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Design of Thoracolumbosacral Orthosis (TLSO) Braces Using CT/MR

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Abstract: The field of orthotics has gained scientific attention over the last few years. Its objective is to correct, adjust, or modify the operation of human limbs, joints, or muscles. Thoracolumbosacral orthosis (TLSO) braces are used by scoliosis and postoperative patients who need back correction and/or support. The anatomic dimensions for TLSO braces have been acquired mainly by casting the patient. Casting is a time-proven method for obtaining surface geometry, but it can be inconvenient in certain situations. For example, casting might not be suitable for postoperative and trauma patients owing to the risk of further injury. Such prohibitive cases can still be handled safely by X-ray CT or MR scanning. This article presents an alternative method for data acquisition of TLSO patients' anatomic dimensions using CT/MRI. The experimental results show the method to be statistically accurate, efficient, and feasible compared with the conventional casting method. **Index Terms:** Computed tomography—Magnetic resonance imaging—Orthotics.

The field of orthotics has continuously advanced over the years and has gained scientific focus and research funding owing to its growing importance. Orthotics attempt to correct orthopedic deficiencies and imperfections such as scoliosis as well as support healing muscles in postoperative cases. Orthotic devices require attention to individual dimensions and characteristics; therefore, they are custom made.

Custom fitting is the key issue, and it entails taking measurements, inquiring about individual physical activities, analyzing gaits, and monitoring the characteristics of the patient to be fitted to determine the optimal design for the fit. Taking measurements is one of the most critical phases in orthotic fitting. Tolerance for thoracolumbosacral orthosis (TLSO) fitting is described in a questionnaire later in the article. The questionnaire was conducted to study the similarity between the conventional and the proposed methods as well as get expert opinions and advice regarding the application of the proposed method. Acquiring patients' geometric measurements accurately and conveniently is the focus of the method presented herein. This report demonstrates how this can be conveniently performed for certain cases by incorporating state-of-the-art imaging using CT/MR.

Fitting a patient with a TLSO brace requires making a jacket to be worn by the patient around the torso. The jacket is designed to closely represent the anthropometric measurements of the patient and is usually made out of a polymeric material. Casting a patient produces a negative impression of the torso, which is then imaged using an optical or tactile machine (Arthur Finnieston Group of Clinics, Coral Gables, FL, U.S.A.). The digital dimensions thus obtained are then input to a computer-aided design/computer-aided manufacturing (CAD/CAM) system for modification and machining (1) (Arthur Finnieston Group of Clinics). A user operating CAD software is able to carry out all the required modifications visually on the model. Modifications include smoothing, cutting, or extending the model as well as modifying a region for a particular purpose, such as a relief for a protuberance. Other corrective procedures are also carried out that are extremely difficult to produce manually. For example, angular corrections required in scoliosis cases are easily performed on the software where virtually any degree of gradual adjustment can be applied to the corrective jacket. After the modification phase, the model is then ready for milling, which usually takes place on a computer numerical control (CNC) machine where a positive model representing the torso is produced.

To fit trauma or postoperative patients using the casting method may be risky and could introduce further injury. Such cases can be handled by using an approxi-

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mate method of taking measurements, without casting, and then producing a model. Trauma and postoperative cases could be easily fitted using the method presented as, most of the time, a CT or an MR scan exists for the patient. CT/MRI provides accurate planar measurements (2,3), and consequently accurate 3D representation would be accessible.

A few difficulties exist in acquiring anatomic information using CT/MR scanning. CT describes volumetric elements, known as voxels, by assigning Hounsfield units to them depending on their density. Therefore, two different organs or voxels within the same body having similar densities will have similar Hounsfield units. Also, within the same body, a specific organ may vary in density; for example, spine density varies with position. Similarly, the same organ might have different densities among different people. Even though ranges of Hounsfield units are known for different structures such as bone, muscle, and skin, the CT/MR scans for a particular patient can be on film where Hounsfield units will not be available. Hounsfield units would be accessible only if the images were transferred electronically from the CT or MR scanner. Hence, image processing is used, and a software program was developed that incorporates an image-processing algorithm for the extraction of geometric and anatomic information embedded in CT/MR images. The output of the program is a 3D cylindrical reconstruction of the human torso. A pilot study and an experiment were conducted to test the feasibility of the method.

