Up in the Air: Orthodontic technology unplugged!

The 2009 film *Up in the Air*, with George Clooney playing Ryan Bingham, is a story I have connected with at various levels. A life that has seen me probably take 150 plus flights in the last 2 years does draw a parallel with the "air miles and hotel reward points" centric character in this movie. Life has, both personally and professionally for most people I know, changed in more ways than one, in recent times. Our interactions with "life" itself are not the same. The "slide and swipe" culture has made sure we touch technology and technology touches us, especially when orthodontists have long enjoyed a reputation for being among the most "progressive, technology embracing, and visionary" dental professionals. *Up in the Air* raises some very robust questions about the meaning and purpose of work. Professionals in general and orthodontists in particular need to look at these manifestations from a holistic perspective in 2017!

Matthew Kaemingk, a theologist from Seattle, WA, lists few pointers that could help us pose some pertinent questions that this movie raises. We go ahead and pose these questions on the orthodontic terrain![1]

Dehumanization at work

Up in the Air appears to record how Ryan Bingham's humanity is slowly being drained away even in a relatively well-paid and white-collar job. Bingham is "a player so expert at the rules of the game… that he doesn't notice, until too late, that the game has hollowed him out." Over years of constant travel and meaningless connections, Bingham loses his ability to connect, sympathize, commit, or remain placed.

- How can technology act as both a gift and a curse to the flourishing of orthodontic practices? What can we dehumanize in orthodontic care, and what is it that we should not?
- Have technological applications "undone" professionals or made patient care subhuman through the years?

The good life

The three main characters (Ryan, Alex, and Natalie), all spend some time in the film discussing their vision of "the good life."

- What does "Good Life" for an orthodontist imply professionally? Does technology impact the quality of life of the orthodontic professional?

Speed and efficiency

Speed and efficiency are critical to Ryan Bingham. He moves smooth and fast throughout the film. When he is forced to wait or is slowed down in any way, he is immediately and visibly annoyed. Efficiency along with efficacy has become a cardinal virtue in many working places - trumping all other values.

- How do the values of speed and efficiency both positively and negatively affect orthodontics and the orthodontist?

The millennial orthodontist will probably practice in a zone where impressions, two-dimensional (2D) radiographs and photographs, and probably a lot of other chairside procedures (considered day to day until just about recently!) will probably fade away into history books. Will these changes - make orthodontics "subhuman," be a "curse" or a "boon" for the specialty, transform our "identity" as care providers, affect the "quality of life-QoL" of the orthodontist and the patient, or create "efficiency-driven practices," which will be a value addition to the profession? As we still search for these answers, one thing is a given- *The impact of technology will affect more than just the domain elements of orthodontics!*

The *Up in the Air* (literally in the cloud computing spheres!) technologies impacting our profession can be summarized broadly in Table 1.

The three areas of application impacting us in an exponential manner are:

- ***Apps and appliances***
- ***Imaging, integrated wraps, and volumetric data sets***
- ***Rapid prototyping***.

We discuss the scope and future of each of these technological infusions, ironically in an unplugged manner, from a clinician's standpoint.

ORTHODONTIC APPS AND APPLIANCES

Apps

Steve Jobs was a visionary with an exceptional understanding of what would come next. When the "app store" was launched in 2008, what essentially was created was "magic glue" that would connect people to content through software. Today smartphones are like handheld computers and are an indispensable technological tool. As of today [Table 2], a total of 350 plus apps on orthodontics exist across both the iOS and android platforms. The range of applications is as varied as practice management, peer-reviewed journals, diagnostic apps, orthodontic education, patient reminder apps, progress trackers, model analysis apps, public awareness information, fun with braces, etc.

Orthodontic information is no longer restricted through just log-ins and regimented discourses. It is out there available as a "slide and swipe" app available for both care providers and seekers! From embracing the internet to use cloud-based systems for communications' way back at the turn of the century, we have indeed come a long way.

Appliances

The digital workflow in creation of orthodontic appliances is a reality today. Progressive practitioners have already wet their fingers with appliances that can be milled, laser sintered, or printed for a given patient. Whether it is an adjunct or an entire appliance system; whether a vestibular, an aligner, or a lingual system; this disruptive infusion of digital technology is slowly becoming orthodontic mainstream. The name of the game is customization.[2-4]

The efficacy of customized computer-aided design (CAD)/computer-aided manufacturing appliances with respect to chairside efficiency, treatment duration, alignment errors, and treatment outcomes has been reported in recent literature.[5-7] Although these appliances are in their relatively early days, the promise of a dehumanized appliance, where the human interface is more cerebral than dexterous, is reality just around the corner!

