X-rays as Evidence in German Orthopedic Surgery, 1895–1900

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ABSTRACT

Historians have found it difficult to give a general account of the early medical use of X-rays in medicine. While the rays were hailed by some as a miracle technology, their early medical application was patchy, often remaining subsidiary to traditional methods of diagnosis and treatment, and was of disputed value. In this essay, I argue that the selective appropriation of the new technology needs to be understood within the wider medical practice of the period. The argument is developed around the case of orthopedic surgery in Germany, probably the first example in which doctors quickly made X-rays indispensable as a medical tool. I show that value of X-rays in this case was contingent upon an ongoing dispute, the theory and practice of surgical intervention, and the sociology of new surgical knowledge.

Received historical accounts of the early uses of X-rays in medicine contain an interesting ambiguity concerning the significance of X-rays as a diagnostic tool. On the one hand, these accounts chronicle and celebrate the widespread excitement generated throughout the international medical community by the unexpected arrival of X-ray photography early in 1896; on the other, they emphasize the limited diagnostic use to which the rays were put until roughly the end of the first decade of the twentieth century.[1] It has been suggested, for example, that X-rays marked, or even prompted, a major shift in progressive medicine, from hygiene and social improvement to "miracle technology," and that the "rapidity with which clinical researchers adopted this new tool for the analysis of medical conditions was unsurpassed." This line of argument sits somewhat uneasily, however, with

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The research for this paper was undertaken while I was on leave from Imperial College at the Max Planck Institute for the History of Science in Berlin. I would like especially to thank Otto Sibum and his group for hosting my visit and for providing the supportive intellectual environment in which I was able to develop a new avenue of research.

[1] Stuart Blume, *Insight and Industry: The Dynamics of Technological Change in Medicine* (Cambridge, Mass./London: MIT Press, 1992), pp. 22–31; Joel Howell, *Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century* (Baltimore/London: Johns Hopkins Press, 1995), pp. 103–107; Bettyann Holtzmann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, N.J.: Rutgers Univ. Press, 1997), pp. 38–69.

Isis, 2005, 96:1–24

0021-1753/2005/9601-0001$10.00

equally general claims, sometimes by the same authors, that the early use of X-rays was confined almost entirely to the detection of foreign bodies and fractures; that many doctors were suspicious of a technology that exemplified the new laboratory medicine and might therefore challenge their professional expertise; and that even in the case of, say, fracture diagnosis, X-rays were regarded for some years largely as a novelty offering little beyond traditional diagnostic techniques such as palpation.[2]

The latter arguments also illustrate a shift in the historiography of early medical X-rays that has taken place during the past decade. Whereas earlier studies focused on the progressive improvement and increasing diagnostic power of X-ray technology, more recent ones have tended to adopt the opposite tack. They question the assumption that X-rays offered self-evident pictures of internal damage or disease, ask why historians have *assumed* doctors would readily abandon entrenched diagnostic techniques that formed part of their clinical expertise, and argue that X-rays could not be widely used in hospital settings until appropriate professional spaces and medical rationales had been established.[3] This turn in historical writing is largely attributable to the forms of historical analysis that have recently been brought to bear on the case of X-rays. Thus it is social historians of medicine who have privileged professional status and social structure over technological innovation and self-evident medical progress, while historians drawing on the sociology and anthropology of scientific knowledge have emphasized the gradual and negotiated process by which agreement was reached over the medical meaning of X-ray images.[4] These studies have greatly enriched our understanding of how the uptake of new technologies in medicine is mediated by social and representational factors, but they tell only part of the story. If X-rays were initially of very limited application and of disputed value and were treated with hostility by many doctors, what drove their early advance and incorporation in medical practice circa 1900?

In this essay, I argue that understanding the highly selective uptake of X-rays in the first five years after their announcement requires us to situate their uses within the development of medical practice in the late nineteenth century. This strategy may sound obvious, but there are several reasons why it is far from easy to implement. First, despite the enormous expansion in history of medicine over the past thirty years, we still know relatively little about medical practice and the rise of scientific medicine in the decades around 1900. As has been pointed out by several leading figures in the field, professional historians of medicine, especially in the English-speaking world, have tended to focus on the subject's social history and to downplay issues concerned with everyday clinical and, especially surgical, practice.[5] The neglect of surgery's history generates special problems for under-

[2] Quotations, respectively, from Blume, *Insight and Industry* (cit. n. 1), p. 171; and Olga Amsterdamska and Anja Hiddinga, "The Analysed Body," in *Medicine in the Twentieth Century,* ed. Roger Cooter and John Pickstone (Netherlands: Harwood Academic Publishers, 2000), pp. 417–434, 418. See also Howell, *Technology in the Hospital* (cit. n. 1), pp. 107–109.

[3] On early histories of X-rays, see Monika Dommann, *Durchsicht, Einsicht, Vorsicht: Eine Geschichte der Röntgenstrahlen 1896–1963* (Zurich: Chronos, 2003), pp. 25–26.

[4] Recent studies drawing on the sociology of scientific knowledge include Bernike Pasveer, "Knowledge of Shadows: The Introduction of X-Ray Images in Medicine," *Sociology of Health and Illness,* 1989, *11:*360–381; idem, "Depiction in Medicine as a Two-Way Affair: X-Ray Pictures and Pulmonary Tuberculosis in the Early Twentieth Century," in *Medical Change: Historical and Sociological Studies of Medical Innovation,* ed. Ilana Löwy (Paris: INSERM, 1993), pp. 85–104; R. G. Arns, "The High-Vacuum X-Ray Tube: Technological Change in Social Context," *Technology and Culture,* 1997, *38:*852–890; Arne Hessenbruch, "Calibration and Work in the X-Ray Economy, 1896–1928," *Social Studies of Science,* 2000, *30:*396–420; and Dommann, *Durchsicht, Einsicht, Vorsicht* (cit. n. 3).

[5] On the social history of medicine and its lack of attention to medical sciences, see John Harley Warner,

standing the early history of X-rays since, as we shall see, in Germany at least it was surgeons who first found important medical uses for X-ray images. The second, related point is that while we now possess a very rich literature on the sociology of science and technology, work in what might be called the *sociology of surgical knowledge* has only recently begun to develop.[6] We still know relatively little about how new surgical procedures are developed and taught; how they are related to surgical skills, support staff, patients, instruments, and machines; how the credibility of new surgical procedures is not only established but also maintained in the face of criticism and alternative procedures; and how these various issues relate to the broader development of surgery as a specialty over historical time. Since X-rays were important to surgery precisely because they impinged upon several of these questions, the present study will implicitly raise a number of issues that relate to the history and sociology of surgery circa 1900.

In the following sections, I show that X-rays *were* adopted extremely rapidly by orthopedic surgeons in Germany, especially for the treatment of congenital dislocation of the hip. My study focuses on the latter example in some detail as it was not only a common and very debilitating condition but also the condition for which X-rays were first recruited to resolve a major medical debate. I believe this case warrants careful analysis as it contains important lessons for understanding the role of medical practice in the uptake of a radically new medical technology. We shall see, for example, that X-rays were not used merely as a diagnostic tool but quickly became part of the therapeutic process itself; that enthusiasm for the new technology depended on whether individual surgeons felt their therapeutic claims were likely to be helped or hindered by X-ray images; and that the use of X-rays produced new definitions of what constituted a satisfactory treatment. X-rays also changed the way surgeons sought to generate credibility among their peers for new surgical procedures. In the present case at least, methods such as collected case histories and public displays of live patients soon gave way to sequences of X-ray images as the new form of persuasive visual evidence. In the final section of the paper, I discuss how these developments relate to work to date in the sociology of surgery. It is by highlighting the interplay between a new kind of medical image, an ongoing medical debate, and changing forms of medical therapy that this study offers a new approach to the early history of X-rays in medicine.

"Science in the Historiography of Modern Medicine," *Osiris,* 2d ser., 1985, 37–58; Michael Hagner, "Scientific Medicine," in *From Natural Philosophy to the Sciences: Writing the History of Nineteenth-Century Science,* ed. David Cahan (Chicago: Univ. of Chicago Press, 2003), chap. 3; and Roger Cooter, " 'Framing' the End of the Social History of Medicine," in *Locating Medical History: The Stories and Their Meanings,* ed. Frank Huisman and John Harley Warner (Baltimore/London: Johns Hopkins Univ. Press, 2004), pp. 309–337. The lack of serious historical attention to surgical concepts of disease and their relation to surgical practice is noted in Christopher Lawrence, "Democratic, Divine, and Heroic: The History and Historiography of Surgery" in *Medical Theory, Surgical Practice: Studies in the History of Surgery,* ed. Christopher Lawrence (London/New York: Routledge, 1992), pp. 1–42, 10.

[6] Notable contributions to the Historical Sociology of Medicine are David Jones, "Visions of a Cure: Visualisation, Clinical Trials, and Controversies in Cardiac Therapeutics, 1968–1998," *Isis,* 2000, *91:*504–541; Thomas Schlich, *Surgery, Science, and Industry: A Revolution in Fracture Care, 1950s–1990s* (Basingstoke/New York: Palgrave Macmillan, 2002); and Sally Wilde, " 'See One, Do One, Modify One': Prostate Surgery in the 1930s," *Medical History,* 2004, *48:*351–366. Studies of the sociology of contemporary surgical practice appear to be confined to Stefan Hirschauer, "The Manufacture of Bodies in Surgery," *Soc. Stud. Sci.,* 1991, *21:*279–319; and T. Pinch, H. M. Collins, and L. Carbone, "Inside Knowledge: Second Order Measures of Skill," *Sociological Review,* 1996, *44:*163–186.