To depend on CT/MR for geometric measurements, pioneering experiments were conducted to establish the accuracy and repeatability of these modalities (2,4). Validation of spiral CT was attempted on transtibial amputees (3), and volumetric information obtained by spiral CT was shown to be manageable in solid modeling (5). Similarly, assessment of mass properties of parts of the human body was also targeted (6). Self-fitting modular orthoses have been designed and analyzed (7).

PROCEDURE AND INSTRUMENTATION

After a few preliminary tests aiming at establishing the feasibility and validity of using CT/MR as a means of acquiring geometric and anatomic information about sections of the human body, a methodology was developed that comprised three stages: image acquisition, image processing, and import of numerical information.

Image Acquisition

In the first stage, image acquisition can be performed using electronic transfer or by optically scanning the CT/MR films on a special optical scanner. If the orthotic clinic and the CT/MR center are equipped with electronic transfer capability, the CT/MR scans can be easily downloaded to the clinic. This is one way of acquiring scans of a patient. The nonproprietary DICOM (Digital Imaging and Communications in Medicine) standard can be used only in the case of an electronic infrastructure. However, as not all clinics and not all CT/MR centers have such an electronic option readily available, a second solution was introduced, which is to optically scan the CT/MR films. Scanning the CT/MR films is performed on large flatbed scanners specifically designed for this purpose. CT/MR films are a reliable means of acquiring patients' measurements. Correspondingly, optical scanners have high scanning resolutions that meet practical requirements.

In case film scanning is required and to optically acquire patient geometric information from film, two procedures were developed, customized, and seamlessly incorporated to the methodology developed for the purpose of complementing the image acquisition phase.

Automatic Scan and Slice-Up of CT/MR Films

The first procedure was developed to acquire digital images from CT/MR film using an optical film scanner. This procedure controls and operates an optical film scanner, specifies the various scan parameters such as image size and resolution, and handles the image transfer from the optical scanner to the computer. To implement this procedure, information had to be acquired from the manufacturer of the optical scanner (Howtek Inc., Hudson, NH, U.S.A.) (8). A typical CT/MR film has 12 cross-sectional slices arranged in a 3×4 format. This procedure, which can handle variable image sizes at various resolutions, has the capability of slicing up the optically scanned image into its 12 CT/MR slices.

Automatic Gray Bar Detection

The second procedure was devised to automatically detect the gray bar on CT films for registration and alignment purposes (9–18). The gray bar appears to the left of each CT slice and is made up of gray scale squares varying in shade from white to black. This procedure implements the nearest neighbor technique (19) for recognition. The gray bar detection is used to accurately adjust and align each of the 12 slices on a film with respect to a fixed position and orientation taking the gray bar as a reference.

Image Processing

The second stage comprises an image-processing procedure targeted at extracting the patient's geometric and anatomic information from CT/MR scans. It uses image-processing techniques to obtain the required information embedded in the digital image. This stage employs such techniques as smoothing, thresholding, and edge detection using a Laplacian filter (20,21). It addresses the serial slices one at a time and then performs a 3D reconstruction of the whole-body segment based on the individual serial contours. This resulting 3D model is a cylindrical system represented by radius, angle, and height (r, θ, z) defined in the right-hand coordinate system (22,23). Although serial contours can be reconstructed into a 3D model using triangular tiles (24), this methodology uses rectangular elements. Splining is applied using standard Bezier techniques (25). The equations used for smoothing, edge detection, and thresholding are shown next.

Smoothing:

For every pixel $P_{i,j}$ (21), compute the new value using

$$P_{i,j} = \frac{P_{i-1,j-1} + P_{i-1,j} + P_{i-1,j+1} + P_{i,j-1} + P_{i,j} + P_{i,j+1} + P_{i+1,j-1} + P_{i+1,j} + P_{i+1,j+1}}{9}$$

$$P_{i,j} = \frac{1}{9x}$$

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

Edge Detection (Laplacian Filter), Continuous Function:

A second-order gradient (Laplacian) (21) is defined as

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

Edge Detection (Laplacian Filter), Discrete Function:

For every pixel $P_{i,j}$ (21), compute the new value using the Laplacian filter equation

$$P_{i,j} = -P_{i-1,j} - P_{i,j-1} + 4 * P_{i,j} - P_{i,j+1} - P_{i+1,j}$$

$$P_{i,j} =$$

$$\begin{matrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{matrix}$$

Thresholding:

For every pixel $P_{i,j}$ (20) , compute the new value using the equation

$$\text{If } P_{i,j} \geq \textit{threshold}, \text{ then } P_{i,j} = 255, \quad \text{else } P_{i,j} = 0$$

Import of Numerical Information

Numerical information obtained in the previous stage is then input to a CAD/CAM system for further modification such as spinal correction (Arthur Finnieston Group of Clinics). This stage comprises two steps: segmental correction using spine reconstruction and segmental correction using X-ray measurement. The amount of segmental correction is clinically determined by a certified orthotist depending on the patient's anatomic constraints. For these modification cases, two procedures have been developed and customized to complement the import of numerical information phase. These two procedures are also incorporated into the methodology.

Segmental Correction Using Spine Reconstruction

In this modification step, the orthotist is assisted in a 3D reconstruction of the spine. This step is used for spinal correction purposes where the orthotist specifies which slices to include in the spine reconstruction process. This procedure was developed to assist the orthotist in accurately representing the spine relative to the reconstructed brace. Using this procedure, the orthotist is allowed a 3D manipulation of the spine and can determine quantitatively the amount of spinal correction required for the patient.

Segmental Correction Using X-Ray Measurement

In some cases, X-ray scans are also available for orthotic patients. For such cases, a spine-measuring procedure was developed to allow the orthotist a rapid determination of the degree of spinal correction required and to automatically transfer this information to an orthotic CAD/CAM system.

Optical Scanner

The optical scanner used in this study is a Howtek 14 × 17 in flatbed scanner. The films to be scanned are placed one at a time in full length on the scanner, and the output is a digital image of the whole film. The specifications of the scanner state that the user may scan films in a variety of resolutions. The resolutions supported by the manufacturer are 64, 73, 102, 128, 170, 256, and 512 dots/in (dpi). The horizontal resolution may be different from the vertical resolution within the same image. A typical resolution used in the runs is 128 dpi. This resolution was selected after a trial-and-error search, and it was found to yield enough image details without producing large file sizes. This resolution was used horizontally and vertically to preserve the aspect ratio of the images. To validate the accuracy of the dimensions yielded by the optical scanner, it is required to show that when an object is optically scanned on the scanner, its dimensions are precisely represented by the resulting scanned image. An experiment was performed where two rectangles of known dimensions were optically scanned on the flatbed scanner. The lengths and widths of their sides imaged and computed in software were compared with those exactly measured using high-precision calipers. The process of physically measuring the rectangles using the calipers was repeated four times, and the average dimensions were calculated. The results are shown in Table 1.

As is logically expected from a typical experiment involving human activities, the error is expected to exist around the exact measurement, either above it or below it. It can be argued that the statistical mean of the error is zero, which makes this error level acceptable in a real-life application.

TABLE 1. *Average computed dimensions*

	Rectangle 1	Rectangle 2
Exact width (in)	3.547	2.005
Exact length (in)	3.695	3.516
Average computed width (in)	3.539	2.004
Average computed length (in)	3.699	3.510
Percent width error	0.23	0.05
Percent length error	–0.11	0.17

Methodology Flow Chart

Electronic Transfer
1. If "Electronic Transfer" Go to 5 (Slice Serialization)
Film Scanning
2. Input number of CT/MR Films to Scan
3. Optically Scan CT/MR Films
4. Cut Scanned CT/MR Films into Slices
5. Serialize Slices starting at 000
Check Configuration
6. Edit Configuration (input parameters, slice thickness, output resolution, etc.)
Slice Construction
7. For Each Construction Slice
7a. Compute Histogram
7b. Compute Valley/Determine Peaks
7c. Select New Threshold from Within Range
7d. Smooth
7e. Threshold
7f. Detect Edge
Contour Generation
7g. Track Contour
7h. Validate Contour
If Contour Valid: Save Reconstructed Slice, Loop at 7 for Next Slice
Or If Done Go to 8
If Contour Invalid Loop at 7c for a New Threshold
Or If Not Possible Flag Slice for Interpolation or Manual Construction
3D Reconstruction
8. Specify Axial Resolution
9. Specify Angular Resolution
10. Reconstruct Cylindrical Model Using Saved Reconstructed Slices
11. Save Reconstructed 3D Cylindrical Model to Disk
Import of Numerical Information
12. User Assisted Spine Reconstruction, or
13. X-Ray Spine Measurement

