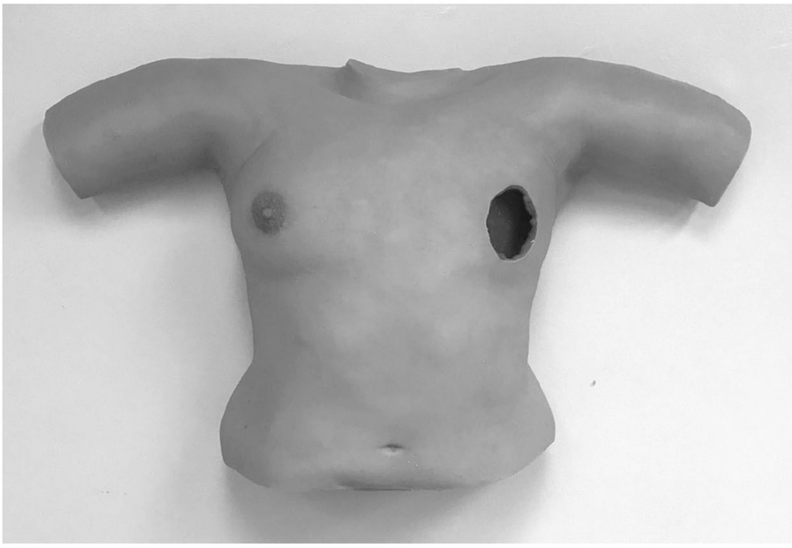
Authors: Morgan Yacoe, BFA, Santosh Kale, MD, Jennifer Rhodes, MD, Peter Pidcoe, D.P.T., Ph.D,
Institution: Virginia Commonwealth University

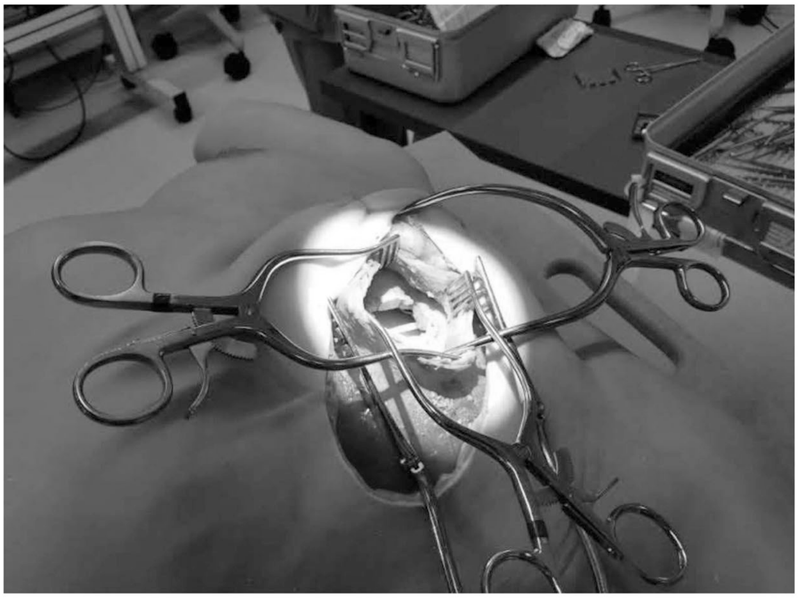
Abstract:
Current options for microsurgical training models are oversimplified, inaccurate, and not reusable . With the collaborative efforts of an artist and engineer, we created a reusable surgical simulation model with accurate human anatomy and physiology. This model gives trainees the skill-set they need to be better prepared for microsurgery, specifically for the training of DIEP flap breast reconstruction.

The model is composed of specialized materials that simulate human tissue and the three-dimensional constraints of the anastomotic environment. Furthermore, the model has a built-in pump which simulates a live vascular system. We regulate the parameters of the pump using an interactive Android application that exposes the trainees to different technical challenges. Additionally, the fabrication principles of the model can be applied to different parts of the body to simulate various microsurgical locations.