ORTHOPEDIC SURGERY AND CONGENITAL DISLOCATION OF THE HIP

A major obstacle to understanding the meaning of X-rays in orthopedic surgery circa 1900 is the current lack of histories of the latter specialty in this period. I begin therefore with a brief outline of the discipline's development in Germany insofar as it relates to our current concerns. My attention will focus on surgeon's attempts to correct congenital dislocation of the hip as this issue is central to the discussion that follows. Orthopedic surgery in Germany underwent a major transformation in the last decade of the nineteenth century. From the 1850s until the late 1880s, German doctors played a far smaller role in developing surgical methods for treating congenital deformities in children than did their contemporaries in Britain, France, and the United States. This is somewhat surprising as, during the 1830s and 1840s, German doctors interested in orthopedics had been central to the development and popularization of the techniques of subcutaneous surgery. This field was based on tenotomy and myotomy, the cutting, respectively, of tendons and muscles as part of the process of correcting deformities.[7] However, the initial wave of enthusiasm for the practice seems to have waned (especially in the German universities) in the latter 1840s. This seeming loss of interest has not been fully explained, but it was partly due to the realization that the practice was of limited scope because of the pain it caused the patient and to the high risk of serious infection.[8] Over the next forty years, subcutaneous orthopedic surgery in Germany was confined mainly to the treatment of the extremities, while the majority of congenital deformities were treated, often by lay practitioners, using long-standing techniques of manipulation, massage, gymnastics, bandaging, plaster casts, splints, corsets, and other mechanical devices for stretching or compensating malformed body parts.[9]

According to received accounts, the resurgence of interest in Germany for treating congenital disabilities using so-called bloody procedures was prompted during the 1880s by two factors. The first was the introduction from the early 1870s of a new system of general health insurance. By the late 1880s, many parents of children born with birth defects could use medical insurance to cover the costs of treatment to correct the conditions. The second factor was that surgeons responded to this financial incentive by applying the new techniques of antiseptic and anesthetic surgery to develop major surgical interventions intended to correct deformities previously treated by the techniques mentioned above.[10] The most common congenital deformity faced by orthopedic surgeons was the so-called dislocation of one or both of a child's hip joints.[11] In this condition, the femur usually stood above its normal position (and might be slightly rotated) while both the ball and socket of the joint were usually malformed to a greater or lesser degree. This was a serious condition that, although not life threatening, impaired a child's posture and walking and normally became more debilitating with age. During the latter nineteenth century, two primary methods of treating the condition were developed, the so-called nonbloody (nonsurgical) and bloody (surgical) procedures.[12] The first deployed a variety of methods for pulling the ball of the

[7] For a contemporary account of the rise of "subcutaneous orthopedics" see C. C. Schmidt, *Encyklopaedie der gesammten Medicin* (Leipzig: Otto Wigand, 1842), vol. 6, "Tenotomie." See also August Rütt, *Geschichte der Orthopädie im deutschen Sprachraum* (Stuttgart: Ferdinand Enke Verlag, 1993), p. 24.

[8] This cannot be the whole explanation as surgeons in other countries continued to develop these techniques. See Rütt, *Geschichte der Orthopädie* (cit. n. 7), pp. 14–26.

[9] *Ibid.,* pp. 14, 29.

[10] *Ibid.,* pp. 19–30.

[11] Adolf Lorenz, "Allgemeine Erfahrungen über die mechanische Reposition der angeborenen Hüftverrenkung," *Berliner klinische Wochenschrift,* 1897, *34:*953–956. At this time the fetal joint was thought to "dislocate" in the womb.

[12] The terms *blutig* and *unblutig* correspond roughly to the English terms "surgical" and "nonsurgical," respectively. The term "surgical" referred to any *unblutig* treatment carried out in a clinic.

femur down to the level of the hip socket and then attempting to maneuver the ball and socket into the proper geometric relationship. These methods often improved the condition, but skeptics argued that improvement was temporary and due mainly to the femur's being brought to the correct level rather than to the proper formation of the joint. The surgical procedure sought to accomplish the same end by a mixture of cutting the tendons that held the dislocated femur above its proper position, reshaping the often-deformed ball, and deepening the shallow socket into which the ball was to be located. Attempts to establish successful surgical procedures of this kind were aided by the development of antiseptic and anesthetic surgery in the 1880s, but the procedures were widely regarded with the same scepticism as were the nonsurgical procedures.[13]

Before discussing the methods by which doctors tried to generate credibility for their new procedures, it will be helpful to introduce the two leading figures in the development of successful surgical and nonsurgical treatments for congenital dislocation of the hip. The first is Albert Hoffa, who did more than any other surgeon to establish orthopedics as a recognized medical specialty in Germany. Born in 1859, Hoffa studied medicine at the universities of Marburg and Freiburg before moving to Würzburg in 1883 to become assistant to the professor of surgery at the university clinic. It is currently unclear exactly when and why Hoffa developed an interest in orthopedic surgery, but by 1886 he was offering lectures on, among other subjects, fractures, dislocations, and bandaging. In 1887, he traveled around Europe to improve his knowledge of orthopedic surgery and opened a small private clinic in Würzburg. Over the next twenty years, Hoffa built up a very substantial private practice; many of his surgical assistants went on to become leading members of the next generation of orthopedic surgeons. Renowned for his surgical skill, personal charisma, and capacity for hard work, Hoffa rapidly became the leading exponent of the new discipline of orthopedic surgery in Germany. Indeed, both the textbook he published in 1891 (*Lehrbuch der orthopaedischen Chirurgie*) and the journal he founded in 1892 (*Zeitschrift für orthopaedische Chirurgie*) played key roles in establishing and defining the new field.[14]

For our present purposes, the most important of Hoffa's numerous surgical accomplishments was the introduction in 1889 of what was widely regarded as the first successful procedure for surgically correcting congenital dislocation of the hip. Hoffa was well aware that many surgeons had tried and failed to perfect this operation. He claimed that his success was based on careful study of the pathological anatomy of the dislocated hip and on consideration of the treatment of clubfoot. At the heart of his procedure lay the surgical opening of the capsule surrounding the joint, the cutting of the shortened muscles and tendons that held the femur above its correct position, the artificial deepening of the underformed hip socket, and the manual replacement of the reshaped ball of the femur in the socket. The operation was first carried out on 4 July 1889 and made public at the annual congress of the German Society for Surgery in April 1890.[15] The first published account of the operation appeared in the society's transactions in 1890, but it probably became

[13] For an overview of these developments, see Bruno Valentin, *Geschichte der Orthopädie* (Stuttgart: Georg Thieme Verlag, 1961), pp. 117–134.

[14] Hoffa's life and work is discussed in N. Buschinger, "Albert Hoffa: Eine biographische Darstellung und Interpretation seines Lebens und Wirkens in Würzburg" (Inaugural-Dissertation der Hohen medizinischen Fakultät der Julius-Maximilian-Universität Würzburg, 1971, unpublished).

[15] Albert Hoffa, "Zur operativen Behandlung der angeborenen Hüftgelenksverrenkungen, mit Krankenvorstellung," *Verhandlung der Deutschen Gesellschaft für Chirurgie,* 19th Congress, 1890, pp. 44–53, 46.

generally known through the accounts given in the first and second editions of Hoffa's widely read textbook on orthopedic surgery.[16]

The other person who played a key role in the development of hip surgery in the 1890s was the Viennese surgeon Adolf Lorenz. A near contemporary of Hoffa's, Lorenz began his academic career with the study of anatomy at the University of Vienna, before moving to the university's surgical clinic in 1882 to study surgery under the renowned Eduard Albert. Working as Albert's assistant, Lorenz intended to become an abdominal surgeon but was forced to switch to the so-called dry surgery of orthopedics when he found he was allergic to the carbolic spray then widely used as an antiseptic.[17] Like Hoffa, Lorenz traveled through Europe to learn new techniques for treating orthopedic conditions and opened his own private clinic in Vienna. Unable to practice as a surgeon, Lorenz spent much of the 1880s developing nonsurgical techniques, most notably that of *modeling redressment* by which he successfully treated clubfoot. The key to this technique was the gradual correction of a deformity using a mixture of massage, mechanical devices, and plaster casts.[18] At the beginning of the 1890s, surgeons in Vienna began to abandon the carbolic spray in favor of the new technique of aseptic surgery, and Lorenz was once again able to use surgical methods when necessary.[19]

Lorenz began carrying out Hoffa's hip operation in 1892 and soon modified the procedure to protect some of the muscles that Hoffa routinely cut. The publication of these modifications and further experience with the operation were to have an important impact on Lorenz's career. He quickly found himself embroiled in a sharp exchange with Hoffa, who claimed that Lorenz had contributed nothing of real significance to his original technique. One of Hoffa's assistants, Alfred Schanz, added in print that any procedure that sought to replace the reshaped ball of the femur in an artificially deepened hip socket was essentially Hoffa's procedure and that Lorenz's proposed modifications were, in any case, already known and used in Hoffa's clinic insofar as they were useful.[20] These complicated and contentions issues were later settled amicably but, in the mid-1890s, Lorenz's implicit criticism of Hoffa's method generated some tension between these emergent leaders of orthopedic surgery in the German-speaking world.[21] It was also of great importance to Lorenz that in the early 1890s he lost the lives of three children as direct or indirect result of carrying out the operation. Bearing in mind that congenital dislocation of the hip was not a life-threatening condition, Lorenz developed serious concerns about recommending Hoffa's procedure and began to seek a nonsurgical means for achieving the same end.[22]

[16] See Albert Hoffa, *Lehrbuch der orthopaedischen Chirurgie* (Stuttgart: Ferdinand Enke, 1891), pp. 515–537. Editions 2, 3, and 4 appeared, respectively, in 1894, 1898, and 1902. References to Hoffa's operation normally refer to his textbooks rather than his research papers.

[17] Lorenz's life and work are discussed in Norbert Steingress, *Adolf Lorenz 1854–1946: Etappen eines langen Lebens* (Vienna: Wiener Medizinische Akademie, 1997).

[18] *Ibid.,* p. 29.

[19] According to Lesky, aseptic surgery was introduced to Vienna in 1891. Erna Lesky, *The Vienna Medical School of the 19th Century* (Baltimore/London: Johns Hopkins Univ. Press, 1976), p. 439.

[20] Albert Hoffa, "Review of Lorenz (1895)," *Deutsche medicinische Wochenschrift,* 1896, *22:*73–75, 74; and Alfred Schanz, "Zur blutigen Reposition der angeborenen Hüftverrenkung," *Zeitschrift für orthopaedische Chirurgie,* 1896, *4:*207–246, 234.

[21] By mid-1897, Hoffa was prepared to acknowledge that Lorenz deserved the highest praise for insisting on the importance of complete muscle protection during the surgical relocation of the hip. Albert Hoffa, "Die Endresultate meiner letzten blutigen Operationen der angeborenen Hüftgelenksluxation," *Deutsche Medicinische Wochenschrift,* 1897, *23:*305–306, 326–331, 305.

[22] Adolf Lorenz, *My Life and Work: The Search for a Missing Glove* (New York: Charles Scribner's Sons, 1936), p. 98.