EXPERIMENTAL PROCEDURE

A pilot study consisting of two CT data sets of the human torso was performed to establish the accuracy level of the method. It was then followed by a validation procedure. Then an experiment involving two MR subjects scanned at the torso was conducted. The two MR subjects undergoing the experiment were also cast to assess the accuracy of the method compared with the conventional casting. Each of the cases in the pilot study and in the experiment was a serial data set scan of the human torso. The pilot study was conducted on the scan data of anonymous subjects who were not accessible to undergo casting. Therefore, a validation procedure was devised to verify the results yielded by the pilot study. The experiment was conducted on two actual subjects who were scanned on an MR scanner and who were cast in the conventional manner. Their models were reconstructed using the method, and then the dimensions of the reconstructed models were compared with their cast counterparts.

Pilot Study

The pilot study was conducted on two CT data sets of the human torso. During this pilot test, the anatomic dimensions of the torso were successfully reconstructed into their original shape. The dimensions of the reconstructed slices have been tested against manual digitization of the same slices as the subjects were not available to be cast. Four digitization runs were performed for each reconstructed slice tested as a method of validation. Two full CT scan sets of the human torso belonging to two different subjects were used in testing. The 3D reconstructed models corresponding to each scan set were obtained by applying the method. Figure 1 shows a 3D rendering of the reconstructed cylindrical models pertaining to the first and second pilot subjects. The error in volume due to reconstruction and compared with manual digitization was determined to be <1.8%.

Experiment

Two male subjects provided informed consent to undergo an MR scan. The subjects were 32 and 33 years old. The MR scanner used in the experiment was a Siemens Magnetom Vision (Radiology Department, HealthSouth Doctors' Hospital, Coral Gables, FL, U.S.A.). The scan specifications for each of the subjects were as follows: The scan ranged 500 mm covering the sternal notch to the hip bone with 125.0 ms TR and 4.8 ms TE. Each scan consisted of 100 slices equally spaced at exactly 5 mm. The FOV contained the torso with no clipping. The subjects were scanned with their arms overhead. Each scan consisted of 10 sections, each scanning 50 mm of the 500 mm range. To minimize the effect of breathing, the subjects were required to inspire and hold their breath during the duration of each section of the scan. Each of the 10 sections of the scan was 22 s in duration. Each scan included a scout showing the exact positions of the slices. The scans were obtained on film in a 3 × 4 format. The films were then optically scanned on a special optical film scanner at 128 dpi. The 12 images on each film were separated by software into serial slices making up a data set for each subject. Reconstruction was then applied to each data set, yielding

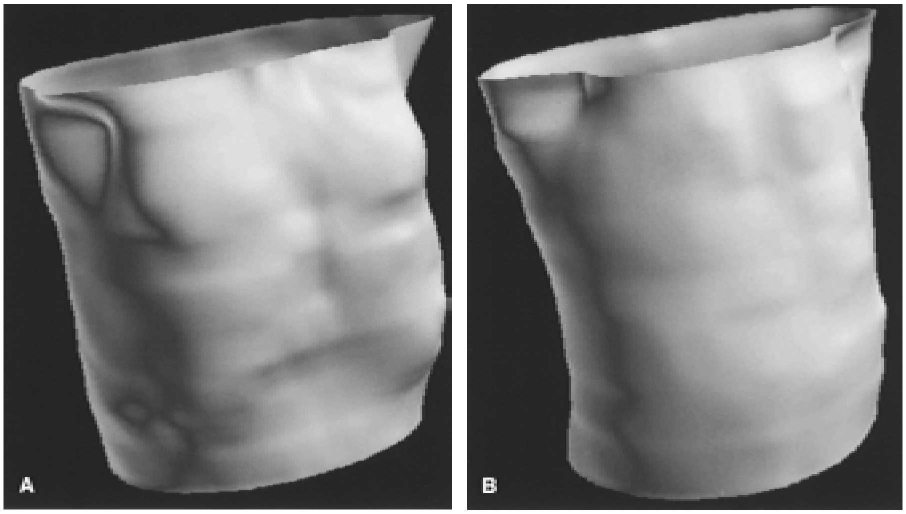

FIG. 1. A: 3D rendering of the reconstructed cylindrical model pertaining to the first pilot subject. **B:** 3D rendering of the reconstructed cylindrical model pertaining to the second pilot subject.

