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Clinical Study

Long-term kinematic analysis of cervical spine after single-level implantation of Bryan cervical disc prosthesis

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Abstract

BACKGROUND CONTEXT: Cervical arthroplasty theoretically reduces the risk of adjacent level disc degeneration and segmental instability that may be seen after a cervical fusion. An essential argument in confirming the utility of cervical arthroplasty is long-term confirmation that cervical disc replacements can maintain physiological kinematics at the index and adjacent levels.

PURPOSE: The purpose of this in vivo prospective study was to characterize the long-term segmental kinematic outcomes after cervical arthroplasty.

STUDY DESIGN/SETTING: Prospective cohort study.

PATIENT SAMPLE: Twenty patients with a 5-year clinical follow-up who underwent anterior cervical discectomy with insertion of the Bryan cervical disc.

OUTCOME MEASURES: Physiological measures (kinematic analysis of lateral neutral, flexion, and extension radiographic imaging).

METHODS: Twenty consecutive patients with degenerative disc disease were followed with regular radiographic imaging after implantation of the Bryan cervical disc prosthesis. Lateral neutral, flexion, and extension radiographs (n=240) were analyzed using Quantitative Motion Analysis software (Medical Metrics, Inc., Houston, TX, USA) to measure the biomechanical profile at the index level and adjacent levels up to 5 years after surgery. Parameters collected included range of motion (ROM), functional spinal unit (FSU) angle, anterior and posterior disc heights, sagittal translation, and center of rotation (COR).

RESULTS: Biomechanics of the implanted artificial cervical disc was maintained up to 5 years with no significant changes in ROM, FSU angle, disc height, sagittal translation, and COR values when compared with early postoperative performance. Artificial discs were able to adequately restore and maintain preoperative kinematics. Early differences seen in disc height and FSU angle did not change during the duration of follow-up. No significant kyphotic changes or decrease in ROM were seen at the adjacent spinal levels.

CONCLUSIONS: The Bryan cervical disc prosthesis provides for a durable solution for functional spinal motion at the operated level and maintained the preoperative kinematics at adjacent levels at the 5-year follow-up.

Keywords: Cervical arthroplasty; Kinematics; Total disc replacement; Bryan disc; Cervical disc replacement

FDA device/drug status: Approved for this indication (Bryan Cervical Disc Prosthesis).

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Introduction

Since the first preliminary European trials of cervical arthroplasty by Goffin et al. [1,2], the Bryan cervical disc prosthesis has been implemented worldwide as an alternative to anterior cervical discetomy and fusion (ACDF) for degenerative disc disease (DDD). Cervical arthroplasty theoretically reduces the risk of adjacent level disc degeneration and segmental instability that may be seen after a cervical fusion [3–5]. An essential argument in confirming the utility of cervical arthroplasty is long-term confirmation that cervical disc replacements can maintain physiological kinematics at the index and adjacent levels. Given that the first Bryan disc was inserted in Europe more than 10 years ago, studying this patient population provides the opportunity of addressing long-term kinematic outcomes of cervical arthroplasty.

Numerous studies have reported the early to intermediate clinical and radiologic outcomes after Bryan cervical disc prosthesis implantation, with most showing positive results [1,2,6–9]. Prospective randomized trials reported for various cervical disc replacements have had follow-up limited to approximately 2 years [10–12]. Three published clinical studies have described the long-term clinical outcomes beyond 4-year follow-up [13–15]. Goffin et al. [13] focused on patient-derived questionnaires to assess clinical outcome and reported on range of motion (ROM). Quan et al. [15] and Walraevens et al. [16] used additional radiographic measurements, such as adjacent level intervertebral disc degeneration and heterotopic ossification.

The purpose of this prospective cohort study was to describe the long-term in vivo kinematic behavior of the Bryan cervical disc prosthesis. Specifically, we characterized the preoperative changes that occur with DDD and quantitatively assessed the longitudinal performance of the artificial cervical disc based on ROM, functional spinal unit (FSU) angle, anterior disc height (ADH), and posterior disc height (PDH), sagittal translation, and center of rotation (COR). In additional, we examined the long-term kinematic impact of cervical arthroplasty on adjacent level kinematics.

EVIDENCE & METHODS

Context
One potential benefit of disc replacement is that motion preservation might decrease the risk of degeneration at adjacent levels. In this study the authors assess motion preservation 5 years after cervical arthroplasty.

Contribution
In a small cohort of consecutive patients, the authors found that some motion, although not exactly physiologic, was maintained at the implanted prosthesis level. They also noted that adjacent levels initially become hyper-mobile (at year 1) and then stabilize (years 2 to 5).

Implication
The findings suggest that maintenance of some motion persisted at the operated level, although the small numbers of subjects lowers the confidence that this is a universal effect. Longer-term, controlled follow-up is needed to determine whether the observed findings impact device longevity and adjacent segment degeneration.

—*The Editors*

Methods

Twenty prospectively enrolled patients with radiculopathy and/or myelopathy secondary to DDD were included in this study. All patients underwent anterior cervical discectomy, followed by implantation of Bryan cervical disc prosthesis. The operative technique has been previously described [17]. Static and dynamic standing radiographic images of upright neutral, flexion, and extension cervical spine were obtained for all 20 patients preoperatively and at multiple postoperative time points: 1 year, 2 to 3 years (3 and 17 patients, respectively), and 4 to 5 years (3 and 17 patients, respectively). A total of 240 radiographs were analyzed for the study. All patients underwent clinical and radiographic assessment at 5 years. Because of poor imaging quality at the 5-year follow-up, in three cases the 4-year (instead of 5 year) radiographs were used for analysis. Radiographic technique has been described previously [18]. This study was approved by the Health Sciences Research Ethics Board at the University of Western Ontario.

Quantitative Motion Analysis software (Medical Metrics, Inc., Houston, TX, USA) was used to analyze the kinematic profile of the cervical spine at the index level along with the superior and inferior adjacent levels. This validated radiographic analysis software uses an advanced pattern-recognition algorithm to generate accurate measurements of ROM, FSU angle, ADH/PDH, sagittal plane translation, and COR in X and Y directions (Fig. 1) [15,18–21]. The COR was obtained for the spinal levels and reported as (X, Y) offset from the midline of the superior end plate of the caudal vertebral body [6,18]. The FSU angle was defined as the angle formed by lines drawn at the superior margin of the superior vertebral body defining the disc space and the inferior margin of the inferior body [6,18].

Mean values and standard deviations were determined for ROM, FSU angle, ADH/PDH, sagittal translation, and COR X and Y. The radiologic measurements were grouped into preoperative, early postoperative outcome (1 year), intermediate postoperative outcome (2–3 years), and late postoperative outcome (4–5 years). The Student *t* test was used to compare the kinematic and biomechanical profiles at the aforementioned time points (significance $p<.05$).