As I have already noted, procedures of this kind had long been tried, but none was generally regarded as satisfactory. What enabled Lorenz to succeed where others had failed was the anatomical knowledge of the dislocated hip he had obtained through carrying out the Hoffa procedure and his experience in using the technique of modeling redressment to treat club foot. Building on this expertise he developed the following series of stages for treating dislocation of the hip: (1) the femur was forcibly pulled down to the correct level; (2) the ball of the femur was manually manipulated into the partially formed hip socket (see Frontispiece); (3) the leg was prevented from spontaneously redislocating by holding it in a "froglike" position using a plaster cast; and (4) weight was gradually applied to the leg, a process which Lorenz believed would cause the joint spontaneously to grow into something close to normal form.

Lorenz's announcement in August 1895 that he had successfully carried out the new procedure some thirteen times prompted considerable surprise and dispute within the German-speaking surgical community. For one thing, he had just published a major treatise on the *surgical* treatment of the same condition. In this treatise, he mentioned in passing that a nonsurgical treatment was highly desirable but gave no indication that he was close to perfecting such a treatment himself.[23] This apparent change of tack perturbed his peers, who initially thought it very unlikely that a nonsurgical treatment could produce similar results to the surgical one. Moreover, although Lorentz's claims were initially taken seriously, he was soon accused of having copied them from an Italian surgeon, Agostino Paci, whom Lorenz had seen demonstrate an apparently similar procedure at the International Congress of surgeons in Rome in 1894.[24] Hoffa was prepared to acknowledge that Lorenz's treatment differed from Paci's but insisted that the former did not offer an effective alternative to the surgical procedure and, like Paci's treatment, merely eased the condition (probably temporarily) by pulling the femur down to the correct level.[25]

As Lorenz's nonsurgical procedure began to attract interest among orthopedic surgeons in 1895 and 1896, Schanz defended Hoffa's surgical procedure by claiming that while there remained differences of opinion concerning the details of the latter treatment, it was now agreed that an ideal therapy had to involve the repositioning of the dislocated ball in the natural socket and that this could only be achieved in the majority of cases through surgery. Schanz also emphasized that Hoffa was not an opponent of nonsurgical treatments and always tried such methods if he thought there was a reasonable chance they might succeed. This experience had merely confirmed, however, that nonsurgical procedures were rarely able to effect a permanent cure "in the anatomical sense."[26] By this Schanz meant that while a child's posture and walking were often improved, the joint had not been fully and permanently relocated. As the child grew older and heavier there remained a serious risk that the joint would become increasingly troublesome.

The debate over the relative merits of the surgical and nonsurgical treatments for congenital dislocation of the hip significantly raised the profile of orthopedics among surgeons.

[23] The method was, respectively, first mentioned in and then described in detail in Adolf Lorenz, *Pathologie und Therapie der angeborenen Hüftverrenkung* (Vienna/Leipzig: Urban and Schwarzenberg, 1895); and *idem,* "Über die unblutige Behandlung der angeborenen Hüftverrenkung mittels der funktionellen Belastungsmethode," *Centralblatt für Chirurgie,* 1895, *32:*761–764. In the latter, Lorenz mentions (p. 762) that his earlier references to the technique were intended to guarantee his claim to priority.

[24] Paci's work is discussed in Valentin, *Geschichte der Orthopädie* (cit. n. 13), p. 132. Lorenz's account of the dispute with Paci is given in Adolf Lorenz, *Über die Heilung der Hüftgelenks-Verrenkung durch unblutige Einrenkung und functionelle Belastung* (Leipzig/Vienna: Franz Deuticke, 1900), pp. 358–359.

[25] Hoffa, "Review of Lorenz (1895)" (cit. n. 20), p. 74.

[26] Schanz, "Zur blutigen Reposition" (cit. n. 20), p. 208.

According to Schanz, Hoffa's pioneering operation had begun such a wave of interest in orthopedic surgery that many surgeons were now actively seeking the ideal form of Hoffa's original procedure. Another of Hoffa's assistants, Paul Paradies, claimed in a similar vein that the combined success of Hoffa and Lorenz's efforts had made the surgical treatment of congenital hip dislocation "one of the most fruitful areas of aseptic surgery."[27] Indeed, by January 1897, when the debate had been further heated by discussion of the relative merits of nonsurgical treatments, one of Germany's leading surgeons, Franz König, complained bitterly that hip surgery was taking up far too much space in medical journals and time at medical congresses. König, who took a keen interest in orthopedic surgery, argued that the claims being made for the new treatments were premature and overblown. He noted somewhat pointedly that Hoffa's surgical operation was not always successful, that it was not suitable for all cases, and that quite a few children had died as a result of this nonessential surgery. It was therefore no surprise to him that Lorenz's new nonsurgical treatment was now being widely hailed as the procedure of choice. König regarded Lorenz's claims as highly improbable and said they reminded him of a child's understanding of the anatomy and mechanics of joints. He believed it unlikely that a strong and freely moving joint would form spontaneously around the relocated bones, and that, even if it did, it would take a lot more than a few months to prove the case. Casting further doubt on the motives of those at the heart of the ongoing debate, König concluded that "if one wanted deliberately to found an institute for the furtherance of one's own deeds, truly one could not set up anything better."[28]

These comments suggest that orthopedics was becoming an important and highly visible area of general surgery in the German-speaking world in the latter 1890s.[29] Hoffa and Lorenz had shown that orthopedic surgeons could provide quick and dramatic surgical treatments for conditions—especially congenital dislocation of the hip—previously treated by a range of largely nonsurgical and palliative methods. Lorenz's nonsurgical hip treatment indicated further that the anatomical knowledge gained through surgery could lead to similarly dramatic cures through new techniques of manipulation while the patient was anaesthetized. However, König's comments also raise the very important question of how surgeons sought to generate credibility for new procedures in the latter nineteenth century. We currently have no general account of how new operative procedures were devised in this period nor how their subsequent success or failure was judged by the rest of the medical community. Since the latter question is of considerable significance to the present study, I shall briefly outline the methods used by Hoffa and Lorenz.

A major factor in assessing the outcome of hip surgery in the early 1890s was the time it took for the efficacy of a treatment to become apparent. A patient could take several weeks to recover fully from an operation while the ongoing functional improvement of the joint could continue for many months or even years. Provided it did not immediately redislocate to a degree detectable by palpation, the joint's state had normally to be inferred from the improved walking and posture of the patient. This point is nicely illustrated by

[27] Paul Paradies, "Die operative Behandlung der doppelseitigen angeborenen Hüftverrenkung aelterer Patienten," *Zeitschrift für Orthpaedische Chirurgie,* 1896, *4:*258–283, on p. 258.

[28] Franz König, "Die congenitale Luxation des Hüftgelenks," *Berliner Klinische Wochenschrift,* 1897, *34:*21–22, on p. 21.

[29] Numerous overviews of the treatment of congenital hip dislocation appeared in the spring of 1897, especially in connection with the use of X-rays. See, e.g., Max Levy-Dorn, "Verwertbarkeit der Röngenstrahlen in der praktischen Medicin," *Deutsche Medicinische Wochenschrift,* 1897, *23:*119–122; and L. Wullstein, "Über Aufnahmen des Rumpfes durch Röngenstrahlen," *Berliner klinische Wochenschrift,* 1897, *34:*334–338.

Hoffa's initial announcement of his new procedure at the German Society for Surgery in 1890 in Berlin. Having outlined the steps in the operation and the various precautions that had to be taken, he used a mixture of photographs, two live patients, and two preparations from a patient who had died to convince his audience that the procedure really worked. Hoffa explained that he had first carried out the operation in July 1889, the patient being a two-and-a-half-year-old girl, Pauline Rottmann, who had suffered with double-sided hip dislocation. He had only operated on one side and, having brought the now three-and-a-half-year-old before his audience, invited them to compare the treated and untreated legs. Hoffa also emphasized that the almost normal form and movement in the treated joint had only developed over time. This, he argued, supported his belief that bones were capable of gradually adopting the normal form when they were loaded and used in the normal way.

The next patient Hoffa discussed, Alwine Eber, had also suffered with double-sided dislocation, but in this case Hoffa had operated on both sides. In order to establish the severity of the original disability, he showed the audience a photograph of Eber taken before the operation. Once again Hoffa outlined the intricacies of the case before bringing out the patient and inviting his colleagues not only to observe her improved posture and walking but also to feel the new joints to confirm that they were virtually indistinguishable by touch from those of a normal child. Hoffa's final piece of evidence consisted of anatomical preparations of the hip joints of a four-year-old child who had died of pneumonia two weeks after an operation to correct double-sided dislocation. Deaths of this kind provided the only circumstance in which the postoperative, anatomical effect of the operation could be witnessed directly. Hoffa used the preparations to show how the modified femur had been fitted into the artificially deepened hip socket, how firmly the former had remained in place, and how the movement of the joint was still limited because the joint parts had not had time to assume normal form. Here again he emphasized that for the joint to become normal the ball and socket had to "learn" through loading over time to "fit into each other."[30]

Lorenz used very similar demonstrations in his attempt to establish credibility for the new nonsurgical procedure. (See Figure 2.) He normally paraded a series of patients before medical congresses to illustrate either the outcome of recent operations or the advantages of new modifications to his procedure. Like Hoffa, he occasionally used preparations from patients who had died many months after an operation to show how a joint developed toward normal form when loaded in the normal way.[31] In the case of the nonsurgical procedure, there was an additional problem of credibility because most surgeons initially doubted Lorenz's claim of being able to relocate one or more joints by hand in a single sitting. The president of the German Society of Surgeons, Ernst von Bergmann, eventually sought to resolve this contentious issue by challenging Lorenz to carry out a public demonstration of the procedure before the society. Lorenz, in fact, gave several demonstrations of this kind, the most famous being one before the International Medical Congress in Moscow in the summer of 1897. On this memorable occasion the already tired Lorenz

[30] Albert Hoffa, "Zur operativen Behandlung" (cit. n. 15), p. 48. Hoffa routinely demonstrated numerous cases when he presented his recent surgical work. See, e.g., Albert Hoffa, "Über die Endresultate der blutigen Operation der angeborenen Hüftgelenksverrenkung," *Vereins-Beilage der Deutschen Medicinischen Wochenschrift,* 1896, *22:*190; and *idem,* "Die Endresultate meiner letzten blutigen Operationenen" (cit. n. 21), p. 306.