the results shown next. The subjects were cast in the conventional way orthotic patients are cast. The subjects were cast in a supine position by two certified orthotists (Arthur Finnieston Group of Clinics). Landmarks were taken on each cast, representing reference planes for comparison with the MR reconstructed models. Landmarks were placed by the certified orthotists based on their position in the MR scout scan. Care was taken to position the landmarks on the cast as accurately as possible compared with their counterparts on the scan. The casts were then digitally imaged using a four axis laser imager yielding a 3D cylindrical (r, θ, z) model. As shown in step 6 of the methodology flow chart described above, 3D reconstruction of the model can be achieved with a user-specified resolution. During reconstruction, splining and interpolation are applied to the reconstructed slices to make the output resolution independent of the number of slices in which the scan is performed. The reconstructed and the cast models were represented by 21,600 3D points each.

RESULTS

The volume and dimensions of the casts were taken as the reference volume and dimensions as casting is a time-proven technique of acquiring patient geometric information. The MR reconstructed models were compared with their cast counterparts on the basis of volume and circumferential values. Table 2 shows the volume of each reconstructed experimental model in comparison with that of the corresponding cast. Table 3 illustrates a comparison between circumferential values at three key planar levels on each reconstructed experimental model and their counterparts on the cast. A statistical analysis using the t test (26) was conducted to establish the insignificance between reconstructed and cast circumferences. Table 4 displays the statistical results of the test. Figure 2 shows a 3D rendering of the reconstructed model and of its corresponding cast for the first experimental subject. Similarly, Fig. 3 shows a 3D rendering of the reconstructed model and of its corresponding cast for the second experimental subject.

TABLE 2. *Volumes of experimental models, reconstructed versus cast (mm^3)*

	Reconstructed	Cast	Error (%)
Subject 1	21.031×10^6	21.399×10^6	2.85
Subject 2	19.441×10^6	19.854×10^6	2.08

DISCUSSION

This section addresses two areas: discussion of the experimental results and a questionnaire conducted with three certified orthotists and a certified prosthetist.

Experimental Results

This experiment yielded relatively accurate volume and circumferential measurements compared with those obtained by the conventional casting method. The volume accuracy achieved by using the proposed methodology was better than 97%, making it a reliable method for volume determination. Circumferential accuracy, on the other hand, achieved a little less than 97% when the

TABLE 3. *Circumferences at three planar levels, reconstructed versus cast (mm)*

	Reconstructed	Cast	Error (%)
Subject 1			
Proximal plane	1,167.64	1,173.99	0.54
Distal plane	980.17	951.23	−3.04
5 in above distal plane	1,013.71	1,022.10	0.82
Subject 2			
Proximal plane	1,062.99	1,051.56	−1.09
Distal plane	972.82	942.34	−3.23
5 in above distal plane	1,006.10	1,003.81	−0.23

TABLE 4. *Statistical* t *test performed on reconstructed versus cast circumferences*

No. of reconstructed slices	240
No. of cast slices	240
Average of differences (theoretical) (in)	0.0
Average of differences (actual) (in)	−0.0062
SD	1.1064
Calculated experimental t value	−0.0865
Degrees of freedom v	239 (∞ infinity for table entry)
Tabulated t value at 0.01 significance	$t < -2.576$ and $t > 2.576$

Difference in circumferences is insignificant at 0.01 level.

worst case is considered. The reason why circumference measurement provided a little less accuracy than volume measurement is because circumferences make up the lower-level building blocks of the 3D model. Their reconstructed values may fluctuate because of possible patient movement or noise artifact in comparison with their cast reference values. As this fluctuation is around a mean error level, assembling the slices together to form a 3D model tends to even out this fluctuation, yielding a little more accurate volume calculation.