Utilizing the model, a training session was held for plastic surgery residents to practice anastomosis. After the training session, the participants filled out a survey evaluating the model. The survey had multiple questions asking the participants to provide a ranking from 1 to 10 on the effectiveness of the model. The model was given a score of 8 for accurately simulating the three-dimensional constraints of the anastomotic environment and a score of 6.7 for increased understanding of the procedure.

Overall, results showed the class had a better understanding of the procedure after using the training model. We believe that trainees who are better prepared with more technical practice will directly benefit with improved surgical technique in the operating room.





日本シミュレーション外科学会会則

1991 年 11 月 12 日設立

第 1 章　総　則

第 1 条（名称）

本会は、日本シミュレーション外科学会（The Japan Society for Simulation Surgery）と称する。

第 2 条（事務局）

事務局を、東京都新宿区大久保 2-4-12　新宿ラムダックスビル㈱春恒社内におく。

第 2 章　目的と事業

第 3 条（目的）

本会はシミュレーション外科の進歩、発展につとめると同時に会員相互の親睦と知識の交換に貢献することを目的とする。

第 4 条（事業）

本会は、前条の目的を達成するために以下の事業を行なう。

1．学術集会、講演会など
2．内外の関連団体との連係、連絡など
3．印刷物の刊行など
4．その他必要な事項

第 3 章　会　員

第 5 条（会員および入会）

会員は、本学会の目的に賛同するもので、正会員、名誉顧問、顧問、名誉会員、準会員、賛助会員をもって構成する。

1．正会員は、医師、それ以外の研究者で所定の入会申込み書式に従い、別に定める入会金および当該年度の会費を添えて本学会事務局に申込み、理事会の承認を受けたものとする。
2．名誉顧問、顧問は、本学会に貢献のあったものから理事長が推薦し、理事会の承認を受けたものとする。ただし本人の承諾を得なければならない。
3．名誉会員は、本学会に特に貢献のあったものの中から理事長が推薦し、理事会、評議員会の議を経て、総会で承認を受けたものとする。ただし、本人の承諾を得なければならない。
4．準会員は、学生で入会手続きは前項に準ずる。
5．賛助会員は、個人、法人または任意団体で推薦により理事会で承認を得たものとし、入会手続きは前項に準ずる。

第 6 条（退会と除名）

6．会員が退会しようとするときは、退会届けを理事長に提出し、理事会の承認を得る。
7．会員が次の項目に該当する時は、理事会、評議員会の議を経て除名することが出来る。
　1）本会の目的に反し、会員として適当でないもの。
　2）会費を 2 年以上滞納したもの。

第 4 章　役員及び評議員

第 7 条（役員）

1．本会に次の役員をおく。
2．会長 1 名。理事長 1 名。理事若干名。および監事 2 名。

第 8 条（理事および監事）

理事および監事は、評議員会において評議員の中から選出し、総会で承認を受ける。

第 9 条（会長）
1．会長は、評議員会において選出し、総会において承認を受ける。
2．会長は、年 1 回の学術集会を主催する。

第 10 条（理事長）
1．理事長は、理事の互選により選出する。
2．理事長は、本会を代表し、理事会、評議員会ならびに総会を招集し、その議長となり会務を統括する。

第 11 条（役員の任期）
1．理事および監事の任期は 2 年とするが重任を妨げない。ただし連続 2 期を越えないものとする。
2．会長の任期は 1 年とし、前年度学術集会終了時から、当年度学術集会終了時までとする。

第 12 条（評議員および評議員会）
1．本会は、評議員をおく。評議員は理事会で選考し理事長が委嘱する。
2．評議員の任期は 2 年とし重任を妨げない。但し理由なく任期中の評議員会を欠席した場合は再任をおこなわない。