[31] Adolf Lorenz, "Über die unblutig-chirurgische Behandung der angeborenen Hüftgelenkverrenkung durch Reposition und functionelle Belastung," *Berliner klinische Wochenschrift,* 1896, *33:*530–531, 531; and *idem,* "Bemerkungen über die unblutige Reposition der angeborenen Hüftverrenkung, mit Demonstrationen an einem pathologisch-anatomischen Praeparate," *Münchener medicinische Wochenschrift,* 1898, *45:*1254.

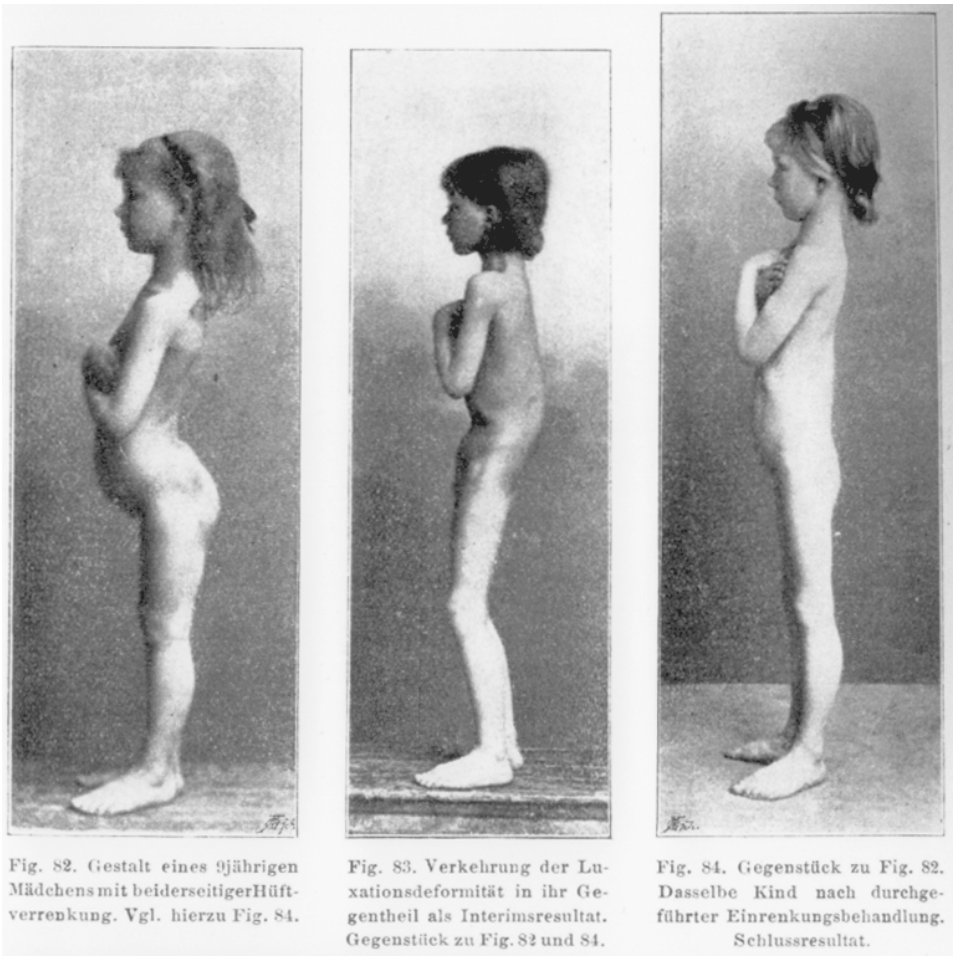

Fig. 82. Gestalt eines 9jährigen Mädchens mit beiderseitiger Hüftverrenkung. Vgl. hierzu Fig. 84.

Fig. 83. Verkehrung der Luxationsdeformität in ihr Gegentheil als Interimsresultat. Gegenstück zu Fig. 82 und 84.

Fig. 84. Gegenstück zu Fig. 82. Dasselbe Kind nach durchgeführter Einrenkungsbehandlung. Schlussresultat.

Figure 2. *This image sequence shows how the diagnosis and treatment (nonsurgical) of congenital dislocation of the hip were depicted as a visual display of the patient's whole body. The so-called Z-shaped stance of the nine-year-old girl on the left provided strong evidence that she was suffering from the condition. The middle image illustrates how the treatment initially overcorrects the faulty stance. The image on the right shows the final, successful functional result, following postoperative therapy. (From Adolf Lorenz,* Über die Heilung der Hüftgelenks-Verrenkung durch unblutige Einrenkung und functionelle Belastung *[Leipzig/Vienna: Franz Deuticke, 1900], 342. Reproduced by kind permission of the President and Fellows of the Royal College of Surgeons, London.)*

became completely exhausted while attempting to treat a difficult case in the heat of a packed lecture room. Fortunately, Hoffa, who was in the audience, came to Lorenz's aid and successfully completed the demonstration.[32] The nonsurgical procedure, which required special apparatus and several pairs of hands, was so alien to most doctors' clinical experience that both Hoffa and Lorenz eventually included a series of photographs in their textbooks showing key stages in the process. (See Frontispiece.)[33]

[32] Adolf Lorenz, *Über die Heilung* (cit. n. 24), pp. 18–19. This public display of camaraderie helped to heal the tensions between Hoffa and Lorenz. Further public demonstrations are mentioned in this passage.

[33] Lorenz, *Über die Heilung* (cit. n. 24); and Albert Hoffa, *Lehrbuch,* 4th ed. (1902), figs. pp. 494–496.

The other significant method of generating credibility for surgical procedures at this time was the publication of collections of case histories. Thus in the immediate wake of Lorenz's announcement of the nonsurgical procedure, Hoffa's assistant Schanz published an analysis of 135 surgical operations carried out over the previous five years by surgeons other than Hoffa and Lorenz. The purpose of the study was to show that Hoffa's procedure had been carried out successfully on numerous occasions in several European countries by surgeons who were nowhere near as "practiced" in the technique as were its originators. Schanz discussed the pros and cons of the minor modifications employed by different surgeons and sought to reassure his readers that deaths due to the operation were rare and mostly avoidable. He concluded that in most cases the procedure gave excellent results and that even in those cases in which the outcome was less than ideal the patient experienced a very definite improvement. The overall message was that surgical treatment provided the way forward and that any competent surgeon could safely and successfully treat congenital dislocation of the hip provided that he carefully followed Hoffa's prescription.[34]

Several aspects of these methods of assessing postoperative success impinge directly on the early medical use of X-rays. First, apart from the few exceptional cases in which a patient died following an operation, these assessments depended almost entirely on the *functional* improvement in the patient's walking and posture. This improvement could take months or even years to complete so that a speedy resolution to disputes over the relative merits of surgical and nonsurgical procedures, or indeed the efficacy of either, was very unlikely. Second, since the anatomical state of a joint could not be monitored directly, the condition of a joint following an operation had to be inferred from the functional improvement. It remained a matter of dispute, for example, whether a majority of joints actually redislocated to a small but undetectable degree following an operation, as did the question of whether such dislocation was significant. Third, the claim that functional improvement over time was due to the gradual formation of a healthy joint remained a controversial assertion that was very hard to prove. Thus the successful treatment of dislocated joints was not generally regarded as evidence that bones changed their shape in response to loading and use. These issues of evidence and credibility are extremely important because they not only prompted men such as König to criticize the apparently premature, overblown, and self-serving claims of some orthopedic surgeons but also provided a fertile ground for the use of X-rays as a new form of visual proof.

X-RAYS, VISUAL PROOF, AND THE LAW OF THE TRANSFORMATION OF BONES

It should be clear from the above discussion that the entirely unanticipated arrival of X-rays early in 1896 occurred at a very significant moment in the unfolding story of hip surgery. The relative merits and originality of the Hoffa and Lorenz methods of surgical treatment were being keenly debated, as was the efficacy and originality of Lorenz's new, nonsurgical treatment. Furthermore, it was the shadows cast by *bones* that were the most obviously discernable images in early X-ray pictures of the living human body. It is not surprising therefore that, at least in the German-speaking world, it was doctors concerned with bone pathology, especially orthopedic surgeons, who were among the first and most enthusiastic advocates of X-ray diagnosis.[35]

[34] Schanz, "Zur blutigen Reposition" (cit. n. 20).

[35] The interest of orthopedic surgeons is confirmed in Oskar Vulpius, "Zur Verwerthung der Röntgenstrahlen," *Deutsche medicinische Wochenschrift,* 1896, *22:*480–481, 480.

Yet even in this seemingly obvious area of application, the practical uses of X-rays took some while to develop. In late July 1896, for example, Oskar Vulpius, an orthopedic surgeon in Heidelberg, noted that little of real value had so far been published on the diagnostic use of the rays and that the initial wave of enthusiasm was fast giving way to a sense that the new technology might actually have rather limited applications. Vulpius attributed the growing sense of disillusionment to two main factors. The first was that doctors had soon discovered not only how difficult it was to obtain, build, and operate X-ray apparatus but also that most parts of the body were nowhere near as easy to X-ray as was the relatively thin, bony, and maneuverable human hand. The second was that in the majority of orthopedic conditions the relationships between the bones were so straightforward and accessible to palpation that X-rays seemed to offer little more than confirmation of what was already known. Vulpius suggested that X-rays might in the future be of use in diagnosing difficult cases of congenital dislocation of the hip and that it would be of "immense importance" if it were possible to use X-rays to track the change in bone structure that occurred in response to an alteration in the function of a bone in a living being. He concluded, however, that for the moment these possibilities remained "idle fantasy."[36]

Vulpius's remarks take us to the heart of how and why X-rays were rapidly drawn into the debate over hip surgery in the second half of 1896. In formulating their new surgical and nonsurgical treatments for hip dislocation, both Hoffa and Lorenz had drawn upon the research work of another orthopedic surgeon, Julius Wolff. Director since 1890 of the newly established Poliklinik for Orthopedic Surgery in Berlin, Wolff had devoted much of his career to experimental work aimed at understanding the relationship between the growth and function of bones in living creatures. His research had played a major role in replacing the long-established view that bones grew simply by increasing in size, with a new "law" of transformation, according to which the shape of bones was partly determined by the way they were loaded in use. This view eventually opened a "new era" in orthopedics by providing a rationale not only for procedures that normalized deformed bones through exercise and loading but also for those who relied upon "nature" to complete an orthopedic treatment begun by medical intervention.[37] The relocation of a congenitally dislocated hip was an excellent example of the latter case. Both the ball and socket of the hip joint were often very underdeveloped so that simply replacing them (surgically or nonsurgically) in the correct geometric relationship would not effect a satisfactory cure. When Hoffa announced his new surgical procedure in 1890, he accordingly claimed that if surgeons created the right "static relationship" between the bones then nature would create their correct form "according to the transformation law due especially to Julius Wolff." Hoffa also presented several of his patients to the congress, suggesting that the dramatic functional improvement of their joints that had taken place over the pervious months strongly supported the transformation law.[38]

Doctors without a vested interest in Wolff's claims would almost certainly have regarded this improvement as furnishing little more than circumstantial evidence. It is clear, however, that the postoperative development of the hip joint could provide a crucial test for the transformation law if it were possible to make the anatomical changes detectable. The

[36] *Ibid.,* p. 480.