Another source of error in general is the accuracy in placing and digitizing landmarks. Landmarks are used to define delimiting planes that enclose the volume of interest. Placing and reading landmarks are performed manually by the orthotist casting the subject. Even though as much care as possible is taken to accurately position them, there is a limit to human accuracy. Furthermore, skin is flexible and has been proven to stretch and extend (27–30). Skin flexibility can cause it to undergo some change in geometry during the casting process. Landmarks are placed on a gauze material that the subject wears before being cast. Casting involves wrapping the subject and adjusting his/her posture throughout the process, which can inevitably introduce slight error to landmark digitization.

Considering the sources of errors, the method discussed can be a potential alternative to conventional anatomy-measuring techniques. Spiral CT causes less radiation than conventional CT for the same longitudinal resolution (31). This would reduce the risk involved in the scanning process. MR, on the other hand, does not involve radiation and can be used for anatomic measurement as well. MR, however, may not be an option for subjects with metallic elements in their bodies (18,32).

The subjects who participated in the experiment had a 500 mm range of scan. The reason for this limited range is that, unlike CT, MR scanners have less scan range. The MR scanner used in the experiment had a maximum range of 500 mm. However, the world's first 8 T whole-body MR system has been released to the market and is now used for medical research, imaging, and spectroscopy (33). Scanners with such a large range would eliminate the restriction of scanning only a section of the body, thus extending the scope of orthotic applications.

Cost Issues

CT scanning applied to diagnostic radiology can be made more affordable with the use of spiral CT technology. Spiral CT possesses equivalent image quality to that of conventional CT with respect to the majority of parameters (34,35). In fact, spiral CT offers better 3D contrast and spatial resolution (36). Moreover, as spiral CT gathers data as the table is moving, more volume of the human body can be scanned in a single breath-hold. Consequently, the number of scans and breathing instructions that the patient follows is significantly reduced (36,37). In general, a spiral CT scan session can be made relatively less expensive by having the patient spend less time in the scanner. The cost of the CT scan required would be even less than regular scans as it would not include the professional cost of a radiologist. In many trauma cases, a CT scan already exists for the patient; therefore, no additional cost would be incurred. Fitting trauma patients with orthoses using the proposed methodology would also reduce hospital stays. Considering all these factors, an overall cost reduction could be as much as 40–60%.

The proposed process is systematic; it does not vary with different orthotists. It is also efficient, taking typically 15–20 min start to finish before the model is ready for machining. The typical duration for a conventional

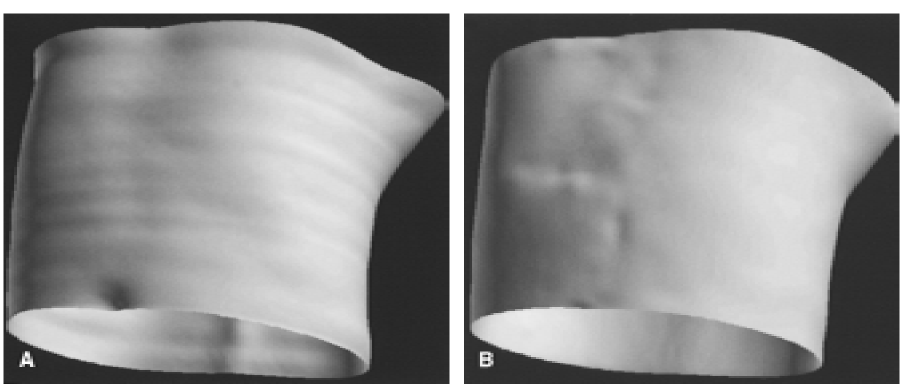

FIG. 2. A: 3D rendering of the reconstructed model for the first experimental subject. **B:** 3D rendering of the cast for the first experimental subject.