IMAGING, VOLUMETRIC DATA SETS, AND INTEGRATED WRAPS

Imaging

The 1990's saw imaging grow to enable the integration of digital X-rays.[8] This was an important landmark in orthodontic diagnostics. Cephalometric and panoramic records could now be a part of electronic charts. Model scanners at the turn of the century created methods to digitize models that could also be incorporated into electronic patient data charts. This period also saw cone beam computed tomography (CBCT) scanners change the face of imaging in orthodontics. Orthodontic informatics, has since improved our understanding of differences between 2D and three-dimensional (3D) imaging and established 3D anatomic interactive modeling as an important aspect of diagnosis, treatment planning, and monitoring treatment processes.

3D imaging of the face by textured images captured by color cameras can be mapped onto 3D models to produce "photorealistic rendered face models." 3D laser scanning, Moiré' topography, structured light techniques, stereophotogrammetry, and 3D Facial Morphometric are all techniques that have been reported in orthodontic literature for the same.[9] Research on 3dMD (3D) facial photographs has made it possible to average multiple facial images of highly variable topology for a given population group. The application of this technology is a rapid and detailed diagnostic imaging analysis for orthodontic and

Table 1: Technological infusions that have been game changers in orthodontics

A	I	R
Apps A number of Apps on the Android and iOS platforms for management , diagnostics, communication and professional interactions PI refer to Table 2	**Imaging** *CBCTs *Facial 3D WL Scans *3D Photography *Intra Oral Scanning *E Models	**Rapid Prototyping** Various applications in Orthodontics *Aligner fabrications *Surgical splints *Bruxism splints *Auto transplantation templates *Customized appliances *Indirect bonding trays *Diagnostics for impacted teeth *3 D printed Jaws (orthognathics) *Cranofacial/Cleft Planning *3D printed Functional Appliances
Appliances/Adjuncts *CAD CAM Customized Appliances *Aligners *Robotic Arch-wires *Customized Adjuncts through digital work-flows	**Volumetric Data Sets and Integrated Wraps** *Professional Companies/Softwares that integrate data and provide 3D volumetric Data Sets-great potential for research and planning in orthognathics *Integrated Volume Wraps of various imaging modalities into a single file that can provide comprehensive information	

Table 2: Orthodontic apps on the Android and iOS platforms for smartphones (compiled by Dr. Gaurav Gupta, India)

Operating system	Category	Number
iOS	Clinicians app	
	Clinic apps/practice management	89
	Publications/journals/ magazines	27
	Orthodontic products	10
	Apps aiding in diagnosis	8
	Orthodontic conferences	6
	Tooth ratio calculators	2
	Orthodontic news	2
	Patient apps	
	Orthodontic education	26
	Reminding patients about elastic wear	3
	Reminding patients about aligner wear	2
	Dealing with orthodontic emergencies	2
	Progress tracker	2
	Total	179
Android	Clinicians app	
	Clinic apps/practice management	95
	Publications/journals/ magazines	15
	Orthodontic products	7
	Apps aiding in diagnosis	10
	Orthodontic conferences	14
	Tooth ratio calculators	5
	Orthodontic news	2
	Patient apps	
	Orthodontic education	18
	Reminding patients about elastic wear	2
	Reminding patients about aligner wear	2
	Dealing with orthodontic emergencies	1
	Progress tracker	4
	Total	175
	Total in both OS	354

surgical treatment planning. There is a great potential for the application of 3D facial scans to anthropometrics and genomics. In 2017, investigations have resulted in establishment of protocols for mapping the surface of the human face in three dimensions accurately.[10]

Volumetric data sets and integrated wraps

3D imaging is appealing for orthodontists as a single CBCT scan can serve as a patient's singular data set from which traditional views of an orthodontic workup can be derived. Software companies have delivered user-friendly programs that enable the practitioner to render these volumetric data sets. 3dMD, Atlanta, GA, Dolphin 3D, and Anatomage, San Jose, Calif, are some of the providers. These 3D rendering programs provide tools for orientation, landmark identification, measuring, tissue segmentation, superimposition, and more.[8]

The next level of the cutting edge diagnostics is the creation of integrated wraps that can merge different diagnostic data. Premjani *et al.*[11] have evaluated the accuracy of 3D facial models obtained from CBCT volume wrapping. What was interesting in their study was the wrapping of 2D photographs on a 3D CBCT. On assessing accuracy, 13 out the 14 measurements on a volume wrapped 3D model compared with direct anthropometric measurements in this study showed no statistical difference between the two methods.

The European University, Dubai, is undertaking a project currently where data from CBCTs, 3D facial scans using an Artec 3D industrial scanner, and intraoral scans with a 3 Shape Trios scanner will be integrated into a comprehensive diagnostic document for diagnostic and clinical planning applications. Soft tissue, hard tissue, and dental data collection for a single patient takes <20 min with this technique. The days of patients getting into multiple rooms for long drawn diagnostic data collections are probably a thing of the past!