[37] On Wolff's life and work, see G. Joachimsthal, "Julius Wolff," *Berliner klinische Wochenschrift,* 1902, *39:*203–204, 203.

[38] Hoffa, "Zur operativen Behandlung" (cit. n. 15), pp. 47–48.

nonsurgical procedure was especially significant in this respect as it brought the ball and socket into the correct geometric relationship without surgical alteration of their form. Wolff first saw Lorenz demonstrate his new procedure in April 1896, and it surely occurred to him—as it had to Vulpius—that the recently announced X-rays offered the possibility of tracking the changing form of the living joint over time. What is certain is that Wolff began carrying out Lorenz's procedure in June 1896 and that at the beginning of July the Berlin physicist Felix Buka sent Wolff two X-ray pictures, one of which showed, probably for the first time, the clear outline of the ball and socket of a healthy hip joint.[39] Wolff realized at once that it should now be possible to gather direct evidence for his law of bone transformation and within weeks had begun using the X-ray facilities of Buka and other Berlin doctors to photograph his patients before and after the nonsurgical procedure.[40] In September 1896, Wolff presented his preliminary findings to the surgical section of the annual meeting of German scientists and doctors in Frankfurt. Speaking on "the further application of X-rays in surgery," he devoted most of his talk to discussion of what could be learned from X-rays regarding the treatment of congenital dislocation of the hip by nonsurgical means. Wolff's remarks are of particular interest as this was almost certainly the fist time X-ray plates were used to illustrate discussion about the treatment of a major medical condition.

Wolff first emphasized that he intended to discuss a technique that had barely been mentioned in the extensive literature on the possible uses of X-rays in medicine. What he had in mind was the repeated X-raying of a "body part of one and the same living individual as an aid to research on otherwise difficult or insoluble scientific questions in the field of surgery."[41] Up until this point almost all X-ray pictures of humans had been used to depict the relative, static positions of bones and foreign objects. But the investigation of an operative procedure and its after effects suggested to Wolff that a comparison *between* pictures taken before, during, and after treatment would be of far greater value. An X-ray taken before treatment of a hip began could indicate the extent and nature of the dislocation as well as the relative development of the bony parts of the joint. Subsequent pictures would show how successful the operation had been in establishing the correct anatomical relationship between the femur and pelvis, whether the joint redislocated during the period of postoperative recovery and exercise, and most importantly for establishing Wolff's transformation law, how the components of the joint responded over time when loaded by the patient's walking.

Wolff began his demonstration by revealing Buka's remarkable photographs to his audience, noting that those who had only seen X-ray pictures reproduced in journals would be "quite astonished" by the "beauty and sharpness" of the original plates.[42] These pictures, he continued, had convinced him "that in X-rays we possess a reliable tool for the solution of a number of important questions that are currently attracting lively discussion among surgeons."[43] He then discussed the amount of detail that could be seen on the X-ray picture

[39] It is unclear why Buka made these pictures but see note 40.

[40] Wolff thanked several military doctors for the care they had taken making pictures of his patients in the Kaiser Wilhelm Academy. Julius Wolff, "Die Bedeutung der Röntgenbilder für die Lehre von der angeborenen Hüftverrenkung," *Fortschritte auf dem Gebiete der Röntgenstrahlen,* 1897/98, *1:*22–28, 130–136, 211–221, 224. The academy was probably the forum that brought surgeons and physicists together.

[41] Julius Wolff, "Zur weiteren Verwerthung der Röntgenbilder in der Chirurgie," *Deutsche medicinische Wochenschrift,* 1896, *22:*645–648, on p. 645. Wolff noted (p. 646, note 2) that a Prof. Goldstein had made similarly beautiful pictures of the hip joint at the Kaiser Wilhelm Academy.

[42] It is unclear how Wolff showed the pictures to his audience. He later projected them on a screen, but on this occasion it is likely that he showed the plates to his audience.

[43] Wolff, "Zur weiteren Verwerthung" (cit. n. 41), p. 646.

of a child's hip by relating the well-known anatomy of the normal juvenile pelvis to the subtle shadows on the plates. As a preliminary to discussing X-ray images of the deformed hip, he turned to the work of Hoffa and Lorenz and reminded his audience that their "assumption"—that the components of a repositioned joint would gradually assume the right form—had not been established for certain. Wolff acknowledged that he was "a priori of the opinion" that the assumption was correct, adding that he believed X-ray pictures would provide the necessary proof.[44] He also pointed out that X-rays not only made it possible to assess the relative merits of the various surgical and nonsurgical procedures for treating hip dislocation but also should in time enable those procedures to be carried out more effectively through continuous monitoring. Wolff was already convinced, for example, that Lorenz's nonsurgical procedure produced better results than those of which it was claimed by some to be a mere copy. He likewise cast doubt on the common claim that joints always redislocated following the Lorenz procedure but confirmed that such joints did partially redislocate more frequently than Lorenz himself had claimed.[45]

Wolff was unable at this point to provide persuasive visual proof for his law of the transformation of bones since the postoperative X-ray pictures he had thus far obtained had been taken just a few weeks after the operation. He nevertheless expressed his firm belief that X-rays would soon settle debates that might have taken "decades" to resolve using "our previous research methods." Thanks to Röntgen's "wonderful discovery," Wolff concluded, doctors could expect in the very near future to receive a clear decision on which method of treating congenital dislocation of the hip was the most effective. Wolff, in fact, believed a series of X-ray pictures to be of such value as a new investigative tool in orthopedic surgery that he was prepared to state that henceforth "every demonstration of the final results of our treatment must be accompanied by a presentation of the relevant X-ray pictures."[46] It should also be noted that Wolff did not, at least on this occasion, display any of his patients before the meeting, nor did he subsequently publish a series of case histories. What he offered was a new kind of visual display in which the *anatomical,* rather than the *functional* effect of the operation, became the main focus of interest. As we shall shortly see, this procedure was ideally suited to helping Wolff establish both his law of bone transformation and the efficacy of the nonsurgical operation.

THE FALL AND RISE OF LORENZ'S NONSURGICAL OPERATION

Wolff's claim that X-rays would prove the key factor in deciding the most effective treatment for congenital dislocation of the hip turned out to be correct, but his view that the decision would be quick was overly optimistic. Hoffa, too, had realized that X-rays could be enrolled as a powerful tool for comparing the outcome of the surgical and nonsurgical procedures, but he, unlike Wolff, initially found powerful support for the surgical operation. Since Hoffa's case makes an informative comparison with those of Lorenz and Wolff, I shall briefly outline how Hoffa initially obtained and utilized X-rays pictures.

We are fortunate that one of Hoffa's young medical assistants, August Blencke, left a detailed account of the early use of the new technology in Hoffa's clinic. Working in Würzburg, the town in which Röntgen had discovered X-rays, Hoffa would almost cer-

[44] *Ibid.,* p. 647.
[45] *Ibid.,* pp. 646–647.
[46] *Ibid.*

tainly have been among the first to appreciate their medical potential.[47] According to Blenke, Hoffa made every effort to introduce X-ray technology to his clinic as quickly as possible but took several months to obtain the necessary apparatus.[48] When it finally arrived, the young Blencke was put in charge of making X-ray pictures, and Hoffa made it clear that his first priority was to obtain an image of the relevant bones of a child suffering from congenital dislocation of the hip. As we have already seen, this was not possible with the technology generally available in the first half of 1896, but Hoffa initially attributed Blenke's failure to incompetent development of the photographic plates.[49] Hoffa eventually realized that the fault lay with the X-ray apparatus and only when a second, more powerful vacuum tube had been obtained was the desired picture finally produced. When Blenke first showed Hoffa a plate on which the relative positions of the ball and socket of a dislocated hip were faintly discernable, his "joy found no end" and he immediately fetched Röntgen to show him the advance.[50]

Blencke does not say exactly when he first obtained these pictures, but it was probably toward the end of 1896 or early in 1897. When, for example, Hoffa spoke at the Frankfurt meeting in September 1896, he made no mention of X-rays but supported the reliability of his surgical operation by displaying thirty children healed using his technique. Hoffa acknowledged that Lorenz's nonsurgical operation represented an important advance in orthopedics, even suggesting that doctors should routinely try this treatment first to see whether satisfactory results were obtainable. He cautioned, however, that one should not expect too much from a nonsurgical procedure, adding that for the more difficult cases his own surgical method continued to provide the best and most reliable alternative.[51]

By the spring of 1897, Hoffa had amassed a large number of X-ray images taken before and after both the surgical and nonsurgical procedures. When he addressed the Congress of the German Society for Surgery in April that year, he strongly emphasized the importance of X-rays to orthopedic surgery, and instead of parading patients before the meeting as he had previously done, he showed a large series of X-ray photographs. The pictures revealed not only that the femur always remained in place after the surgical operation but also that it was often hard at first glance to tell a treated joint from a normal, healthy one. By contrast, the X-rays he had taken after carrying out Lorenz's nonsurgical procedure seemed to show "without exception" that the joint subsequently redislocated to a greater or lesser degree.[52] When a text of Hoffa's Frankfurt address appeared in May 1897, it praised Wolff for having shown the importance of sequential X-ray pictures and expressed Hoffa's agreement that X-ray photographs should henceforth be regarded as a "very good criterion of the success of the [hip] operation." The text was accompanied by X-ray pictures he had subsequently taken of several of the patients he had displayed at Frankfurt. These

[47] Röntgen held a public lecture on X-rays before the Physical-Medical Society of Würzburg on 23 January 1896. The lecture included a demonstration of X-raying a human hand and made an enormous impact on the audience. See August Blencke, "Vierzig Jahre im Dienste der Röntgenstrahlen," *Radiologe,* 1995, *35:*302–310, 303. Previously unpublished notes for a talk given in January 1936.