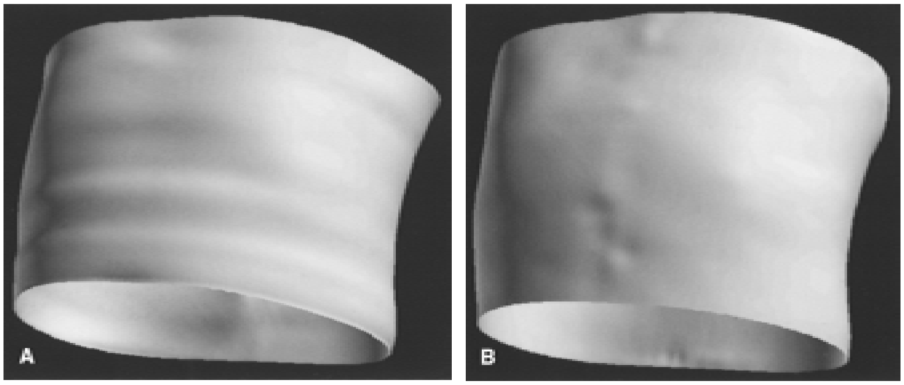

FIG. 3. **A:** 3D rendering of the reconstructed model for the second experimental subject. **B:** 3D rendering of the cast for the second experimental subject.

casting process takes approximately 2 h and requires the patient to be present. With the advent of telemedicine and teleradiology, the patient does not have to be at the clinic during fitting; only the patient's scan data are required.

Questionnaire

A questionnaire was conducted with three certified orthotists and one certified prosthetist. Technical issues and inquiries were raised and discussed. The questionnaire helps to explain how CT or MR scanning can be a practical way of acquiring patient geometric information. The outcome of the questionnaire is summarized below.

Being used as a corrective method, orthotic devices are allowed to be a little tight for better correction results. Orthotists maintain that up to −0.5 inches in circumference is acceptable. Some even state that up to a −1.0-inch difference in circumference is acceptable. This generally translates to about 2–4% accuracy (depending on the patient size). Typical accuracy demonstrated by the method discussed in this article is better than 3.1%.

Casting the patient is usually performed with the patient lying down. In this case, the patient is lying supine (face up), and, depending on the situation at hand, the patient is either lying flat on the back or supported at two places: the shoulders and the buttocks. This posture is similar to that assumed in a CT/MR scanner. Some orthotists cast their patient standing up where s/he remains standing for the duration of the cast. According to the orthotists interviewed, casting the patient lying down is practical because the patient can maintain a stationary posture more comfortably when lying down. Also, casting the patient lying down is at least as good as casting him/her standing up. In other words, there is no benefit the stand-up method achieves that the lie-down method does not. Measurements are generally checked at five key landmarks within the torso. These are circumference measurements that could be easily checked on a CT/MR scan.

All the certified orthotists and the prosthetist consulted with believed in the practicality of using CT/MR scanning as a means of acquiring geometric and anatomic information of a patient to bypass casting. As prosthetic fitting using CT has been addressed in the literature, they agreed that it would involve less patient preparation to scan for an orthotic fit than it does for a prosthetic fit. In scoliosis cases, it is sometimes difficult to cast the patient in the desired position. Using the patient's scan and applying the method would make it easier on the orthotist. The types of braces that could be used by applying this method include postoperative, scoliosis, kyphosis, and trauma.

Internal Structure

Other cases such as musculoskeletal deficiency could apply this methodology for other sections of the human body. The patient's exact anatomy is available during fitting, which enables the orthotist or prosthetist to take some characteristics into consideration. For example, a bony spur in the case of CT or a vascular problem in the case of MR with dye injection would be easy to spot. The availability of 3D spinal simulation would allow the methodology to be used as a graphical planning tool for surgery. A simulation of where to apply the hooks and rods may be even performed before surgery. The time factor would be improved with the use of scans in CAD/CAM.

CONCLUSION

The method presented herein has achieved its objective of proving its feasibility in achieving more efficiently what conventional techniques provide. It was also proved statistically accurate compared with the conventional casting method. An overall cost reduction could be achieved with its application. Costs attributed to radiologists' professional charges, hospital stays, and casting fees can be eliminated. The method is systematic and is invariant to the orthotist applying it. In general, it is characterized by its inherent ease of adaptation, low inception cost, efficiency, and accuracy. The method also targets the application of CT/MR in the field of orthotics; pioneers in the literature, to the best of the authors' knowledge, have targeted prosthetics.

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