第 13 条（幹事）
事務局に幹事をおく。幹事は事務局事務を担当し、理事会、評議員会に出席する。

第 5 章　会　議

第 14 条（理事会）
1．定例理事会は、通常総会前に開催するが、理事長は必要に応じて招集することが出来る。
2．理事会は、理事の 3 分の 2 以上の出席を要する。
3．あらかじめ委任状を提出したものは出席とみなす。

第 15 条（評議員会）
1．定例評議員会は、通常総会前に理事長が招集する。
2．評議員会は、評議員の 3 分の 2 以上の出席を要する。
3．あらかじめ委任状を提出したものは出席とみなす。
4．名誉顧問、顧問は、評議員会に出席し意見を述べることができるが決議には参加しない。

第 16 条（総会）
年 1 回定例総会を開催する。総会は正会員をもって構成する。

第 6 章　会費および会計

第 17 条（入会金および年会費）
1．会員は、所定の入会金と年会費を納入する。ただし名誉顧問、顧問、名誉会員は、会費を免除する。
2．既納の会費は、いかなる理由があっても返却しない。
3．入会金は 5,000 円。年会費は正会員 5,000 円、準会員 2,000 円、賛助会員 30,000 円以上とする。

第 18 条（会計）
1．本会の経費は、会費および寄付金、その他の収入を持って充てる。
2．本会の会計年度は、毎年 9 月 1 日から 8 月 31 日までとし、会計業務は株式会社春恒社に委託する。

付　則

第 19 条（会則の変更）
本則の変更は、理事会ならびに評議員会において審議し総会において承認を求める。

第 20 条（会則の発効）
本会則は、1991 年 11 月 12 日から実施する。
改正会則は、1993 年 11 月 20 日から実施する。
改正会則は、2003 年 4 月 2 日から実施する。
改正会則は、2013 年 4 月 1 日から実施する。
改正会則は、2014 年 11 月 15 日から実施する。

日本シミュレーション外科学会会誌投稿規定

1．投稿資格

1）本誌への投稿者は、本学会会員に限る。

2）論文は、シミュレーション外科の進歩発展に寄与する独自性のあるもので、他誌に未発表のものに限る。ただし、編集委員会が認めた場合はこの限りではない。

2．論文の採否、修正

論文の採否は、編集委員会で決定する。必要に応じて書き換え修正を求めたり、編集委員会の責任において修正を行うことがある。

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配列は引用順とし、本文中の引用箇所に肩番号（例：1））を付ける。著者が 3 名までは全員、4 名以上のときは 3 名までを書き、以降は「ほか」または「et al」を付ける。雑誌名は、Index Medicus、または医学中央雑誌の表記に従い略記する。外国語の雑誌は前者を、日本語の雑誌は後者を優先する。

a．雑誌

著者名（発行年）表題名．雑誌名　巻：ページ

（例）養父孝乃介，田嶋定夫，今井啓介ほか（1993）頭蓋底・眼窩部の 3 次元実体モデルの切削法における分割作製法．日頭蓋顎顔面外会誌　9：7-11

Kato A, Yoshimine T, Hayakawa T et al（1991）A frameless, armless navigational system for computer－assisted neurosurgery. J Neurosurg 74：845－849

b．単行本

著者名（発行年）書名．ページ，発行所，発行地

（例）千代倉弘明（1985）ソリッドモデリング．pp 123，工業調査会，東京

Fujino T（1994）Simulation and computer aided surgery. pp 123, Jobn Wiley and Sons, Chichester c．分担執筆

著者名（発行年）題名．書名（版），編集者名，ページ，発行所，発行地

（例）横井茂樹（1992）シミュレーション外科と VR．人工現実感生成技術とその応用（初版），岩田洋夫編，pp 137－156，サイエンス社，東京

Kuboki Y, Yamaguchi H, Ono I et al（1991）Osteogenesis induced by BMP-coatedbiomaterials：Biochemical principles of bone reconstruction in dentistry. The bone－biomaterial interface（1st Ed), edited by Davies JE, pp127-138, Tronto University Press, Tronto

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