[48] Unlike Wolff's physicist colleagues in Berlin, Röntgen seems to have taken little or no interest in helping with the medical application of his discovery.

[49] On one occasion, Hoffa locked Blenke in the darkroom and threatened to leave him there until he had produced the desired picture. See Blencke, "Vierzig Jahre im Dienste der Röntgenstrahlen" (cit. n. 47), pp. 304–305.

[50] *Ibid.,* p. 305.

[51] Hoffa claimed that the willingness of so many parents to bring their children to the meeting was a mark of the success of his operation. Hoffa, "Die Endresultate meiner letzten blutigen Operationenen" (cit. n. 21), p. 306.

[52] Albert Hoffa, "Address to the 26th Congress of the German Society for Surgery," *Berliner klinische Wochenschrift,* 1897, *34:*394.

images now provided the key resource for his claims that the surgical operation gave excellent anatomical results and could therefore be "recommended with good conscience" whenever the nonsurgical procedure failed.[53]

It is not surprising in the light of these developments that Lorenz's early response to the use of X-rays was somewhat more muted than that of his German peers. There can be little doubt that he had earlier access to good quality pictures than did Hoffa as Vienna, unlike Würzburg, was a major center of medical education and rapidly became a leading site for the application of the new X-ray technology.[54] For Lorenz, however, the arrival of X-rays initially proved something of a setback. The nonsurgical procedure had rapidly gained ground over 1895 and 1896 because it was easier and safer than the surgical operation and seemed to produce satisfactory functional results. A major drawback to Hoffa's surgical procedure was the damage to the joint and reproductive organs that could be caused by an inexperienced surgeon while deepening the socket with a knife. This problem did not arise with Lorenz's procedure but, as we have just seen, the X-ray evidence from late 1896 and 1897 indicated that the nonsurgical procedure did not constitute what was now being referred to by Hoffa and his assistants as an anatomical healing or cure.[55] If joints treated this way normally redislocated, then Lorenz's procedure was really little improvement on Paci's and did not constitute a long-term cure. Another problem for Lorenz's procedure at this time concerned the characteristic sound (*Einrenkungsgeräusch*) he claimed to be an important guide to surgeons that the femur had been successfully snapped into place. X-ray images now showed that this sound was often absent when the procedure had been successfully carried out, and, even more troubling, was sometimes heard when the ball and socket were far too underformed to lock together. An important and commonsensical hallmark of the nonsurgical procedure was thereby badly undermined.[56]

Lorenz subsequently admitted that these developments had presented a serious setback, causing him to delay publication of a planned treatise on the nonsurgical procedure. He continued to believe, however, that nonsurgical relocation was the way forward and resisted the notion that an anatomical cure, as revealed by X-ray evidence, should be the only touchstone of success. In the summer of 1897, he noted that his own X-ray pictures had revealed postoperative redislocations that were "not detectable through clinical investigation" but concluded that since "the functional results nevertheless leave little to be desired," the procedure should "obviously be judged according to the patient's walking and not the X-ray."[57] Lorenz believed that the functional improvement obtained, even in cases in which the joint could be shown to have slightly redislocated, would be permanent. His faith turned out to be well placed, but what he did not realize was that the ultimate acceptance of his procedure would depend to a considerable extent on the use of X-rays to monitor and control nonsurgical relocations.

The steps to this resolution are best traced through a large study by Julius Wolff on

[53] Hoffa, "Die Endresultate meiner letzten blutigen Operationenen" (cit. n. 21)," pp. 330, 331.

[54] On the collaboration between Viennese physicists and doctors, see Lesky, *Vienna Medical School* (cit. n. 19), pp. 303–307.

[55] Schanz, "Zur blutigen Reposition" (cit. n. 20), p. 208. Hoffa claimed in 1898 that the nonsurgical procedure rarely achieved a "real" repositioning and used X-ray illustrations to show that his surgical procedure achieved an anatomical healing ("*anatomische Heilung*"). Hoffa, *Lehrbuch,* 3d ed. (1898), pp. 579, 595.

[56] This issue is discussed in Hermann Kümmell, "Discussion über den Vortrag des Herrn Kümmell," *Vereins-Beilage der Deutschen Medicinischen Wochenschrift,* 1899, *25:*201–203, 202–203.

[57] Lorenz, "Allgemeine Erfahrungen" (cit. n. 11), p. 955.

what could be learned about congenital dislocation of the hip through X-ray images. In the first part of the study, published toward the end of 1897, Wolff strongly emphasized that a great deal of uncertainty continued to surround the treatment of the condition, especially as regards Lorenz's procedure. Why, for example, did the difficulty of relocating a joint vary so much from patient to patient? Why did treated joints sometimes redislocate and sometimes not? Why was a dramatic functional improvement often achieved even though X-ray pictures showed that the joint had partially redislocated? Would a joint automatically grow into a normal form once correctly aligned and loaded? The main point Wolff emphasized was that questions of this kind would "only be resolved in the foreseeable future, at least for the most part, if we approach these questions in the broadest way with the help of X-rays."[58]

By the time the final part of Wolff's study was completed in May 1898, he had reached a number of tentative conclusions regarding the questions he had posed nearly a year earlier. During this period, he had carried out numerous nonsurgical relocations, each under the control of X-rays, and arrived at the following conclusions. First, that the difficulty experienced in relocating a joint was due largely to the precise degree and nature of the dislocation. The latter could not be accurately ascertained by palpation but only by the use of X-rays. With this information the doctor could decide in advance how difficult the relocation was likely to be and exactly what technique was best adopted. Second, an X-ray picture taken shortly after treatment could reveal a redislocation that was too small to detect by palpation yet sufficiently large to warrant a second treatment. This led to a third and very important point. It was becoming clear that to achieve a good, long-term functional result, it was not necessary for the femur head to remain precisely at the site of the normal socket. It could slip a small distance away from this site yet still settle in a firm and permanent position. Only through experience in judging X-ray pictures could a doctor estimate whether the relative positions of the ball and socket were likely to remain stable. It followed that clinical judgments based solely on the immediate functional improvement of a joint were unreliable because a short-term functional improvement could occur even though the joint remained too dislocated to be stable over a long period. Likewise an initially poor functional improvement could sometimes occur even though the joint was well repositioned and would almost certainly improve substantially and permanently with time. Wolff argued that if X-rays were used to control the Lorenz procedure in the manner he suggested, then a successful and permanent relocation could normally be achieved. Furthermore, he now believed he was accumulating definitive X-ray evidence that a correctly realigned and loaded joint did begin spontaneously to grow into something very close to normal form.[59] As another orthopedic surgeon noted, by the end of 1897 the use of anatomical preparations as evidence of surgical success was rapidly being superseded by X-ray images. What had once been studied through "laboriously and fortuitously" obtained preparations could now be seen "case by case in the living body with ones own eyes."[60]

[58] Julius Wolff, "Die Bedeutung der Röntgenbilder für die Lehre von der angeborenen Hüftverrenkung," *Fortschritte auf dem Gebiete der Röntgenstrahlen,* 1897/98, *1:*22–28, 130–136, 211–221, 22–24.

[59] Wolff, "Die Bedeutung der Röntgenbilder," pp. 212–221. Wolff claimed (p. 221) that the "ideal goal" of the treatment would be reached when the joint was seen to assume a normal anatomical relationship. He anticipated that further X-ray pictures would bring the required confirmation.

[60] Otto Büttner and Kurt Müller, *Technik und Verwerthung der Röntgen'schen Strahlen* (Halle: Wilhelm Knapp, 1897), p. 107.

General acceptance that the nonsurgical operation was the procedure of choice appears to have occurred toward the end of 1898. For example, when the Hamburg-based surgeon Hermann Kümmell gave a paper on 13 November that year, he revealed that he had now rejected Hoffa's surgical treatment on the grounds that it was too difficult and dangerous to undertake and because the artificial deepening of the socket sometimes impaired the long-term functional improvement of the joint. Kümmell confirmed that the X-ray evidence had initially led many doctors to doubt the efficacy of Lorenz's nonsurgical treatment because photographs had shown that joints located in this way frequently redislocated. He now agreed with Wolff, however, that further experience had revealed not only how X-rays could be used effectively to control the nonsurgical procedure but also that, to everyone's surprise, an excellent and long-term functional improvement was often achieved even when the hip socket was barely formed and/or the joint partially redislocated. The key characteristic of the operation was that the femur head remained firmly in position in the vicinity of the hip socket, something that could only be properly ascertained using X-ray images. Kümmell concluded that, when carried out under X-ray control, the Lorenz procedure normally achieved excellent results, a claim he illustrated using some forty-five X-rays of his own patients.[61]

The most important events in the acceptance of Lorenz's procedure probably occurred shortly after Kümmell's talk, when Wolff himself addressed first the Free Association of Surgeons in Berlin and then the Berlin Medical Society on the same topic. The talks were illustrated with a mixture X-ray images and living patients to demonstrate the relationship between anatomical and functional results. Wolff covered much the same ground as had Kümmell but added two additional points of great importance. First, Wolff now believed he had conclusive X-ray evidence that a properly relocated joint would develop toward normal form under the loading of the patient's walking. (See Figure 3.) He showed several sets of images to establish this point of which those shown in Figure 3 are exemplary. The first image (10 August 1897) shows the hips of a three-and-a-half-year-old girl (Käthe J.) suffering from double-sided dislocation. As can easily be seen by comparison with subsequent images, the ball of the femur on both sides stands well above its normal position. The second image (20 February 1898) shows the hips six months after the right hip had been relocated using the nonsurgical procedure and immediately before the left hip was similarly relocated. The final two images (3 August and 9 November 1898) show the hips six and nine months after the second relocation, respectively. What Wolff wished to emphasize was that the femur head remained firmly in place in both cases, that the ball and socket can be seen to develop toward normal form over a six- to fifteen-month period, and that the hips had settled into a normal, level form by the final photograph. (The left joint is underdeveloped on 3 August 1898.) For Wolff, this provided very persuasive evidence for the efficacy of the Lorenz procedure and for his own law of the transformation of bones.[62]

Wolff's second point was that X-ray images provided such powerful anatomical knowledge that they ought henceforth to be used as a new and definitive form of evidence in orthopedic surgery. He pointed out:

> The procedure used until now in the literature and related discussions has almost always been to prove what was to be demonstrated by listing or showing the largest possible number of

[61] Hermann Kümmell, "Die congenitale Hüftluxation in Röntgen'scher Durchleutung und die Resultate ihrer Behandlung," *Münchener medicinische Wochenschrift,* 1898, *45:*1656–1657.

