OBJECTIVE

• Amputation of the thumb presents a serious insult to the hand and can result in diminished quality of life for the patient physically, vocationally, and possibly psychologically.
• According to the American Medical Associations Guide to the Evaluation of Permanent Impairment, loss of the thumb results in a 40% impairment of the hand, and a 36% and 22% impairment of the upper limb and whole person, respectively.
• An epidemiology study on limb amputation by Dillingham et al., revealed that the most common causes of limb amputation are trauma-related, dysvascular, and neoplastic. Over the nine-year study period, a total of 27,021 cases of thumb amputation were recorded and, as a result of the study, prospective studies estimate an average of 3200-3300 thumb amputations for the year 2010.
• To date, several different techniques have been explored for reconstruction of the thumb, such as lengthening, toe-to-hand transfer, pollicization, and osseointegration. In particular, osseointegration presents the most promising solution. However, despite good results, osseointegration procedures have been limited by the need to measure and develop an implant for each individual, as well as the requirement of a two-step procedure and lack of an ideally designed stem for skin interface.
• Due to the limitations of the currently available techniques for thumb reconstruction, a novel surgical approach is desired.
• The answer may lie in an osseointegrated percutaneous implant for the first metacarpal, which would provide a means of treating patients with thumb amputation and address the limitations of current techniques.
• In order to successfully create an osseointegrated prosthesis, the size and shape of the first metacarpal must be better defined.
• Thus, the purpose of this study was to define the geometry of the first metacarpal in order to help create a standardized set of stems and prosthesis to treat patients who have suffered amputation of the thumb at the level of the first metacarpal phalangeal joint (MCPJ).

METHODS

• A total of eighty first metacarpals were dissected from forty one cadavers and all soft tissues were removed.
• These metacarpals were then imaged with a computed tomography (CT) scan and three-dimensional models were constructed using cuts from the coronal, sagittal, and axial planes.
• Using HyperMesh software, the following measurements were taken:
  1. Overall Length - measured as the distance from the most distal and most proximal point on the external portion of the bone.
  2. Medullary Canal Diameter - major axis (lateral plane) and minor axis (AP plane) were measured separately for analysis. The medullary canal diameter was measured in four planes: distal, isthmus, center, and proximal. The distal and proximal planes were determined by translating toward the center, from each end, a distance of twenty percent of the overall length. The isthmus was defined as the center of the narrowest portion of the inner bone diameter.
  3. Cortical Thickness - measured in four planes (see medullary canal diameter). Measurements were taken at four equal points around the circumference of each plane, and then averaged for that specific plane.
  4. Radius of Curvature - measured using the calculated midpoint of the medullary canal at the distal, center, and proximal planes.
  5. Distance to Isthmus - measured from the distal end of the bone. The isthmus was defined as the center of the narrowest portion of the medullary canal.
• Data was then analyzed for use in development of standardized stems to fit the contour of an average first metacarpal bone.

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RESULTS

• Figure 1: Current osseointegrated stem, by Lundberg et al.
• The new proposed stem, which will be standardized and designed for improved skin interface.

Figure 1: A current osseointegrated stem, by Lundberg et al.

Figure 2: A wireframe model of the first metacarpal. Blue represents the outer cortex of the bone, and red represents the inner medullary canal. All four cut planes are also shown and labeled proximal (p), center (c), isthmus (i), and distal (d). The proximal end of the bone is at the bottom of the image.

Figure 2: A wireframe model of the first metacarpal

Figure 3: A 3D solid whole bone model image showing radius of curvature (r) as well as the four planes used for measurements (major axis). The proximal end of the bone is at the bottom of the image.

Figure 3: 3D solid whole bone model image showing radius of curvature (r) as well as the four planes used for measurements (major axis). (p) Proximal, (c) Center, (i) Isthmus, and (d) Distal. (The proximal end of the bone is at the bottom of the image)

Figure 4: A 3D solid whole bone model cut at the level of the isthmus. The cut view shows cortical thickness (c) in white, and inner bone diameter (d) labeled. The proximal end of the bone is at the bottom of the image.

Figure 4: A 3D solid whole bone model cut at the level of the isthmus

Figure 5: A graphical comparison between the left and right first metacarpal of nineteen different cadavers showing the average values and one standard deviation for each measurement. No statistically significant difference was found between left and right metacarpals (p > 0.05). All measurements are in mm.

Figure 5: A graphical comparison between the left and right first metacarpal

Figure 6: A bar graph comparing the average values and one standard deviation for each measurement taken of the first metacarpal for all of the data collected (N=80). All measurements are in mm.

CONCLUSIONS

• Amputation of the thumb presents a serious injury to the hand and results in considerable disability for the patient.
• Osseointegration is the process of direct skeletal fixation of a prosthesis by bone ingrowth around the implant. Lundberg et al. has shown that an osseointegrated percutaneous prosthesis of the first metacarpal could provide a reliable and effective means for treating patients with an absent thumb at the level of the first MCPJ.
• In order to develop a standardized set of stems and design an osseointegrated prosthesis for these patients, the morphometrics of the first metacarpal must be better defined.
• Here, we have measured several essential dimensions in order to provide an accurate analysis of the size and shape of the first metacarpal. This data will be invaluable for future standardization of the first metacarpal geometry and development of a set of stems and prosthesis.
• Importantly, the results of this study show a minimal degree of variance in most measurements. The data also demonstrates no statistically significant difference between left and right first metacarpals. The difference in male and female cadavers is shown in figure 6.
• The greatest limitation of this study is due to the subjective estimation of data points by the naked eye in locating the center of the isthmus and proximal and distal extremities of the bone. Care was taken to attempt to remain consistent with the placement of all points, but there will inevitably be some small degree of error with subjective measurements.
• Future studies will focus on selecting a more diverse sample size, particularly in regards to age, and create a standard method or form for placing the metacarpals when scanning them via CT. Additional considerations will help decrease any degree of measurement error in future studies.

REFERENCES