RAPID PROTOTYPING

While industrial applications of 3D printing are becoming immensely popular, orthodontics has integrated this technology for some time now. Rapid prototyping (RP) is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using 3D CAD data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology. Although media likes to use the term "3D printing" as a synonym for all additive manufacturing processes, there are actually lots of individual processes that vary in their method of layer manufacturing. Hence, in 2010, the American Society for Testing and Materials (ASTM) group "ASTM F42 – Additive Manufacturing" formulated a set of standards that classify the range of additive manufacturing processes into seven categories (Standard Terminology for Additive Manufacturing Technologies, 2012). They are (1) VAT photopolymerization, (2) material jetting, (3) binder jetting, (4) material extrusion, (5) powder bed fusion, (6) sheet lamination, and (7) directed energy

deposition.[12] While a binder jetting and powder bed fusion use a powder material, VAT photopolymerization, material jetting, and material extrusion use liquids that created into 3D models by an additive layering process.

Hazeveld *et al.*[13] studied the accuracy and reproducibility of dental RP models created by the digital light processing, jetted photopolymer, and 3D printing methods and found that all the methods produced acceptable models for orthodontic applications. Aligner fabrications, surgical and bruxism splints, autotransplantation templates,[14] customized appliances and robotic wires,[2-7] bonding trays, and diagnostic casts for impacted teeth[15] are some of the many applications that have been successfully employed and are perhaps routine in progressive orthodontic protocols today.

I have personally been enthralled at the integration and conversion capabilities of file formats to literally generate 3D prototyped appliances that have and will continue to revolutionize orthodontic care. With 3D desktop printers already on the market, I envisage a not too distant tomorrow, where 3D printers will be a part of the orthodontic office machinery for on-site applications.

TECHNOLOGY UNPLUGGED - SOME CRYSTAL GAZING!

In 1965, Gordon Moore, cofounder of Intel, predicted that the number of transistors on a microchip could double every 24 months (Moore, 1965; Twist, 2005). Known as "Moore's Law," this prediction has held true for more than 50 years. The consequence of this prediction has been the rapid pace of software evolution, with more powerful software being released each year. This rapid increase has included more sophisticated solutions for the orthodontist regarding diagnosis, treatment planning, case presentation, and patient communication. One example is the dynamic, interactive patient education systems that have appeared in the last few years. Professionals are discovering that the animated imagery used by these systems greatly enhances a patient's comprehension of the diagnosis and treatment process.[16] A classical example of a "plugged in dehumanized device system" that allows us time for more "humane unplugged doctor–patient interactions!"

Technology in the orthodontic office will continue to become more sophisticated as bandwidths get faster and hardware devices become smaller and more mobile. In the beginning, the focus of employing technology was to increase accuracy of diagnosis and results; as a result, workflow became more streamlined. Technological advancements in the future will help to reduce treatment time and further perfect results. Along the way, human intervention will be reduced for further automation,accuracy of data gathering, and treatment. In 1999, Ray Kurzweil, a futurist, stated "We won't experience 100 years of progress in the 21st century – it will be more like 20,000 years of progress (at today's rate)."[17]

Machine interactions, changing interfaces with them and our understanding of their processing of data, will involve information that the human brain is probably not capable of synthesizing just yet. My dear friend, and one of the pioneers in incorporating technological advances into orthodontics, Prof. Jorge Faber in a candid telephonic conversation last week said, "Machine learning is a skill set that the orthodontists of tomorrow will have to delve into," and I agree with him emphatically! Machine learning is a type of artificial intelligence that allows computers to learn without being explicitly programmed. While Machine learning algorithms have been around for some time, the ability to automatically apply complex mathematical calculations to big data - over and over, faster and faster - is a recent development.

This science is gaining fresh momentum, and the orthodontic resident of tomorrow could well be taking these courses instead of conventional skills that we thought traditionally made orthodontic professionals! Sydney Harris, a journalist, is spot on when he predicts the need for such education but with a proverbial pinch of salt! He states, "The real danger is not that computers will begin to think like men, but that men will begin to think like computers."[18]

A 25- or a 50-year "Crystal Gazing" vision for what orthodontic technology could have in store for us reveals nanosensor infused appliances and gene-based therapies that could create magic we have not even conceptualized as of today![16] This could usher in a time, where the orthodontist consults, diagnoses, and controls therapeutics from a customized protocol professional app on a smartphone, or probably just smart lenses while leading a holistic life that ironically could be *"Up in the Air!"*

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