[62] Julius Wolff, "Über die unblutige Einrenkung der angeborenen Hüftgelenksverrenkung," *Berliner Klinische Wochenschrift,* 1899, *36:*381–385, 414–417, 468–472, 384–385.

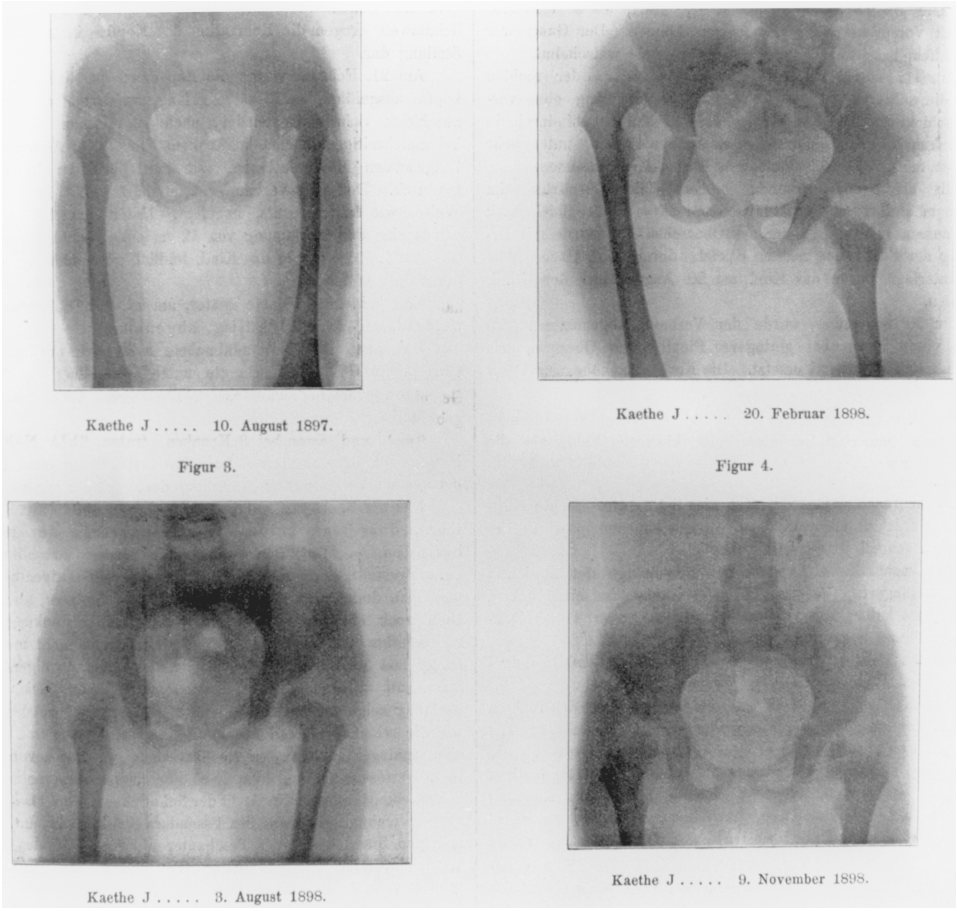

Figure 3. *This image sequence shows (compare* Figure 2*) how X-rays transformed the doctor's understanding of the diagnosis and treatment of a malformed hip. The functional fault and cure, assessed by the stance and gait of the whole patient, have been replaced by the anatomical diagnosis and cure assessed through disembodied X-ray shadows. One should keep in mind Wolff's comment that these images had lost "beauty and sharpness" compared with the original plates. (Julius Wolff, "Über die unblutige Einrenkung der angeborenen Hüftgelenksverrenkung,"* Berliner Klinische Wochenschrift, *1899, 36:383. Reproduced by kind permission of the Royal Society of Medicine, London.)*

> patients. Each of these individual cases was not sufficiently verifiable and people could therefore form this or that judgment over the facts and the effects of the ongoing relocation.[63]

Wolff then suggested that a much better and "more correct" procedure would be "to consider very carefully only a few cases, but just those in which the conditions [were] absolutely unambiguous and correspondingly instructive." What made this new approach possible was the consultation of good X-ray pictures taken before, during, and after treatment. In Wolff's opinion, such pictures had "inexorably destroyed" those "unwarranted illusions to which we are inclined to resort in unsuccessful or partially unsuccessful treatments"

[63] *Ibid,* p. 470.

while "completely fulfill[ing] our expectations in those cases in which we have succeeded in getting ideal results." In other words, X-rays reliably established the relationship between the changing anatomical and functional states of a relocated joint. Wolff concluded that this not only afforded the "greatest satisfaction" but also offered the "greatest possible certainty for the further establishment of useful measures for achieving success."[64] It is a measure of the effectiveness of Wolff's presentation that even Franz König was now persuaded of the success and importance of the nonsurgical procedure. Having attacked Hoffa and Lorenz in 1897 for making overblown, naïve, and self-serving claims, he now spoke warmly on behalf of the whole association in thanking Wolff for a presentation, which had "demonstrated the favorable outcome of the nonsurgical procedure."[65]

From the end of 1898 there was little published resistance to the claim that Lorenz's operation was the one of choice for the majority of cases of congenital dislocation of the hip. Lorenz also felt the time was now right to publish a definite treatise on the procedure. He freely admitted that the work had been long delayed, partly because the arrival of X-rays had cast doubt on the procedure's efficacy, partly because he had underestimated the importance of X-ray images both for controlling the nonsurgical relocation and for proving that a relocated joint would develop with the patient's walking. In this context, he praised Wolff for showing how X-rays were best used in orthopedic surgery, for realizing the power of a projected image to sway an audience and, specifically, for convincing König who previously had expressed his "disparaging opinion in rather drastic terms."[66] By 1902, when the fourth edition of Hoffa's *Lehrbuch* appeared, the author was prepared to admit that credit was due to Lorenz for showing that the nonsurgical procedure was capable of relocating a joint in the overwhelming majority of cases. Lorenz's operation was now offered as the one of choice, and Hoffa included the series of photographs showing how he and his assistants carried out the procedure. (See Figure 1.)[67] Indeed by 1908 it had become so popular that some surgeons complained that the surgical operation was no longer being used even in those few cases where it offered the best outcome. As the Hamburg surgeon Carl Deutschländer remarked, Hoffa's operation had fallen increasingly in the background and was now spoken of as "obsolete and belonging to the past."[68]

X-RAYS, VISUAL EVIDENCE, AND THE HISTORICAL SOCIOLOGY OF SURGERY

I believe this study demonstrates conclusively that German orthopedics is one field of medicine in which X-rays quickly became an important and then indispensable aid to medical practice. Judging by the historical studies mentioned in my introduction, this speedy uptake is not representative of the wider medical use of the new technology in the late 1890s. For that reason, we need to understand which factors are peculiar to the case discussed above. First, despite the rising sense of despondency regarding the real medical value of X-rays in the spring of 1896, they were regarded as offering potential solutions to two very well-defined problems concerning congenital dislocation of the hip. We saw

[64] *Ibid.*

[65] Franz König, "Freie Vereinigung der Chirurgen Berlins," *Berliner klinische Wochenschrift,* 1898, *35:*1071. König added that he nevertheless considered Wolff's judgment somewhat too favorable.

[66] Lorenz, *Über die Heilung* (cit. n. 24), pp. 92–93, on p. 270. Lorenz claimed (p. 75) that X-ray control had enabled his treatment to produce the "complete anatomical result," and that (p. 267) it had since spread "extraordinarily fast" throughout Germany.

[67] Hoffa, *Lehrbuch,* 4th ed. (1902), pp. 631–638.

[68] Carl Deutschländer, "Die blutige Reposition der angeborenen Hüftverrenkungen," *Zeitschrift für Orthopädische Chirurgie,* 1908, *20:*189–253, on p. 191. Deutschländer had been a student of Hoffa's.

that Vulpius raised the possibility of their use both in the differential diagnosis of the condition and in testing Wolff's law of bone transformation well before usable images of the human hip had been obtained. A second factor is that, unlike many other fields in which X-rays were initially expected to make a major impact—such as the detection of tuberculosis or of bladder and kidney stones—the technology did soon produce practically usable pictures. This was due in part to the relative ease with which bony structures cast sharp and anatomically comprehensible images, and in part to the technical skill and laboratory resources deployed by physicists such as Buka to enable X-rays to penetrate thick tissues such as the hip.

The more general point I want to emphasize, however, is that the rapid and successful uptake of X-rays in orthopedic surgery is as much a story of medical practice as it is one of scientific and technological innovation. My point is not that diagnostic and investigative techniques were somehow lacking in the early 1890s—no one suggested this at the time—but rather that X-rays offered a new resource that was ripe for appropriation by the various factions participating in a specific field and debate. Wolff, for example, was motivated by a strong desire to find definitive proof of his law of bone transformation and by his wish to improve Lorenz's nonsurgical operation. These interests lent special scientific and medical value to Buca's hip images and prompted Wolff to show how a series of X-rays of the same patient could be of far greater value than a single image. The initial impact of Wolff's technique was nevertheless to undermine the credibility of Lorenz's procedure that, until then, had been gaining ground on Hoffa's surgical operation. Hoffa himself sought to produce images of the hip to show that only his operation effected a permanent location of the joint; and that is exactly what the first image sequences seemed to prove. Lorenz was at first skeptical about the medical value of X-rays because they undermined the credibility of an operation that in his opinion was safer than Hoffa's and that seemed frequently to produce excellent functional results.

Moreover, these uses of X-rays were not merely, or even primarily, diagnostic but were related to a number of specific aspects of surgical practice in the mid-1890s. Surgeons such as Wolff slowly learned to use a sequence of X-ray images to improve and control Lorenz's nonsurgical procedure. As the images became part of the procedure itself, they not only revived faith in Lorenz's operation but also enabled it to succeed Hoffa's as the one of choice. In the process, X-rays generated new criteria for establishing the outcome of surgical intervention. Hoffa and his students argued that only the new notion of an "anatomical cure," as revealed by the X-ray, provided reliable evidence that an effective and long-term treatment had been carried out. Lorenz, by contrast, insisted that where conflict between the functional and anatomical evidence occurred, the former should remain the hallmark of a successful treatment. In time, surgeons, Lorenz included, learned that success was best judged by a combination of anatomical and functional evidence, the X-ray image revealing the anatomical effect of a given treatment and, with experience, the functional improvement it would probably produce. Once incorporated in the operative process, X-rays helped to generate new criteria for judging the relative merits of different forms of treatment, progressively to improve a treatment by judging its anatomical outcome, and significantly reduced the time required to assess whether a given treatment was likely to effect a satisfactory cure.

The other factor that enabled the rapid adoption of X-ray images in orthopedic surgery was their power as a tool of visual evidence and persuasion. We have seen that orthopedic surgeons routinely staged visual displays of successfully treated patients to try to convince their peers that a new procedure worked. A sequence of projected X-ray images fitted

smoothly into this familiar repertoire by rendering an ongoing anatomical cure as visually, dynamically, and collectively accessible as a succession of walking patients. However, the X-ray also changed the repertoire in important ways. Once the simultaneous display of X-ray images and live patients had established that certain anatomical changes corresponded to a functional improvement, the total number of cases displayed began to go down and the live patients were replaced, sometimes entirely, by images. The latter point was probably due in part to the relative ease with which an X-ray plate could be brought to a medical meeting, but the former seems to have constituted the realization of Wolff's claim that it was more instructive to observe a small number of cases in which the outcome was ideal and unambiguous than a large number for which the cause of the improvement was open to debate. The visual, anatomical evidence produced by X-rays thus provided new causal criteria for an ideal cure around which surgeons reached agreement while looking collectively at projected images. They were convinced that the nonsurgical procedure could produce the right geometric relationship between bones and that normal anatomical development and functional improvement would then occur automatically in what henceforth would be regarded as the normal way.

These characteristics of X-rays as a new form of medical evidence support and supplement the general conclusions that can currently be drawn from the emergent field of the historical sociology of surgical knowledge. One point that scholars in this field have emphasized is that new surgical procedures are best propagated by direct demonstration. This is partly because complicated procedures are not easily communicated in written form and partly because surgeons tend to trust their own surgical experience and to be skeptical about published claims by others concerning both the relative ease of a new procedure and the likely success of its outcome.[69] These conclusions are generally supported by my study. Lorenz had initially to give public demonstrations of his nonsurgical procedure to lend it any credence at all, while from the late 1890s on it was only Hoffa and his students who continued to use the surgical operation in some cases. Schanz's study makes it clear that some of Europe's leading orthopedic surgeons did successfully carry out Hoffa's operation in the mid-1890s, having seen only written accounts, but a major purpose of the study was clearly to allay concern that only exceptional surgeons and their students could really get satisfactory results.[70] The specific relevance of X-rays to these issues is that they generated additional credibility for new orthopedic procedures by supplementing the subjective testimony of the surgeon with an independent, visual verification of the anatomical result. As we saw, by the autumn of 1896, Wolff was prepared to assert that no claims regarding the final outcome of surgical treatments should be taken seriously unless they were substantiated by the relevant X-ray pictures.

This brings us to the second, related sociological point that a new surgical treatment is more likely to be regarded as credible if it produces visible effects that conform to an accepted model of an organ and its pathology. David Jones has argued, for example, that heart surgeons in the 1960s and 1970s placed excessive faith in the efficacy of bypass surgery partly because imaging techniques enabled them and their patients literally to see that the heart's reduced blood supply was restored by the surgery.[71] The issue of how surgeons visualize organic systems is relevant to the present case because it helps to explain

[69] Schlich, *Surgery, Science and Industry* (cit. n. 6), pp. 65–85; and Wilde, " 'See One, Do One, Modify One' " (cit. n. 6), pp. 362–364.

[70] Schanz, "Zur blutigen Reposition" (cit. n. 20).

[71] Jones, "Visions of a Cure" (cit. n. 6), pp. 531–534.

the early consensus among orthopedic surgeons regarding the meaning of images on X-ray plates. We saw, for example, that Lorenz readily accepted the claim by Hoffa and others that X-rays revealed varying degrees of hip dislocation following the nonsurgical procedure, even though Lorenz's case was thereby greatly weakened. This was, I suggest, because the bone shadows seen in X-ray pictures conformed from the start to surgeons' anatomical understanding of the skeleton and its orthopedic conditions.[72] What needed to be negotiated in this case was not what was shown on the X-ray plate, but the relationship between the anatomical evidence the plate supplied and the functional improvement of the patient. The rapid acceptance of the Lorenz procedure after 1898 may also have been aided by the visualization process. The procedure remained controversial in 1897 because it was often followed by minor redislocation and because it assumed Wolff's unproven law of bone transformation. Once it had been established that small dislocations were irrelevant and that Wolff's law was true, X-ray pictures made it possible for surgeons to see that the treatment of congenital dislocation of the hip progressed in the way Lorenz and others described.

A third sociological point of relevance to the early use of X-rays is that new surgical procedures are more likely to be accepted if they are linked to established scientific theory and/or laboratory tests. The current evidence for this claim relates to the middle decades of the twentieth century and suggests that the growing prestige of laboratory science could be mobilized to lend credence to procedures that might otherwise seem implausible or counterintuitive.[73] In the case of hip surgery, the establishment of Wolff's law appears to have functioned in a similar way. Wolff's work on bone growth was related to a broader research program in developmental physiology and opened a new era in orthopedics by providing a rational foundation for cures completed by the body's physiological response to orthopedic intervention.[74] Doctors almost certainly found Lorenz's procedure the more plausible because its least intuitive aspect (Wolff's law) came to be supported experimentally by X-ray images and theoretically by association with ongoing research in developmental physiology.

It should also be noted in this context that X-rays were themselves a product of laboratory research and that this may help to explain why orthopedic surgeons were the first to mobilize the rays so successfully in medicine. Most orthopedic therapies were inherently technological and most orthopedic surgeons were therefore accustomed to making and using a wide range of instruments, prosthetic devices, corrective apparatus, and such. These doctors were in an unusually good position to acquire, tinker, and experiment with a new, complicated, and highly temperamental piece of equipment. Many of the leading orthopedic surgeons also worked in large and profitable private clinics in which new forms of electrotherapy were already being tried. Their patients paid regular visits, often suffered with conditions that would show up in an X-ray image, and were probably willing and able to pay for such pictures if the doctor deemed them necessary. Orthopedic surgery was also a new specialty in the 1890s that was struggling to establish itself both as the legitimate site for orthopedic treatments and as an equal to other branches of surgery and clinical medicine. In this context, the use of X-ray apparatus may well have lent an air of modernity,

[72] This makes an informative comparison with the case of tuberculosis in which early X-ray evidence disagreed radically with accepted conceptions of the disease. See Pasveer, "Depiction in Medicine as a Two-Way Affair" (cit. n. 4).

[73] Schlich, *Surgery, Science, and Industry* (cit. n. 6), pp. 86–109, 248–252.

[74] *Ibid.,* pp. 88–89. Wolff's work is outlined in Joachimsthal, "Julius Wolff" (cit. n. 37), pp. 203–204.

progress, and scientific wonder that impressed patients and other surgeons, and contrasted productively with the familiar, holistic, and bedside approach long used by elite physicians.

The present study indicates, then, that none of the major issues so far highlighted in sociological studies of surgery are peculiar to the mid-twentieth century but go back at least to the end of the nineteenth. As we have just seen, orthopedic surgeons were prepared from the 1890s to enroll new physiological theory and the products of the laboratory in support of their discipline's progress. We should not be surprised, moreover, that even in the 1890s new surgical procedures were best learned by watching a technique's inventor at work. The emergent anesthetic and aseptic surgery of this period was a highly skilled, manual activity, involving considerable risks and uncertainties that not only affected the outcome of an operation but also could mean life or death for the patient. Watching an operation enabled surgeons to experience at firsthand those especially difficult or novel maneuvers that are very hard or impossible to describe adequately in written form.[75]

Perhaps the most interesting aspect of this study is the role of X-rays as a new tool of visual evidence. We have seen that this kind of evidence can persuade surgeons and patients that a treatment is effective even when the observed effect might not translate into a successful cure. But the visual evidence provided by X-rays also constituted a powerful new tool both for the individual surgeon and for the surgical community. For individual orthopedic surgeons, X-ray pictures narrowed the uncertainties associated with surgery and improved therapeutic outcomes. Thanks to X-rays, the surgeon had a better idea of what would be found when a patient's body was opened and of how successful an intervention had been once the wound was closed. This applied even in the case of nonsurgical hip relocation as the patient was still anaesthetized and subject to powerful and potentially damaging manipulation. For the wider community, X-rays played a slightly different but no less important role. Surgeons had little opportunity either directly to witness their peers at work or to examine the after effects of their treatments. X-ray pictures provided a token of publishable evidence that mediated visually between diagnosis, treatment, and therapy. Other surgeons could attempt to obtain similar images before and after surgical intervention and, if successful, expect to obtain a similar therapeutic outcome.

The general lesson that I hope emerges from the present study is that ascertaining the medical value of early X-ray images of the human body is a challenging task and one that needs for the moment to be undertaken on a case-by-case basis. The ambiguity referred to in my introduction regarding the early impact of X-rays almost certainly originates in the historical evidence itself. It is impossible to tell simply by surveying the numerous images that appear in medical atlases, textbooks, and journals from the late 1890s, whether they were reproduced as a practical aid to medical diagnosis and therapy or merely as an illustration or curiosity. My study shows that resolving this issue requires us carefully to replace the images within the dynamic development of the therapeutic field in question. In the case of hip surgery, this process has revealed that X-ray images were the focus of a heated debate over which therapy was the most effective, what kind of evidence was the most appropriate, and whether Wolff's law of bone transformation was true. Equally important is that by 1897, X-rays had become an indispensable aid to orthopedic surgery and as such helped firmly to establish X-ray technology within medicine in the German-speaking world. It remains to be seen in which other therapeutic fields X-rays played a similarly important role and whether these fields varied from one country to another.

[75] It was for this reason that both Hoffa and Lorenz published series of photographs in their later textbooks (see Frontispiece) showing how the operating staff, the anesthetist, and the patient were positioned during a difficult maneuver.